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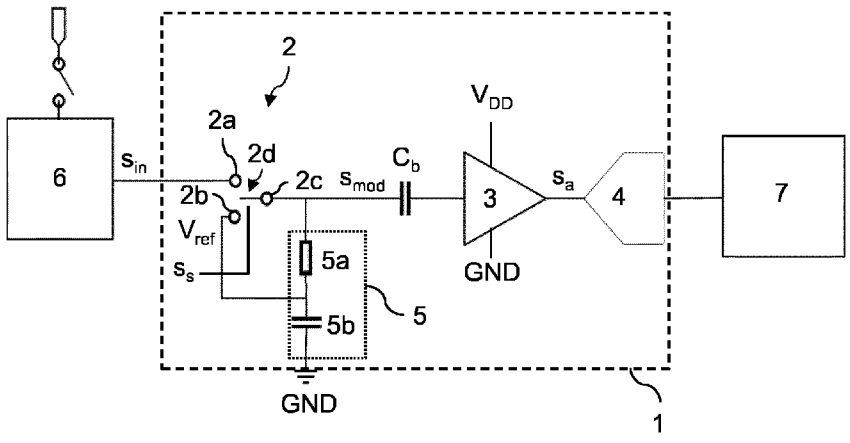

FIG. 1

(57) Abstract: An amplifier or amplifying arrangement for amplifying an input signal that employs a modulating arrangement. The modulating arrangement generates a modulated signal that alternates between a reference voltage level and a voltage level of the input signal. This modulated signal is then amplified, and the amplified modulated signal is sampled to thereby obtain amplified samples of the original input signal. The reference voltage level is based upon one or more magnitude characteristics of the input signal.

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ARRANGEMENT FOR AMPLIFYING AN INPUT SIGNAL

FIELD OF THE INVENTION

The present invention relates to the field of amplifiers, and in particular to the field of amplifiers for an alternating current (AC) signal.

BACKGROUND OF THE INVENTION

There has been an increasing interest in amplifiers for low-magnitude and low-frequency alternating current (AC) signals. One known method is to use a chopper amplifier to amplify such signals. Chopper amplifiers help avoid pink noise, mains supply interference and (parasitic) piezoelectric noise introduced by vibrations.

A chopper amplifier operates by chopping an input signal at a frequency greater than a frequency of interest (i.e. an AC component) in the input signal. The chopped signal is then amplified to produce an amplified chopped signal. The amplified chopped signal can then be smoothed, e.g. using a capacitor arrangement, to generate an amplified version of the input signal.

Signals of higher frequencies suffer less from the aforementioned noise sources than signals of lower frequencies during an amplification process. Thus, by converting the input signal into a signal of a higher frequency before amplification, these noises can be mitigated during the amplification process.

However, whilst current chopper amplifiers provide good low-noise amplification, they can be large and expensive, especially in the context of conventional consumer electronics such as lighting devices. There is therefore an ongoing desire to minimize the cost of low-noise alternating current amplifiers, as well as to improve the signal-to-noise ratio of such amplifiers and reduce a power consumption of said amplifiers.

SUMMARY OF THE INVENTION

The invention is defined by the claims.

According to an embodiment of the invention, there is provided an amplifying arrangement for amplifying an input signal of a first frequency. The amplifying arrangement further comprises a reference voltage level generator adapted to generate a reference voltage

level having a magnitude based on one or more magnitude characteristics of the input signal. The amplifying arrangement also comprises a modulating arrangement adapted to receive the input signal and generate a modulated signal that alternates, at a second frequency, between a current voltage level of the input signal and a reference voltage level, the second frequency being greater than the first frequency. The amplifying arrangement further comprises an amplifying circuit adapted to amplify the modulated signal to thereby provide an amplified modulated signal. The amplifying arrangement also comprises an analogue-to-digital converter adapted to perform a demodulation operation comprising sampling the amplified modulated signal at the second frequency and synchronized with portions of the amplified modulated signal corresponding to amplifications of the input signal, to thereby obtain amplified samples of the input signal.

