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(54) **Title:** DEVICE FOR SENSING AND PROCESSING AN AC SIGNAL

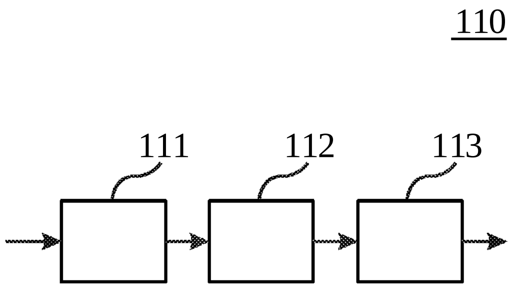

Fig. 1

(57) Abstract: A preprocessing device for use with a processing device which comprises a first processing module is provided. The preprocessing device comprises a passive amplifying module, a first rectifying module and a first conversion module. The passive amplifying module is configured to receive an AC signal and to amplify the AC signal to generate an amplified signal. The first rectifying module is coupled to the passive amplifying module and configured to rectify the amplified signal to generate a first rectified signal. The first conversion module is coupled to the first rectifying module and configured to convert the first rectified signal to generate a first converted signal and provide the first converted signal to the first processing module when the first processing module is controlled to be coupled to the first conversion module. An apparatus comprising a preprocessing device and a processing device is also provided.

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Device for sensing and processing an AC signal

TECHNICAL FIELD

[0001] The disclosure relates to signal sensing and processing. More particularly, the disclosure relates to a device of sensing and processing a fast changing AC signal.

BACKGROUND

[0002] Transducers are commonly used to detect information of an object. The information to be detected may include fast changing signals, such as vibration of the object. The detected information is transformed to corresponding electrical signals or other types of signals to output to other devices for further processing or transmission.

[0003] In industry, detecting the vibration of an object is of high importance in the preventive maintenance of the mechanical equipment such as electric drives, bearings, gearboxes, for example and the monitoring of machines in production lines. The vibration data of the equipment or machines that belong to one kind of field data may be collected by the transducers that are placed on or near the equipment or machines. The collected vibration data may be further processed to achieve desired characteristic information. For example, the intensity and spectral properties of the vibration data may be derived and analyzed in order to have knowledge of the operating time and load conditions of the equipment, the mechanical faults and upcoming device failures.

[0004] One known drive-train-analytics solution is mainly based on the evaluation of vibration sensor data sampled at frequencies of tens of kHz and sophisticated pre-processing by industry PCs.

[0005] The collection of the vibration sensor data may depend on IEPE (Integrated Electronics Piezo Electric) sensors. Since the sensed electrical signals which are representative of the vibration signals are usually weak, they are easily interfered by the noise. IEPE sensors integrate amplifiers inside them for amplifying the sensed electrical signals, and therefore can provide amplified vibration data for subsequent processing.

SUMMARY

[0006] Although the known systems are able to pick up the fast changing signals, they usually need a fixed power supply or allow only a very limited operation time on battery. For example, in the drive-train-analytics solution described above, sampling at frequencies of tens of kHz is very power consuming, and thus continuous operating time is limited, if the data acquisition system is running on battery power. In addition, for the IEPE sensors, operation of the integrated amplifiers is also a relatively high power consumption task, which requires a constant power supply as well.

[0007] In some situations, especially for monitoring the vibration of the equipment or machines in brownfield scenarios, adding sensors to the equipment or machines may encounter challenges regarding the connection to electric power. In this connection, a battery-powered signal sensing and processing device is more preferable. Considering an acceptable battery lifetime (e.g. >5 years) at an acceptable battery size and cost, the components or modules of the signal sensing and processing device shall be power-efficient, and complex processing of the sensed signals shall be avoided and performed at the backend side.

[0008] In view of above, one embodiment provides a preprocessing device for use with a processing device which comprises a first processing module. The preprocessing device comprises a passive amplifying module, a first rectifying module and a first conversion module. The passive amplifying module is configured to receive an AC signal and to amplify the AC signal to generate an amplified signal. The first rectifying module is coupled to the passive amplifying module and configured to rectify the amplified signal to generate a first rectified signal. The first conversion module is coupled to the first rectifying module and configured to convert the first rectified signal to generate a first converted signal and provide the first converted signal to the first processing module when the first processing module is controlled to be coupled to the first conversion module.

[0009] In the embodiment, since the amplifying module is passive, the fast changing AC signals may be continuously received and preprocessed by the preprocessing device with low power consumption.

[0010] Another embodiment provides an apparatus comprising a preprocessing device and a processing device coupled to the preprocessing device. The preprocessing device includes a passive amplifying module, a first rectifying module and a first conversion module. The passive amplifying module is configured to receive an AC signal and to amplify the AC signal to generate an amplified signal. The first rectifying module is coupled to the passive amplifying module and configured to rectify the amplified signal to generate a first rectified signal. The first conversion module is coupled to the first rectifying module and configured to convert the first rectified signal to generate a first converted signal. The processing device includes a first processing module and a first control module. The first control module is configured to control the first processing module to be coupled to the first conversion module when a first predetermined trigger condition is satisfied such that the first processing module receives the first converted signal from the first conversion module.

