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The following information is taken from the documents submitted by the applicant

(54) Electronic detection system and method for acoustic signals

(57) The invention relates to an electronic detection system for acoustic signals, wherein the acoustic signals comprise, in particular but not exclusively, warning signals from other vehicles and unusual noises from one's own vehicle. Furthermore, the invention relates to a vehicle monitoring method.

The detection system for acoustic signals according to the invention, which comprises at least one receiver (1, 2) for detecting acoustic signals outside the vehicle and in the interior of the vehicle and at least one output unit (9) for outputting information and control signals on the basis of the acoustic signals, is characterized by an analog-to-digital converter (3) for converting the acoustic signals into digital data, an evaluation unit (4) for detecting classification features from the data and a computing unit (5) with at least one storage device (13) for storing comparison signals and at least one comparison device (10) for comparing the detected classification features with previously stored classification features and for generating the information and control signals on the basis of the comparison result.

The method according to the invention for the acoustic monitoring of a vehicle and the processing of acoustic signals, comprising the steps of detecting acoustic signals inside and outside the vehicle and outputting information and ...

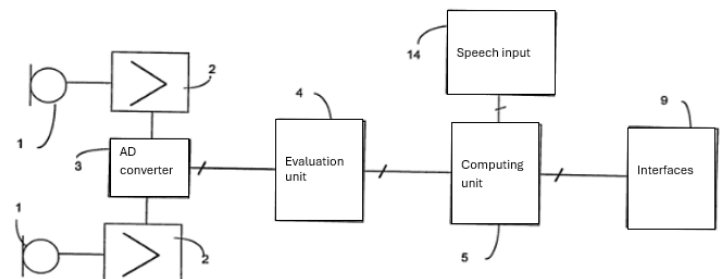


Fig. 1

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Description

The invention relates to an electronic detection system for acoustic signals according to the preamble of claim 1, wherein the acoustic signals comprise, in particular but not exclusively, warning signals from other vehicles and unusual noises from one's own vehicle. Furthermore, the invention relates to a vehicle monitoring method according to the preamble of claim 8.

Almost all modern vehicles are equipped with devices such as parking sensors and distance sensors. Their operation is based on the transmission of signals and the reception of the backscattered signal. In addition to a transmitter, the device also includes a receiver for optical or acoustic signals. The signals picked up by the receiver are only accepted for further processing by an evaluation unit of the device if they are correlated in some way with the transmitted signal, i.e., they have the same frequency or the same pulse shape.

Furthermore, systems are known in which random events such as a horn or other warning signals are detected as well, resulting in a communication between a plurality of vehicles. Such a system is described, for example, in the German utility model DE 94 10 485 as a device for the direction-dependent detection of weak acoustic signals. This device comprises a directionally constant transmitter operating at an angle of up to 110 degrees and is installed in an emergency vehicle. The respective motor vehicle of the other road users is equipped with one or more receivers which pick up the signals from the transmitter and which are each coupled to an electrical converter which in turn is connected to the loudspeaker lines transmitting a humming sound to the loudspeaker.

A further device of the above-mentioned type is known from DE 30 46 862. The volume control for electro-acoustic playback devices in vehicles described in that patent comprises a detector which, when acoustic warning signals are issued by privileged road users, emits an output signal to an actuator which reduces the volume of the electro-acoustic playback devices or even turns it to zero.

However, the systems according to the prior art only take into account a partial aspect of the acoustic information in road traffic. They only serve to assist the driver in the detection of warning signals by influencing the setting of a playback device in the vehicle. Acoustic signals in road traffic can, however, be used in a variety of ways and can contribute to a comprehensive and more complete assessment of the current traffic situation than is possible by visual means alone, for example.

The invention is based on the task of creating a detection system for acoustic signals and warning signs, with which the traffic situation and the vehicle condition can be fully determined and taken into account when controlling the vehicle, as well as a method for the acoustic monitoring of a vehicle and the processing of acoustic signals.