Thus, there is provided an amplifier that generates a modulated signal that alternates between a reference voltage level and a voltage level of an input signal. The reference voltage level is based upon or is representative of one or more magnitude characteristics of the input signal. This modulated signal is then amplified, and the amplified modulated signal is sampled to thereby obtain amplified samples of the original input signal. In this way, the amplifying arrangement effectively acts as an analogue-to-digital amplifier.

Effectively, the input signal is represented as pulses in the modulated signal, with the modulated signal being held at a reference voltage level (based on the input signal) between pulses.

It has been recognized that alternating between the input signal and the reference voltage level enables a modulated signal to be generated with a voltage offset, in the portions of the modulated signal that do not correspond to the voltage level of the input signal (i.e. the "input signal portions"). Thus, the overall voltage range/swing of the modulated signal can be modified by adjusting the reference voltage level.

By producing the reference voltage level based on one or more magnitude characteristics of the input signal, a modulated signal can be produced that has a voltage swing similar to or based on the voltage swing of the input signal. Thus, a modulated signal having a voltage swing comparable to the voltage swing of the input signal can be obtained without requiring large and/or expensive DC blocking capacitors (e.g. to block the DC component of the input signal). Large capacitors would be sensitive to mechanical vibrations and temperature gradient effects, leading to additional noise in the amplified signal.

Moreover, the peak-to-peak voltage swing of the modulated signal can be reduced without reducing a voltage swing of the portion of interest of the modulated signal

(i.e. those parts of the modulated signal corresponding to the input signal). In other words, the voltage swing of portion(s) of interest in the modulated signal takes up a greater proportion of the overall voltage swing of the modulated signal. In particular, the peak-to-peak voltage swing of the modulated signal can be reduced to be equal to the voltage swing of the portion of interest.

Amplifying a modulated signal having a larger voltage swing than that of the input signal would significantly reduce possible resolution and/or amplifier headroom and could cause saturation or limit a maximum allowable gain of the amplifying arrangement. Resolution would be reduced because the analogue-to-digital converter would need to be able to sample a larger range of voltage values in the amplified modulated signal than a range of voltage values that correspond to parts of the amplified modulated signal that correspond to the input information (i.e. information of interest).

Thus, proposed embodiments enable a resolution and/or amplifier headroom of the amplifying arrangement to be increased/maintained (whilst avoiding amplifier saturation or limitations to amplifier gain), without the need for a large DC blocking capacitor. A cheaper amplifying arrangement with improved signal-to-noise ratio can therefore be provided.

The proposed amplifying arrangement thereby enables accurate and cost-effective amplification of a small magnitude and low-frequency AC signal that is superimposed on a (relatively) large DC signal, without the need for expensive DC blocking capacitors or complex and expensive amplifying arrangements.

Possible magnitude characteristics include: an average magnitude of the input signal, a maximum magnitude of the input signal (within a predetermined time period); a minimum magnitude of the input signal (within a predetermined time period); a range/swing of the input signal and so on.

Moreover, basing the reference voltage level on magnitude characteristics of the input signal allows changes or fluctuations of (the DC component of) the input signal to be taken into account, such fluctuations caused by, for example, temperature changes or change of noise sources. Thus, a more consistent and noise-resistant amplifier can be provided.

In particular embodiments, the reference voltage level may be set to be equal to a particular magnitude characteristic of the input signal, such as the average magnitude of the input signal.

In embodiments, the reference voltage level is generated so that the voltage swing of the modulated signal is no greater than the voltage swing of the input signal (of interest).

In some embodiments, the reference voltage level generator is adapted to generate the reference voltage level having a magnitude based on an average magnitude of the input signal. Preferably, the reference voltage level generator is adapted to generate the reference voltage level having a magnitude equal to an average magnitude of the input signal.

Providing a reference voltage level with a magnitude equal to an average magnitude helps to minimize the voltage swing of a modulated signal, and thereby improve a resolution of the amplifying arrangement. Such a reference voltage level also helps minimize the impact of a fluctuating DC offset in the input signal.

Optionally, the reference voltage level generator is adapted to generate the reference voltage level based on a maximum and/or minimum magnitude of the input signal. In some embodiments, the reference voltage level generator is adapted to generate the reference voltage level based on a maximum and/or minimum magnitude of the input signal within a predetermined period.