[0011] In the embodiment, the fast changing AC signals with low amplitude are preprocessed by the preprocessing device with low power consumption. With the preprocessing device continuously recording the sensor signal and performing part of the sensor signal processing, the processing device may operate at a low duty cycle and only acquire and process the results of the preprocessing during the wakeup time periods. Therefore, the overall power consumption of the signal sensing and processing device is reduced while continuously monitoring the object, and thus the battery may be used as a power supply for several years without involving a large investment in equipment and infrastructure, which provides convenience for deployment and saves the deployment cost.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] In the text which follows, the disclosure will be explained in greater detail, without restricting the general concept of the disclosure, on the basis of example embodiments and with reference to the figures.

[0013] FIG. 1 is a block diagram of a preprocessing device for use with a processing device in accordance with one embodiment.

[0014] FIG. 2 is a block diagram of an apparatus comprising a preprocessing device and a processing device in accordance with one embodiment.

[0015] FIG. 3 is a block diagram of an apparatus comprising a signal generating module, a preprocessing device and a processing device in accordance with one embodiment.

DETAILED DESCRIPTION

[0016] The disclosure will be further described in detail in conjunction with the accompanying drawings and embodiments. It should be understood that the particular embodiments described herein are only used to illustrate the disclosure but not to limit the disclosure.

[0017] Although the terms first, second, etc. may be used herein to describe various elements, it should be understood that these elements should not be limited by these terms. These terms are only used to distinguish them from each other. For example, a first element could be termed a second element, and similarly, a second element could be termed a first element without departing from the scope of the disclosure.

[0018] It also should be understood that when an element is referred to as being “connected”, or “coupled”, to another element, it can be directly connected or coupled to the other element or intervening elements may be present. Other words used to describe the relationship between elements should be interpreted in a similar fashion (e.g., “between”, “adjacent”, etc.).

[0019] FIG. 1 shows a block diagram of an exemplary preprocessing device in accordance with one embodiment. The preprocessing device may be used to receive an AC signal and preprocessing the AC signal. The AC signal may be a fast changing AC signal indicative of vibration of an object. Then, the preprocessed signal may be provided to the processing device (not shown) for further processing.

[0020] Referring to FIG. 1, the preprocessing device 110 includes a passive amplifying module 111, a first rectifying module 112 and a first conversion module 113.

[0021] The passive amplifying module 111 is configured to receive the AC signal and amplify the AC signal to generate an amplified signal. The AC signal may be received from a signal generating module which senses the vibration of an object.

[0022] The first rectifying module 112 is coupled to the passive amplifying module 111 and is configured to receive the amplified signal as the input signal. The first rectifying module 112 rectifies the amplified signal to produce the absolute value of the amplified signal as the output signal, i.e., a first rectified signal. Then, the first rectified signal is provided to the first conversion module 113 which is coupled to the first rectifying module 112.

[0023] The first conversion module 113 converts the first rectified signal based on the application requirements and generates a first converted signal, which will be described in more detail with reference to FIG. 3.

[0024] When the first processing module (not shown) of the processing device is controlled to be coupled to the first conversion module 113, the first converted signal is provided from the first conversion module 113 to the first processing module for further processing.

[0025] Since the amplifying module of the preprocessing device 110 is passive, the fast changing AC signals may be continuously received and preprocessed by the preprocessing device 110 with low power consumption.

[0026] For selecting frequency bands of interest to analyze the spectral characteristics of the AC signal, the amplified signal may be split into one or more frequency bands. In one embodiment, the preprocessing device 110 may further include a first frequency selection module coupled between the passive amplifying module 111 and the first rectifying module 112 and configured to pass the amplified signal in a first predetermined frequency band to generate a first filtered signal and provide the first filtered signal to the first rectifying module 112.

[0027] In other embodiments, the preprocessing device 110 may further comprise a second signal path including a second frequency selection module which passes the amplified signal in a second predetermined frequency band to generate a second filtered signal, a second rectifying module which rectifies the second filtered signal to generate a second rectified signal, and a second conversion module which converts the second rectified signal to generate a second converted signal. The second converted signal is then provided from the second conversion module to a second processing module of the processing device when the second processing module is controlled to be coupled to the second conversion module.

[0028] In other embodiments, the preprocessing device 110 may further include a signal generating module coupled to the passive amplifying module 111. The signal generating module is configured to sense vibration and generate the AC signal indicative of vibration and to provide the AC signal to the passive amplifying module 111. The vibration may originate from a piece of equipment or a machine, or from a detected sound signal.

[0029] FIG. 2 depicts a block diagram of an exemplary apparatus including a preprocessing device and a processing device in accordance with one embodiment.

[0030] Referring to FIG. 2, the apparatus 200 includes a preprocessing device 210 and a processing device 220. The arrangements and functions of the passive amplifying module 211, the first rectifying module 212 and the first conversion module 213 of the preprocessing device 210 as shown in FIG. 2 may be similar to those of the passive amplifying module 111, the first rectifying module 112 and the first conversion module 113 of the preprocessing device 110 as shown in FIG. 1, and thus will not be repeated in details for simplicity.