This task is performed by a detection system for acoustic signals with the features according to claim 1 and a method for the acoustic monitoring of a vehicle and the processing of acoustic signals according to claim 8. The subclaims relate to respective advantageous embodiments of the invention.

The detection system for acoustic signals according to the

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Invention, which comprises at least one receiver for detecting acoustic signals outside and inside the vehicle and at least one output unit for outputting information and control signals on the basis of the acoustic signals, is characterized by an analog-to-digital converter for converting the acoustic signals into digital data, an evaluation unit for detecting classification features from the data, and a computing unit with a storage device for storing comparison signals and a comparison device for comparing the detected classification features with previously stored classification features and for generating the information and control signals on the basis of the comparison result.

The method according to the invention for monitoring a vehicle, comprising the steps of detecting acoustic signals inside and outside the vehicle and outputting information and control signals on the basis of the detected acoustic signals, is characterized by the steps of converting the detected acoustic signals into digital data, detecting classification features in the data, comparing the detected classification features with previously stored classification features, and generating the information and control signals on the basis of the comparison result.

The invention is based on the insight that an optimum acoustic monitoring of the vehicle is achievable with microphones, each of which is attached to the vehicle with a preamplifier and whose output signals are converted into digital data using an analog-to-digital converter (ADU). For this purpose, the data is transferred from the ADU to an evaluation or processing unit to obtain the classification features in the data. Once the classification has been carried out, the results are compared with predefined classification features in a computing unit and then either displayed for the driver, for example on an LED or LCD display, or used to control the vehicle in an autonomously driven vehicle via an interface, for example a CAN bus interface. In addition to their visualization and their use for control elements and actuators, the data can also be output via a computer interface to an external (vehicle) computer for further processing.

The advantage of the invention over the prior art is that the acoustic signals in a vehicle are detected and classified (especially with regard to warning signals), and a response adapted to the respectively classified signals occurs, taking into account the existing boundary conditions (vehicle with or without driver).

In a preferred embodiment, after a classified signal has been detected, a rough directional detection is performed to distinguish whether the signal is coming from the opposite or same direction of travel or from the side. A plurality of microphones or sound sensors are attached to the vehicle for this purpose.

In further preferred embodiments of the invention, the frequency spectrum of the detected acoustic signal is analyzed and/or a voice input of control commands by the user is permitted.

Signals for a visual or acoustic reproduction for the driver or signals for a direct intervention in the vehicle control system are possible as output signals. The display of the signals in the first case can comprise a direction display for the siren or information

displays, such as a localization display in the vehicle in the event of a component failure.

For clarity purposes, the invention will be explained in more detail below, indicating further features and advantages, with reference to the embodiments shown in drawings.

Fig. 1 shows a block diagram of a first embodiment of the detection system according to the invention,

Fig. 2 shows a part of the block diagram according to **Fig. 1** with further details.

The embodiment of an electronic detection system for acoustic warning signs and signals according to the invention shown in **Fig. 1** comprises microphones **1** for picking up acoustic signals, each of which is directly connected to a preamplifier **2**. The preamplifier **2** raises the signal picked up by the microphone **1** above a noise threshold and makes it available for further processing.

For reasons of clarity, only two microphones **1** with a preamplifier **2** are shown in **Fig. 1**, but the detection system preferably has four microphones **1** that are attached to the outside of the vehicle, or at least in such a way that they can pick up acoustic signals outside the vehicle. The four microphones **1** cover the surrounding area of the vehicle from the corners of the vehicle and thus allow for a precise localization of sound sources in the surrounding area. However, with two microphones instead of four, the system can only distinguish sound sources in front of and behind the vehicle but cannot locate them when coming from the side. In addition, microphones **1** can be arranged inside the vehicle, either for monitoring the passenger cabin or for monitoring the engine compartment or other vehicle regions, such as radar and the like. Instead of the external microphones **1**, existing microphones can also be used if they are sensitive enough in the corresponding frequency range.