By basing the reference voltage level based on a maximum/minimum magnitude of the input signal, a voltage range/swing of the modulated signal will be no more than a voltage range/swing of the input signal. This improves a resolution of the amplifying arrangement.

The modulating arrangement may comprise a first input terminal adapted to receive the input signal; a second input terminal adapted to receive the reference voltage level; a output terminal; and switching logic adapted to alternately connect, at the second frequency, the output terminal to the first input terminal and the second input terminal, to thereby generate the modulated signal on the output terminal.

The proposed modulating arrangement provides simple and low-cost circuitry for modulating an input signal.

Preferably, the reference voltage level generator comprises: a capacitor connected between the second input terminal and a reference voltage; and a resistor connected between the output terminal and the second input terminal, so that a voltage level at the second input terminal is held at an average of the input signal.

In an alternative embodiment, the reference voltage level generator comprises: a capacitor connected between the second input terminal and a reference voltage; and a

resistor connected between the first input terminal and the second input terminal, so that a voltage level at the second input terminal is held at an average of the input signal.

In other words, a reference voltage level generator estimates the mean of the input signal by storing the average charge of the input signal on a capacitor, by charging the capacitor via a resistor. The proposed embodiments for the reference voltage level generator provide low cost and effective methods of generating a reference voltage level having an average magnitude of the input signal.

The amplifying arrangement may further comprise a filter arrangement connected between the modulating arrangement and the amplifying circuit, wherein the filter arrangement is adapted to filter at least a direct current component from the modulated signal.

By way of example, a filter arrangement may comprise a DC blocking capacitor connected between the modulating arrangement and the amplifying circuit. The DC blocking filter can be significantly reduced in size, magnitude and/or cost compared to DC blocking filters known in the art. This is because the pass-band of the filter arrangement can have a much greater cut-off frequency (and thereby smaller DC blocking capacitor) due to the modulated signal carrying information (of interest) of the input signal at a higher frequency than the input signal.

There is also proposed a sensing arrangement comprising a sensing module adapted to generate a sensing signal for amplification, the sensing signal carrying information of interest at a first frequency; and any herein described amplifying arrangement, wherein the sensing signal output by the sensing module is received as the input signal.

By way of example, the sensing module may comprise a transmission circuit adapted to transmit an electromagnetic wave and a sensing circuit adapted to: receive a reflection of the transmitted electromagnetic wave; determine a difference in frequency between the transmitted electromagnetic wave and the reflection of the transmitted electromagnetic wave; and output a sensing signal having a frequency equal to the difference in frequency (this frequency being the first frequency).

There is also proposed a method for amplifying an input signal of a first frequency, the method comprising: receiving the input signal; generating a reference voltage level having a magnitude based on one or more magnitude characteristics of the input signal; generating a modulated signal that alternates between a current voltage level of the input signal and the reference voltage level at a second frequency, the second frequency being greater than the first frequency; amplifying, using an amplifying circuit, the modulated signal

to thereby provide an amplified modulated signal; performing a demodulation operation comprising sampling the amplified modulated signal at the second frequency and synchronized with portions of the amplified modulated signal corresponding to amplifications of the input signal, to thereby obtain amplified samples of the input signal.

The step of generating the reference voltage level may comprise generating the reference voltage level having a magnitude based on an average magnitude of the input signal.

The step of generating the reference voltage level may comprise generating the reference voltage level having a magnitude equal to an average magnitude of the input signal.

The step of generating the reference voltage level comprises generating the reference voltage level based on a maximum and/or minimum magnitude of the input signal. The step of generating the reference voltage level comprises generating the reference voltage level based on a maximum and/or minimum magnitude of the input signal within a predetermined period.