[0031] The processing device 220 includes a first processing module 221 and a first control module 222.

[0032] When a first predetermined trigger condition is satisfied, the first control module 222 controls the first processing module 221 to be coupled to the first conversion module 213 of the preprocessing module 210, and thereby the first processing module 221 receives the first converted signal from the first conversion module 213 for further processing, for example, A/D conversion, storage or transmission. When a second predetermined trigger condition is satisfied, the first control module 222 controls the first processing module 221 to be disconnected from the first conversion module 213 such that the first processing module 221 does not receive the first converted signal any longer.

[0033] With the preprocessing device 210 continuously recording the sensor signal and performing part of the sensor signal processing, the processing device 220 may operate at a low duty cycle and only acquire and process the results of the preprocessing during the wakeup time periods.

[0034] For selecting frequency bands of interest to analyze the spectral characteristics of the AC signal, the amplified signal may be split into one or more frequency bands. In one embodiment, the preprocessing device 210 may further include a first frequency selection module coupled to the passive amplifying module to pass the amplified signal in a first determined frequency band, and to provide the filtered signal to the first rectifying module 212.

[0035] In other embodiments, similar to those described with reference to FIG. 1, the preprocessing device 210 may further include a second signal path including a second frequency selection module which passes the amplified signal in a second predetermined frequency band to generate a second filtered signal, a second rectifying module which rectifies the second filtered signal to generate a second rectified signal, and a second conversion module which converts the second rectified signal to generate a second converted signal.

[0036] Correspondingly, the processing device 220 may further include a second processing module (not shown) and a second control module (not shown) to further process the second converted signal. The second control module is configured to control the second processing module to be coupled to the second conversion module when a third predetermined trigger condition is satisfied such that the second processing module receives the second converted signal from the second conversion module. When a fourth predetermined trigger condition is satisfied, the second control module is further configured to control the second processing module to be disconnected from the second conversion module, and the second processing module does not receive the second converted signal any longer.

[0037] FIG. 3 is a block diagram of an exemplary apparatus comprising a signal generating module, a preprocessing device and a processing device in accordance with one embodiment.

[0038] Referring to FIG. 3, the apparatus 300 includes a signal generating module 330, a preprocessing device 310 and a processing device 320. The signal generating module 330 is used to sense vibration and generate an AC signal indicative of vibration.

[0039] For reducing cost and power consumption, in one embodiment, the signal generating module 330 may include at least one piezoelectric transducer which is attached to the object of which the vibrations shall be monitored. The piezoelectric transducer is capable of generating an electrical vibration signal representative of the mechanical vibration without requiring an external electric power. The sensed values may be quantitative representations of the maximum/average velocity, the acceleration, the displacement of the vibration, for example. In other embodiments, the signal generating module 330 may include other kinds of transducers which could output a weak and fast changing AC signal, such as magnetic pick-ups. The magnetic pick-ups may be dynamic microphones, for example.

[0040] Still referring to FIG. 3, the passive amplifying module 311 of the preprocessing device 310 is coupled to the signal generating module 330 and configured to receive the AC signal generated from the signal generating module 330 and amplify the level of the AC signal to a value suitable for further processing. In one embodiment, the passive amplifying module 311 may include a transformer, such as a miniature-size audio transformer, for example. The amplifying factor may be set based on the ratios of the primary winding and the secondary winding of the transformer. The passive amplifying module 311 is able to work without requiring a fixed power supply, and therefore significantly reduces the power consumption compared with an active amplifier.

[0041] In addition, the impedance matching network 315 of the preprocessing device 310 is coupled between the signal generating module 330 and the passive amplifying module 311 in order to match the output impedance of the signal generating module 330 and input impedance of the passive amplifying module 311. In one embodiment, the impedance matching network 315 may include a combination of capacitors, inductors and/or resistors so as to form a passive impedance matching network. For example, the impedance matching network 315 may consist of a signal capacitor in parallel to the primary winding of the transformer. In other embodiments, the impedance matching network 315 may include an active component, for example, a MOSFET buffer amplifier, an operational amplifier (OpAmp), etc. In other embodiments, the impedance matching network 315 may be omitted such that the size and cost of the overall system may be reduced.

[0042] Still referring to FIG. 3, following the passive amplifying module 311, two frequency selection modules, i.e. a first frequency selection module 314 and a second frequency selection module 314’ are configured to receive the amplified signal and pass the amplified signal in a first predetermined frequency band and a second predetermined frequency band, respectively. The first and the second predetermined frequency bands are frequency bands of interest for analyzing the spectral characteristics. The selection of the frequency bands depends on the specific application and requirements.

[0043] In the embodiment shown in FIG. 3, two frequency selection modules are applied. For analyzing the spectral characteristics in more frequency bands, in other embodiments, the preprocessing device 310 may include more frequency selection modules with different frequency bands for passing the amplified signal so as to split the amplified signal into several frequency bands or filter out particular frequencies of interest. For example, some slightly overlapping frequency bands within a certain frequency range may be selected.