The signals picked up by the microphones **1** and processed by the preamplifiers **2** are fed to an AD converter **3**, which converts the analog signals into digital data. This has the advantage that the transmission quality from the AD converter **3** is significantly improved (noise sources no longer play a significant role) and the processing of the data is greatly simplified, or processing is possible taking many aspects into account. The functionality of AD converters is generally known and will not be explained further.

In the embodiment of the detection system shown in **Fig. 1**, an AD converter **3** is provided for all microphones **1**, in other words, the AD converter **3** is a multi-channel AD converter that reads the individual microphone signals one after the other via a multiplexer at the input and then converts them individually. The digital data is then further processed in the order of its AD conversion from the acoustic signal. The design with a (multi-channel) AD converter and a multiplexer has the advantage that only one AD converter is required.

Instead, each microphone **1** can also be equipped with its own AD converter, a single-channel AD converter. In this case, the multiplexer is omitted, and the individual microphone output signals are converted directly. Their further processing is staggered in time on the digital side.

In any case, the system clock is preferably specified by the AD converter in such a way that, during further processing, differences in the propagation time between the signal recorded

by the first microphone **1** and the signal recorded by the second microphone **1** can be determined. This means that the digital data is output by the AD converter with information that indicates the time at which it was generated in relation to a system clock. The localization of the sound source from the time difference of the individual data is explained below in connection with **Fig. 2**.

In **Fig. 1** and **Fig. 2**, the lines from the AD converter **3** are shown with small horizontal lines. This is to indicate that these are lines for digital data. These lines represent data buses with a width of 8 bits, for example. In particular, existing buses in the vehicle, such as a CAN bus etc., can be used as data lines.

The data formed from the acoustic signals via the AD converter **3** is analyzed in an evaluation unit **4**, and classification features of the data are determined. The function of the evaluation unit **4** and the main classification features are explained in more detail in **Fig. 2**.

The classification features of the data correlated with the captured acoustic signals, which were determined by the evaluation unit **4**, are fed into a computing unit **5**. In the computing unit **5**, the classification features are compared with predetermined and previously stored patterns or with temporarily stored previous data. The main classification features are the frequency response of the signal and other signal characteristics such as their repetition rate. These characteristics are preferably determined via a Fourier transformation of the signals in the evaluation unit **4**. In addition, the amplitude response of the signal can be tracked over a specified period of time. This is particularly important for deciding whether the signal transmitter is approaching or moving away. Further details of the functions of the computing unit **5** are explained in **Fig. 2**.

In addition, the embodiment of the invention shown in **Fig. 1** and **Fig. 2** comprises a voice input device **14**. The voice input device **14** can be used to specify patterns in the broadest sense, with which the classification features of the digitized signal are compared. In particular, the voice input device **14** can be used to store command or key words, the repetition of which, for example by the driver, causes a previously defined function to be executed by the detection system. Special sounds can be stored in this manner as well, however, and can, for example, be assigned to a malfunction of a component of the vehicle.

The comparison result of the computing unit **5** is output to an output via an interface **9** as an information and control signal. In the embodiment shown, an acoustic output device **15** for speech reproduction and an optical display device **16** for the visualization of the evaluation results are part of the detection system. The output is used to inform the driver or to directly intervene in the control of the vehicle, particularly in the case of autonomously driven vehicles.

The acoustic output device **15** comprises a speech generator (not shown) for the composition of speech sequences depending on the evaluation result of the computing unit **5**. In addition, the output device **15** comprises a loudspeaker, which can be part of an existing playback device in the vehicle.

The display device **16** is preferably an LCD or an LED display.

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Fig. 2 provides details of the evaluation unit 4 and the computing unit 5, both of which are shown as dashed lines. For reasons of clarity, the AD converter 3, the voice input device 14, and the interface 9 with the display and output device 15 and 16 are shown again in Fig. 2.

In the evaluation unit 4, a spectrum analyzer 6 performs a spectral analysis of the acoustic signal (more precisely, the corresponding data). Basically, this can be done by bandpass circuits or circuits for a Fourier transformation.