[0044] In other embodiments, the preprocessing device 310 may include one frequency selection module in the case that only one frequency band is of interest. In other embodiments, the frequency selection module may also be omitted so as to reduce the size and cost of the overall system.

[0045] In one embodiment, the first frequency selection module 314 and the second frequency selection module 314’ may be passive filters, such as LC-type filters, such that the power consumption may be reduced.

[0046] The following description takes the first signal path (the upper branch) in FIG. 3 as an example. The first frequency selection module 314 is configured to generate a first filtered signal, and then the first filtered signal is provided to a first rectifying module 312 and rectified by a first rectifying module 312 such that the output voltage is always positive and the current flows in one direction. In one embodiment, the first rectifying module 312 may include a single diode for performing rectification in order to reduce the size and the required voltage level. In other embodiments, the first rectifying module 312 may include other rectifiers, such as a full-wave bridge rectifier, or a half-wave rectifier, for example.

[0047] The first rectifying module 312 rectifies the first filtered signal and generates a first rectified signal. Following the first rectifying module 312 is a first conversion module 313, which is configured to convert the first rectified signal to generate a first converted signal.

[0048] For reducing power consumption, in some embodiments, the first conversion module 313 may be passive, for example, it may include an RC circuit with a resistor coupling to the first rectifying module 312 and a capacitor coupling between the other terminal of the resistor and the ground.

[0049] The conversion of the first rectified signal depends on the specific application and requirements. In one embodiment, when it is measuring vibration on a motor that is running only short periods of time and idle most of the time, the peak value of the vibrations is of high interest. In this regard, the RC circuit may act as a peak-hold circuit. The capacitor will be charged to the maximum value of the first rectified signal, and hold the maximum value for a sufficient period of time for the processing device 320 to read the maximum value, until it is discharged.

[0050] In another embodiment, the RC circuit may act as an integrator such that the voltage over the capacitor gradually builds up over time based on the intensity and duration of the vibrations within the first predetermined frequency band. In other embodiments, the first conversion module 313 may include other circuits, such as an integrator circuit based on an operational amplifier.

[0051] The first converted signal is then fed into the processing device 320. In one embodiment, a current-limiting resistor may be applied before the first converted signal is fed into the processing device 320, in order to protect the processing device 320 from being damaged by a large current.

[0052] The processing device 320 may include a first processing module 321, a first control module 322, a first terminating module 323 and a first reset module 324, which constitute a first module (not shown) operating at a low duty cycle, i.e. is normally in sleep mode. In one embodiment, the processing device 320 may be a microcontroller or SOC (System-on-chip) or a device containing a microcontroller core.

[0053] The operation of the modules of the processing device 320 will be described in detail with reference to FIG. 3. Initially, the first module is in sleep mode, that is, the first conversion module 313 is disconnected from the first processing module 321 and coupled to a first terminating module 323. In this case, the first converted signal is not received by the first processing module 321. In one embodiment, the first terminating module 323 includes a high-impedance node. The first conversion module 313 is coupled to the high-impedance node when the first module is sleeping. While the first module is sleeping, the vibration signal is continuously picked up by the signal generating module 330 and preprocessed by the preprocessing device 310. In the embodiment that the first conversion module 313 consists of an RC circuit, the capacitor will be gradually charged, depending on the frequency components contained in the vibration, the characteristics of the filters and the values of the resistor and capacitor in the RC circuit.

[0054] The first control module 322 in the processing device 320 determines whether a first predetermined trigger condition is satisfied. If yes, the first control module 322 controls the first processing module 321 to be coupled to the first conversion module 313, that is, the first module is switched to the wakeup mode, such that the first processing module 321 receives the first converted signal from the first conversion module 313.

[0055] In one embodiment, the first predetermined trigger condition may depend on a timer. For example, a first predetermined time period for sleeping is preset. Once the first predetermined time period has expired, the first control module may control the first processing module 321 to be coupled to the first conversion module 313 such that the first module wakes up from the sleep mode.

[0056] In another embodiment, the first control module 322 may include a comparator for comparing the first converted signal with a predetermined value. Upon detection of the first converted signal exceeds the predetermined value the first control module 322 controls the first processing module 321 to be coupled to the first conversion module 313 such that the first module is awaken from its sleep mode.

[0057] Using a comparator allows a non-constant wakeup cycle, and thereby potentially allowing very low power consumption. For example, in the case that there is no or little vibration in the frequency band of interest, the first module would wake up infrequently, whereas in the case of strong vibrations, the wakeup frequency would automatically increase.

[0058] In another embodiment, the first predetermined trigger condition may be based on the combination of the timer and the comparator. The first predetermined time period of the timer may be set to be relatively long, and if the comparator does not trigger the wake-up event before the first predetermined time period expires, then the first control module 322 controls the first processing module 321 to be coupled to the first conversion module 313 such that the first module wakes up based on the first predetermined time period. Otherwise, when the comparator triggers the wake-up event before the first predetermined time period expires, the first control module 322 controls the first processing module 321 to be coupled to the first conversion module 313 such that the first module wakes up based on the output of the comparator and then the timer is reset.

[0059] Then the first processing module 321 processes the received signal which has been preprocessed. In one embodiment, the first conversion module may include an RC circuit, and the first processing module 321 may include an A/D converter to convert the analog voltage of the capacitor into digital values.

[0060] In other embodiments, the first processing module 321 may include other components. For example, a FLASH memory may be included to store the preprocessed signal or processed signal locally, and a transmission unit may be included to send out the preprocessed signal or processed signal to a data sink, such as a cloud platform, a mobile device, a server, an edge computing device, etc., either by wired or wireless connection.

[0061] In addition, the first control module 322 further controls the first processing module 321 to be disconnected from the first conversion module 313 when a second predetermined trigger condition is satisfied. In this case, the first processing module 321 does not receive and process the first converted signal any more.

[0062] In some embodiments, the first control module 322 controls the first terminating module 323 to be coupled to the first conversion module 313 when the second predetermined trigger condition is satisfied, such that the first module is brought back to the sleeping mode. In one embodiment, the second predetermined trigger condition may include the processing of the first converted signal being finished by the first processing module 321. In another embodiment, the second predetermined trigger condition may include a second predetermined time period being reached.

[0063] In other embodiments, the first control module 322 controls the first reset module 324 to be coupled to the first conversion module 313 when the second predetermined trigger condition is satisfied. In one embodiment, the first conversion module 313 may include an RC network and the first reset module 324 may include a discharge module, when the second predetermined trigger condition is satisfied, the first control module 322 controls the discharge module to be coupled to the RC network such that the capacitor in the RC network is discharged for a sufficient period of time and the voltage across the capacitor is pulled down to logical low.

[0064] In some embodiments, the first control module 322 may further control the first reset module 324 to be disconnected from the first conversion module 313 and the first terminating module 323 to be coupled to the first conversion module 313 based on a predetermined trigger condition. In one embodiment, the predetermined trigger condition of the switch from the first reset module 324 to the first terminating module 323 may be based on a timer. The timer is capable of being set a fixed time or a calculated time in order to reset the first conversion module 313. For the calculated time, an initial value of the first converted signal may be measured and then the time for resetting the first conversion module 313 may be calculated.

[0065] In other embodiments, the value of first converted signal may be periodically measured to determine whether the fist conversion module 313 has been reset or not. In the case that it is determined that the first conversion module 313 has been reset, the first control module 322 controls the first reset module 324 to be disconnected from the first conversion module 313 and the first terminating module 323 to be coupled to the first conversion module 313, and thereby the first module goes back to sleep.

[0066] In other embodiments, a comparator may be included in the first control module 322 with a predefined value. In the case that the measured value of the first converted signal is below the predefined value, the first control module 322 controls the first reset module 324 to be disconnected from the first conversion module 313 and the first terminating module 323 to be coupled to the first conversion module 313, and thereby the first module goes back to sleep.

[0067] Still referring to FIG. 3, the second rectifying module 312’ is coupled to the second frequency selection module 314’ and configured to rectify the second filtered signal and generate a second rectified signal. The second conversion module 313’ is coupled to the second rectifying module 312’ and configured to convert the second rectified signal and generate a second converted signal. The second control module 322’ of the processing device 320 is configured to control the second processing module 321’ to be coupled to the second conversion module 313’ when a third predetermined trigger condition is satisfied such that the second processing module 321' receives the second converted signal from the second conversion module 313'.

[0068] In one embodiment, the second control module 322' may be further configured to control the second processing module 321' to be disconnected from the second conversion module 313' when a fourth predetermined trigger condition is satisfied such that the second processing module 321' does not receive the second converted signal from the second conversion module 313' any more. The third predetermined trigger condition and the fourth predetermined trigger condition are similar to those described with reference to the first predetermined trigger condition and the second predetermined trigger condition, and therefore will not be described in detail for simplicity.

[0069] The configurations and functions of the second rectifying module 312', the second conversion module 313', the second control module 322', the second processing module 321', the second terminating module 323' and the second reset module 324' are similar to those of the first rectifying module 312, the first conversion module 313, the first control module 322, the first processing module 321, the first terminating module 323 and the first reset module 324 of the upper branch in FIG. 3, and therefore will not be described in detail for simplicity.

[0070] As discussed above, two frequency bands of interest are selected in the embodiment shown in FIG. 3. In other embodiments, if more frequency bands are of interest, more branches of modules including a frequency selection module, a rectifying module, a conversion module of the preprocessing device, and a control module, a processing module, a terminating module and a reset module of the processing device may be added. The number of the branches corresponds to the number of frequency bands of interest.

[0071] In other embodiments, if one frequency band is of interest, only one branch of modules including a frequency selection module, a rectifying module, a conversion module of the preprocessing device, and a control module, a processing module, a terminating module and a reset module of the processing device may be applied.

[0072] In other embodiments, the frequency selection performed by the frequency selection modules may be achieved by the impedance matching network which can perform filtering when matching the impedances. In this case, the frequency selection modules may be omitted and the power consumption may be further reduced.

[0073] In one embodiment, if one frequency band is of interest, only one branch of modules including an impedance matching network, a passive amplifying module, a rectifying module, a conversion module of the preprocessing device, and a control module, a processing module, a terminating module and a reset module of the processing device may be applied.