The classification features obtained in the spectrum analyzer 6 are compared to the classification features of a predefined spectrum in a spectrum comparison circuit 10. This way, a siren, for example, can be clearly identified via the audio frequency and its time characteristic. To this purpose, the audio frequency with its time curve for a siren is stored in a spectrum storage 13.

In a preferred embodiment of the invention, the storage device 13 for the classification features of a spectrum is connected to the voice input device 14. In this constellation, it is possible to make individual specifications with regard to the stored classification features. In particular, keywords or the spectrums of spoken commands can be stored and later compared to acoustic signals detected by the microphones. The system then responds to the commands as requested by the driver. The voice input device 14 can be linked in particular with the spectrum analyzer 6 and the spectrum comparison circuit 10 in a neural network, so that a learning algorithm can be performed to ensure reliable recognition of spoken commands.

In order to determine the direction from which an acoustic signal is recorded, a reference point in time is defined in each signal in a marking circuit 7 connected downstream of the spectrum analyzer for detecting the propagation time differences of acoustic signals. With this marking in the data corresponding to an acoustic signal, the time difference of a signal between two microphones 1 can be determined by a travel time detection circuit 11. In addition, the rate of return of the detected sound, i.e., of low-frequency sound changes, can be determined as well. Thus, in addition to the localization, the classification features filtered out by the spectrum analyzer 6 and the marking circuit 7 can be used together, for example, to identify a signal from a siren that emits an acoustic signal with a lower frequency in a first interval and an acoustic signal with a (by a fifth) higher frequency in a second interval.

The localization of a sound source can be further improved by comparing the amplitude of two recorded signals in addition to their travel time difference. The amplitude of microphone 1 that is slightly further away from the sound source is slightly lower than the amplitude of microphone 1 that is closer to the sound source. A corresponding comparison is made by means of an amplitude analyzer 8 and an amplitude comparator 12. The amplitude of the signal is determined by the amplitude analyzer 8 at a point in time determined by the marking circuit 7. It is compared in the amplitude comparator 12 with a signal from the other microphone 1 at the corresponding time. Depending on whether it is larger or smaller, the direction of the sound source can be determined with a high degree of certainty.

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In particular, the computing unit 5 also takes into account time changes in the classification features over larger periods of time, i.e., for example, the first temporal derivative is formed to obtain information about the relative movements of the sound source with regard to the vehicle is.

If, based on the evaluation of the acoustic signals in the evaluation unit 4 and the comparison with predefined patterns, the detection system determines that a driver intervention is necessary or that a change in the driving parameters is required in an autonomously driven vehicle, the corresponding information and control signals are output acoustically or optically, or a direct intervention is made in the vehicle control by means of interfaces.

The method according to the invention comprises the following steps, which are necessary to control the above-mentioned components of the detection system.

In a first step, the signals processed by the preamplifiers are converted into digital data. In the following process step, the data is examined for classification features. This takes place in the evaluation unit 4. The results obtained from the classification are compared to predefined classification features in the computing unit 5.

The results are then either displayed for the driver, for example on an LED or LCD display 16, or used to control the vehicle in an autonomously driven vehicle by means of an interface (not shown), for example a CAN bus interface. In addition to the data being displayed and used for actuators and actuating elements, it can also be output to an external computer for further processing via a computer interface (not shown). Furthermore, voice playback by means of an acoustic output device 15 is possible as well.

The method for one embodiment of the detection system according to the invention with a voice input device 14 additionally comprises a learning algorithm for recording and recognizing user-specific acoustic triggers for the system.

Some of the responses that are possible with the detection system according to the invention are listed below. A distinction is made according to the boundary conditions, i.e., whether the vehicle is an autonomously driven vehicle (1) (electronic driving system) or a manually driven vehicle (2).