[0074] In other embodiments, if two or more frequency bands are of interest, the corresponding number of passive amplifying modules may be applied. The signal generating module 330 may include the corresponding number of transducers (for example, piezoelectric transducers) which are coupled to the passive amplifying modules respectively. Also, the corresponding number of impedance matching networks may be applied. They are configured to match the impedances of the transducers and the passive amplifying modules respectively and perform the frequency selection. The frequency bands may be selected by adjusting the components and the values of the components of the impedance matching networks.

[0075] The selection of the components of the impedance matching networks may depend on the specific application and requirements. In some embodiments, if only one or two frequency bands are of interest, the impedance matching networks may consist of purely passive devices, such as an RLC network, such that the power consumption may be reduced.

[0076] In other embodiments, if slightly more frequency bands are of interest, some active device (such as a MOSFET buffer amplifier) may be included in the impedance matching networks such that the frequency bands may be extended for selecting.

[0077] While the foregoing is directed to some embodiments of the disclosure, it will be appreciated by those skilled in the art that the disclosure can be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The presently disclosed embodiments are therefore considered in all aspects to be illustrative and not restricted. The scope of the disclosure is indicated by the claims rather than the foregoing description and all changes that come within the meaning and the range and equivalence thereof are intended to be embraced therein.

CLAIMS:

1. Preprocessing device, for use with a processing device which comprises a first processing module, the preprocessing device comprising:

a passive amplifying module configured to receive an AC signal and to amplify the AC signal to generate an amplified signal;

a first rectifying module coupled to the passive amplifying module and configured to rectify the amplified signal to generate a first rectified signal; and

a first conversion module coupled to the first rectifying module and configured to:

convert the first rectified signal to generate a first converted signal; and

provide the first converted signal to the first processing module when the first processing module is controlled to be coupled to the first conversion module.

2. The device of claim 1, further comprising:

a first frequency selection module coupled between the passive amplifying module and the first rectifying module, and configured to pass the amplified signal in a first predetermined frequency band to generate a first filtered signal and provide the first filtered signal to the first rectifying module.

3. The device of claim 2, wherein the first frequency selection module is passive.

4. The device of claim 1, wherein the first rectifying module is passive.

5. The device of claim 1, wherein the first conversion module is passive.

6. The device of claim 2, wherein the processing device further comprises a second processing module, the preprocessing device further comprising:

a second frequency selection module coupled to the passive amplifying module and configured to pass the amplified signal in a second predetermined frequency band to generate a second filtered signal;

a second rectifying module coupled to the second frequency selection module and configured to rectify the second filtered signal to generate a second rectified signal; and

a second conversion module coupled to the second rectifying module and configured to:

convert the second rectified signal to generate a second converted signal; and

provide the second converted signal to the second processing module when the second processing module is controlled to be coupled to the second conversion module.

7. The device of claim 1, wherein the first conversion module comprises a peak-hold unit configured to identify and hold the peak value of the first rectified signal so as to generate the first converted signal.

8. The device of claim 1, wherein the first conversion module comprises an integrator unit configured to perform integration of the first rectified signal so as to generate the first converted signal.

9. The device of claim 1, wherein the AC signal is received from a signal generating module, the preprocessing device further comprising:

an impedance matching module configured to match the impedances of the signal generating module and the passive amplifying module.

10. The device of claim 1, wherein the AC signal is a signal indicative of vibration.

11. The device of claim 1, wherein the passive amplifying module is a transformer.

12. The device of claim 1, further comprising:

a signal generating module configured to sense vibration and generate the AC signal indicative of the vibration and to provide the AC signal to the passive amplifying module.

13. Apparatus, comprising:

a preprocessing device, comprising:

a passive amplifying module configured to receive an AC signal and to amplify the AC signal to generate an amplified signal;

a first rectifying module coupled to the passive amplifying module and configured to rectify the amplified signal to generate a first rectified signal; and

a first conversion module coupled to the first rectifying module and configured to convert the first rectified signal to generate a first converted signal; and

a processing device coupled to the preprocessing device, comprising:

a first processing module;

a first control module and configured to control the first processing module to be coupled to the first conversion module when a first predetermined trigger condition is satisfied such that the first processing module receives the first converted signal from the first conversion module.

14. The apparatus of claim 13, wherein the first control module is further configured to control the first processing module to be disconnected from the first conversion module when a second predetermined trigger condition is satisfied.

15. The apparatus of claim 14, wherein the processing device further comprises a first reset module, and the first control module is further configured to control the first reset module to be coupled to the first conversion module when the second

predetermined trigger condition is satisfied such that the first conversion module is reset by the first reset module.

16. The apparatus of claim 14, wherein the processing device further comprises a first terminating module, and the first control module is further configured to control the first terminating module to be coupled to the first conversion module when the second predetermined trigger condition is satisfied such that no signal is provided from the first conversion module to the first processing module.