If the detection system according to the invention recognizes a siren, for example, it classifies this as a warning device for priority road users:

(1) If an emergency vehicle is approaching, the speed is reduced, and the system is put into a state of heightened alertness. For emergency vehicles traveling in the same direction, the system searches for a way to allow the emergency vehicle to pass on the left. If no specific direction detection is possible, the system is put into a state of heightened alertness and attempts to detect the direction of the emergency vehicle by using optical sensors and the acoustic detection system.

(2) After the warning signal has been detected (regardless of the direction), the driver is informed by means of acoustic or optical signaling devices (LED or LCD) that a vehicle with priority use of the road has been detected. In

addition, the volume level of the audio system in the vehicle is reduced to a certain level via actuators so that the driver's attention is drawn to the emergency vehicle. Furthermore, it is intended to provide an optical display or acoustic announcement of the direction of the emergency vehicle.

If, on the other hand, the system detects a horn or other device for sound signals on road vehicles such as bicycle bells, warning signals from rail vehicles, or general warning signals (construction sites, companies, etc.), the following responses are triggered:

(1) Regardless of the direction of the cause, the system is put into a state of heightened alertness and attempts to detect the cause by using other sensors (not shown), in particular optical sensors. Depending on the vehicle's own speed, said speed is reduced as well. Furthermore, the driver or the passengers can be informed by means of acoustic or optical devices **15**, **16** that there is an increased danger situation. If necessary, the automatic system can be switched off in a semi-automatically driven vehicle, e.g. when cruise control is set, so that a manual intervention is possible.

(2) After the warning signal has been detected, the vehicle's driver is informed by means of acoustic or optical devices **15**, **16** that a danger signal has been detected, irrespective of the direction from which the acoustic signal is coming. In addition, in a further embodiment of the invention, the volume level of the vehicle's audio system is reduced to a certain level via actuators, so that the driver's attention is drawn to the emergency vehicle. In addition, the acoustic and optical output devices **15** and **16** can be used to provide an optical display or acoustic announcement of the direction of the point of origin of the danger signal.

In a further preferred embodiment of the invention, the detection system can also be used for voice control purposes, i.e., human command words (calls for help, stop, code words) can be programmed into the system and used to trigger a command: (1) and (2) Execution of the command (such as "STOP"), but also a response to defined, possibly personal code words (e.g., to open the door, deactivate the anti-theft device and/or the immobilizer) Furthermore, the recorded acoustic signal can also be used to detect abnormal driving noises (squealing tires, the sound of a flat tire, engine or exhaust defects) and thus be used to detect vehicle malfunctions in a timely manner and to provide an early warning prior to scheduled maintenance.

(1)

(1) The system reacts depending on the cause, e.g., if a flat tire is heard, the vehicle is stopped, and a corresponding message is sent to a service center. On the other hand, the speed is reduced if the tires squeal. In addition, the system can be set to a state of increased alertness.

(2) The driver is given a cause message by means of optical and acoustic output devices **15** and **16**.

The detection system can also be used to detect weather conditions (rain, snow):

(1) The vehicle's speed is adapted to the corresponding weather condition, i.e., it is reduced, and a corresponding system state is assumed.

(2) The driver is informed about the respective weather condition by means of the optical and acoustic output devices **15** and **16**.

List of reference symbols

- 1** Microphone
- 2** Preamplifiers
- 3** AD converters
- 4** Evaluation unit
- 5** Computing unit
- 6** Spectrum analyzer
- 7** Marking circuit
- 8** Amplitude analyzer
- 9** Interface for display, further processing, and vehicle control
- 10** Spectrum comparison circuit
- 11** Travel time detection circuit
- 12** Amplitude comparator
- 13** Spectrum storage
- 14** Voice input device
- 15** Acoustic output device
- 16** Optical display device

Claims

1. Detection system for acoustic signals, comprising at least one receiver (**1**, **2**) for detecting acoustic signals outside the vehicle and/or inside of the vehicle, at least one output unit (**9**) for outputting information and/or control signals that are based on the acoustic signals,
- characterized by**
- an analog-to-digital converter (**3**) for converting the acoustic signals into digital data, an evaluation unit (**4**) for detecting classification features from the data, a computing unit (**5**) comprising at least one storage device (**13**) for storing comparison signals, and at least one comparison device (**10**) for comparing the detected classification features with previously stored classification features and for generating the information and/or control signals on the basis of the comparison result.
2. Detection system for acoustic signals according to claim 1, **characterized in that** the evaluation unit comprises filtering devices (**6**) for detecting the frequency distribution of the acoustic signal.
3. Detection system for acoustic signals according to claim 1 or 2, characterized in that the evaluation unit comprises locating devices (**7**, **8**, **11**, **12**) for determining the distance and/or the relative speed of the signal source of the acoustic signal.
4. Detection system for acoustic signals according to any of the

preceding claims, characterized by a voice input device (14) for recording and storing user commands.

5. Detection system for acoustic signals according to claim 1 or 2, characterized by a display device (16) for a visualization and/or sound reproduction device (15) for the acoustic reproduction of the evaluation steps. 5

6. Detection system for acoustic signals according to any of the preceding claims, characterized by actuators for automatically controlling the vehicle on the basis of an output signal from the computing unit. 10

7. Detection system for acoustic signals according to any of the preceding claims, characterized by a computer interface on the computing unit.

8. Method for the acoustic monitoring of a vehicle and the processing of acoustic signals comprising the steps: 15

Detecting acoustic signals inside and outside the vehicle and outputting of information and control signals depending on the detected acoustic signals, 20

characterized by the steps:

Converting the detected acoustic signals into digital data,

Detecting classification features in the data,

Comparing the detected classification features with previously stored classification features, and 25

Generating the information and control signals depending on the comparison result.

9. Method according to claim 8, characterized in that the detection of classification measures comprises filtering the acoustic signals to generate a frequency spectrum of the signal. 30

10. Method according to claim 8, characterized by a learning algorithm for storing selected classification features. 35

2 page(s) of drawings

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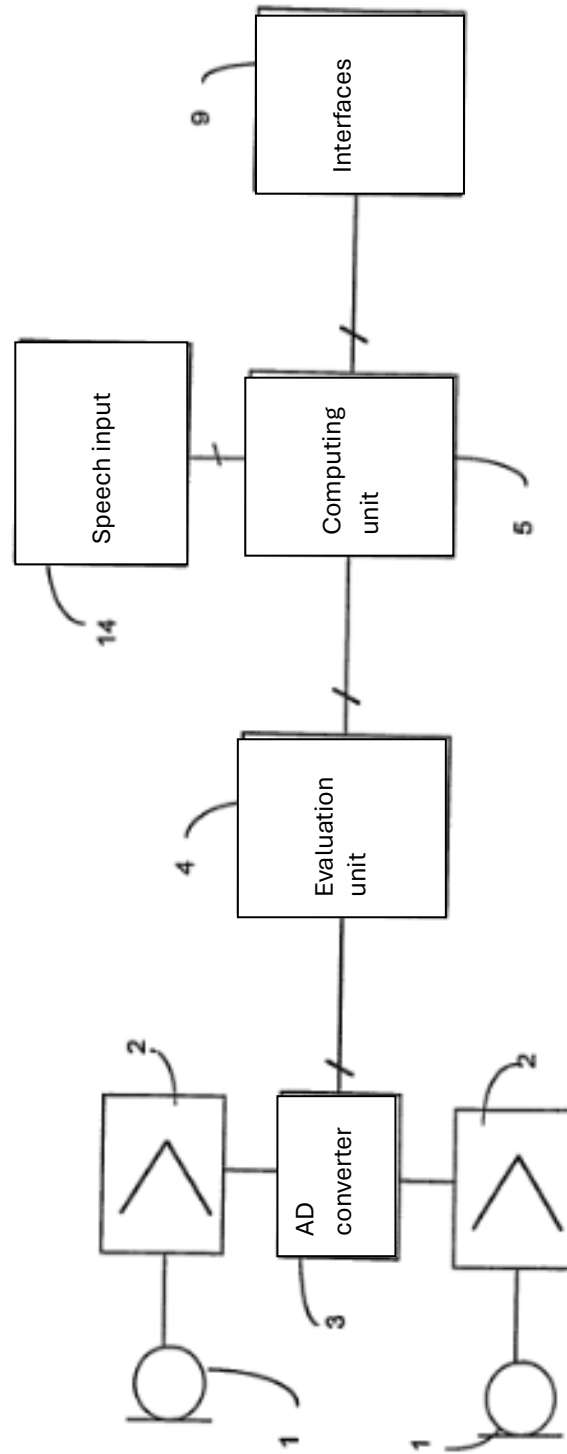