17. The apparatus of claim 13, wherein the preprocessing device further comprises:

a first frequency selection module coupled between the passive amplifying module and the first rectifying module, and configured to pass the amplified signal in a first predetermined frequency band to generate a first filtered signal and provide the first filtered signal to the first rectifying module.

18. The apparatus of claim 17, wherein the preprocessing device further comprises:

a second frequency selection module coupled to the passive amplifying module and configured to pass the amplified signal in a second predetermined frequency band to generate a second filtered signal;

a second rectifying module coupled to the second frequency selection module and configured to rectify the second filtered signal to generate a second rectified signal; and

a second conversion module coupled to the second rectifying module and configured to convert the second rectified signal to generate a second converted signal; and

wherein the processing device further comprises:

a second processing module;

a second control module configured to control the second processing module to be coupled to the second conversion module when a third predetermined trigger condition is satisfied such that the second processing module receives the second converted signal from the second conversion module.

19. The apparatus of claim 18, wherein the second control module is further configured to control the second processing module to be disconnected from the second conversion module when a fourth predetermined trigger condition is satisfied.

20. The apparatus of claim 13, wherein the first predetermined trigger condition being satisfied comprises one or more of:

the first converted signal exceeding a predetermined value; and

a first predetermined time period being reached.

21. The apparatus of claim 14, wherein the second predetermined trigger condition being satisfied comprises one or more of:

the processing of the first converted signal being finished by the first processing module; and

a second predetermined time period being reached.

22. The apparatus of claim 13, further comprising:

a signal generating module configured to sense vibration and generate the AC signal indicative of the vibration and to provide the AC signal to the passive amplifying module.