Fig. 1

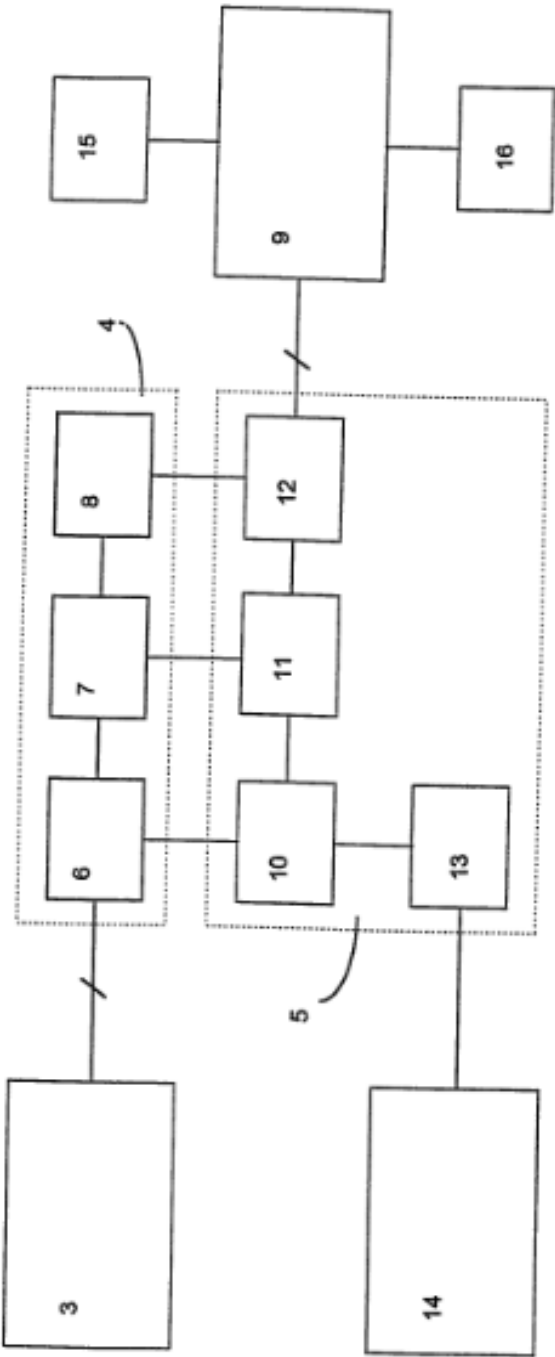


Fig. 2



TRANSLATION CERTIFICATION

Date: September 1, 2024

To whom it may concern:

I, Ute von Wietersheim, a translator fluent in the German and English languages, on behalf of Morningside, do solemnly and sincerely declare that the following is, to the best of my knowledge and belief, a true and correct translation of the document(s) listed below in a form that best reflects the intention and meaning of the original text.

All statements made in this declaration of my own knowledge are true and all statements made on information and belief are believed to be true. I make these statements with the understanding that willful false statements are punishable by fine or imprisonment, or both (18 U.S.C. 1001).

The document is designated as:

- DE19749372 A1

A handwritten signature in dark ink, appearing to read "Ute v. Wietersheim", followed by a horizontal line.

Signature

Ute von Wietersheim

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