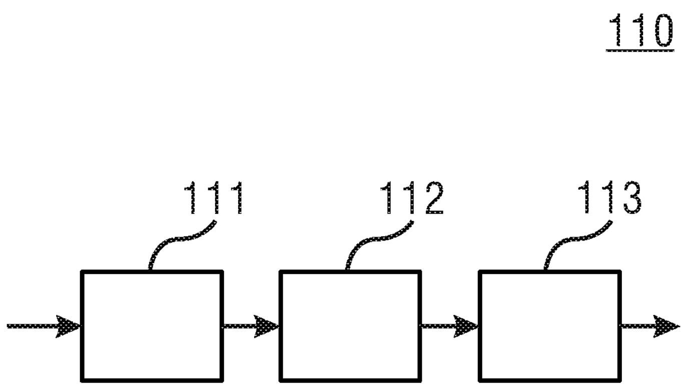

Fig. 1

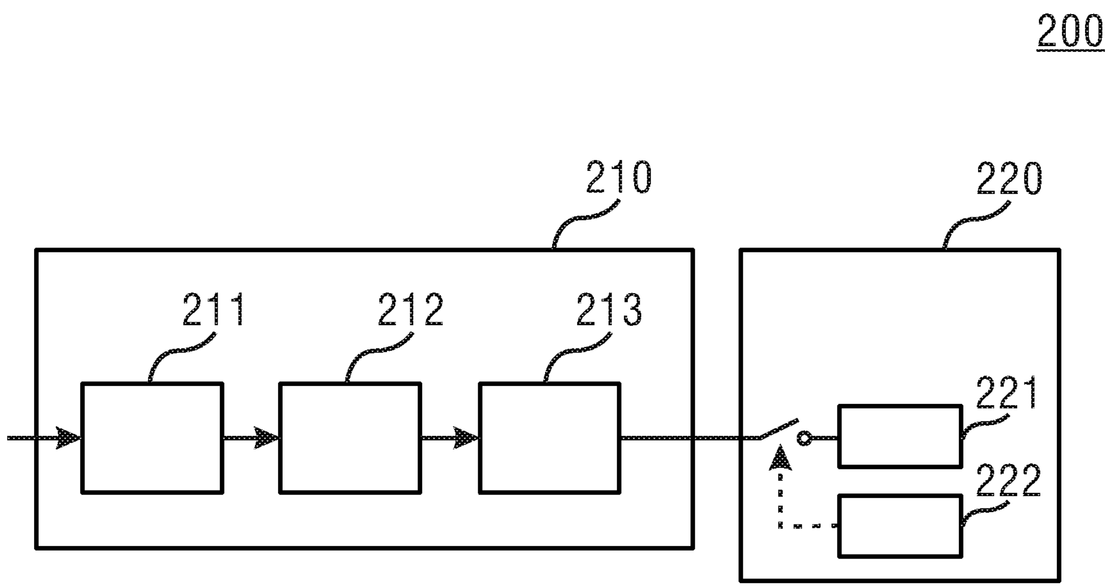

Fig. 2

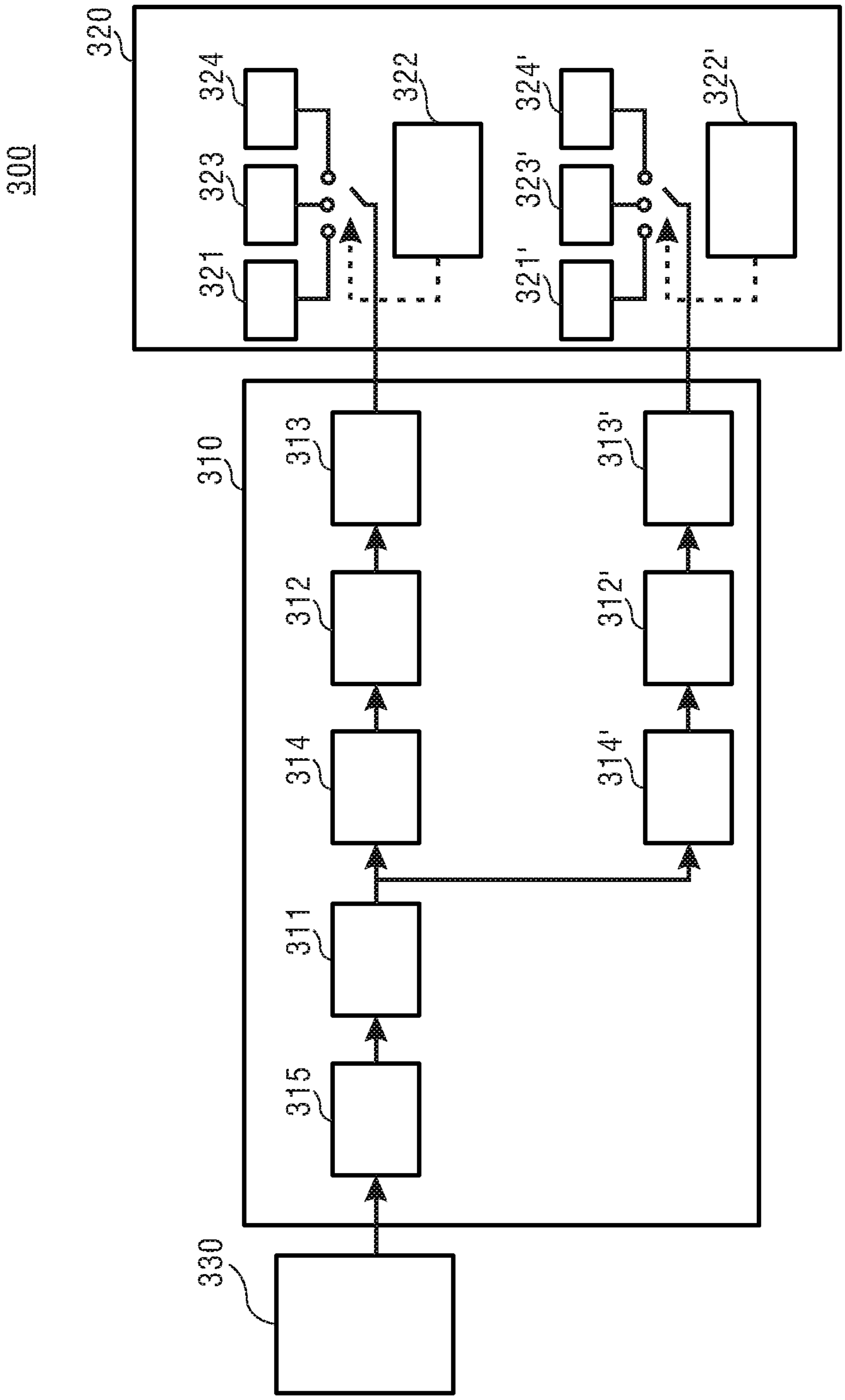
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Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2018/100969

A. CLASSIFICATION OF SUBJECT MATTER

H04R 3/08(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT,CNKI,WPI,EPODOC:transducer, power consumption, AC, coil, number, turn, winding, primary, secondary, transformer, rectification, resistance, capacitance, filtering

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 102200528 A (TAIYUAN UNIVERSITY OF TECHNOLOGY) 28 September 2011 (2011-09-28) see description, paragraph[0014], figures 1-2	1-22
Y	CN 106685259 A (CANON KABUSHIKI KAISHA) 17 May 2017 (2017-05-17) see description, paragraph[0061], figure1	1-22
Y	CN 106357153 A (CANON KABUSHIKI KAISHA) 25 January 2017 (2017-01-25) see description, paragraphs[0048]-[0049], [0054], figures 2A, 8A	1-22
A	CN 103278558 A (CHONGQING JIAOTONG UNIVERSITY) 04 September 2013 (2013-09-04) the whole document	1-22
A	CN 106154061 A (STATE GRID CORPORATION OF CHINA ET AL.) 23 November 2016 (2016-11-23) the whole document	1-22

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 April 2019	**06 May 2019**
Name and mailing address of the ISA/CN **National Intellectual Property Administration, PRC** **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	Authorized officer **WANG,Jimei**
Facsimile No. **(86-10)62019451**	Telephone No. **86-(10)-53961802**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2018/100969

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	102200528	A	28 September 2011	None			
CN	106685259	A	17 May 2017	JP	2017022943	A	26 January 2017
				US	2017017058	A1	19 January 2017
CN	106357153	A	25 January 2017	JP	2017022941	A	26 January 2017
				US	2017017137	A1	19 January 2017
CN	103278558	A	04 September 2013	None			
CN	106154061	A	23 November 2016	None			