There is also proposed a method of sensing a signal representative of motion comprising: transmitting an electromagnetic wave; receiving a reflection of the transmitted electromagnetic wave; determining a difference in frequency between the transmitted electromagnetic wave and the reflection of the transmitted electromagnetic wave; generating a sensing signal having a frequency equal to the difference in frequency; and amplifying the sensing signal by performing any previously described method, wherein the sensing signal is provided as the input signal.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiment(s) described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example only, to the accompanying drawings, in which:

Fig. 1 illustrates an amplifying arrangement according to an embodiment of the invention;

Figs. 2 to 5 illustrates waveforms for understanding an operation of the amplifying arrangement according to an embodiment;

Fig. 6 is a circuit diagram of an amplifying arrangement according to an embodiment;

Fig. 7 is a flow chart illustrating a method according to an embodiment of the invention; and

Fig. 8 illustrates a sensing arrangement according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The invention will be described with reference to the Figures.

It should be understood that the detailed description and specific examples, while indicating exemplary embodiments of the apparatus, systems and methods, are intended for purposes of illustration only and are not intended to limit the scope of the invention. These and other features, aspects, and advantages of the apparatus, systems and methods of the present invention will become better understood from the following description, appended claims, and accompanying drawings. It should be understood that the Figures are merely schematic and are not drawn to scale. It should also be understood that the same reference numerals are used throughout the Figures to indicate the same or similar parts.

According to a concept of the invention, there is proposed an amplifier or amplifying arrangement for amplifying an input signal that employs a modulating arrangement. The modulating arrangement generates a modulated signal that alternates between a reference voltage level and a voltage level of the input signal. This modulated signal is then amplified, and the amplified modulated signal is sampled to thereby obtain amplified samples of the original input signal. The reference voltage level is based upon one or more magnitude characteristics of the input signal.

Embodiments are at least partly based on the realization that, in chopper amplifiers, a resolution or headroom is affected when a voltage swing of a chopped signal is significantly different to a voltage swing of an input signal. This can be accounted for by filtering a DC component of the input signal before modulating or by using other expensive DC filtering arrangements during amplification. However, by providing a modulated signal that alternates between the input signal and a voltage level that is based on the input signal, a voltage swing of the modulated signal can more closely match that of the input signal, without the need for a large DC blocking capacitor, and thereby improve a resolution and/or headroom of the amplifier (allowing the use of more simple amplifying circuits such as operational amplifiers).

Thus, a modulating amplifier can be effectively employed to take advantage of the low-noise amplification provided by a chopper amplifier, without the need for a large (i.e. high capacitance) and expensive DC blocking capacitor or other expensive (filtering) circuitry.

Illustrative embodiments may, for example, be employed in RADAR sensors in which a difference between an emitted electromagnetic wave and a received electromagnetic wave is provided as an input signal for the amplifying arrangement. Such RADAR sensors typically provide signals of a low amplitude and low frequency (e.g. <500Hz) and are therefore highly subject to noise (e.g. pink noise or mains supply noise) during an amplification process. The proposed amplifying circuit enables accurate amplification of low amplitude and low frequency signals with an improved signal-to-noise ratio.

The hereafter described amplifying arrangement(s) are particularly suitable for amplifying input signals having a very low amplitude variation or range (e.g. $\pm 0.1\mu V$ to $\pm 1mV$) and a low frequency into an amplified signal in which these variations have been subject to a very large gain (e.g. a gain of between 50dB and 90db or a gain factor of between 500 to 30,000). Thus, the amplifying arrangement is particularly suitable for use in amplifying the output of a RADAR sensor, in which signals having a low frequency and low varying amplitude are typically generated.

Where reference is made to the frequency of a signal, this should generally be understood to refer to the dominant frequency of the signal, i.e. that frequency providing the largest contribution to a variation of the signal (excluding any DC component).

Figure 1 illustrates a block diagram of an amplifying arrangement 1 according to an embodiment of the invention.

The amplifying arrangement 1 is formed of a modulating arrangement 2, an amplifying circuit 3, an analogue-to-digital converter 4 and a reference voltage generator 5.

The amplifying arrangement 1 may further comprise a blocking capacitor C_b connected between the modulating arrangement 2 and the amplifying circuit 3. The blocking capacitor C_b may be adapted to block direct current (DC). Proposed embodiments enable the size and/or cost of the blocking capacitor to be reduced, compared to blocking capacitors of known amplifying arrangements. However, in some embodiments, the blocking capacitor may be omitted.

The operation of the amplifying arrangement 1 will be hereafter described with reference to Figure 1 and accompanying Figures 2 to 4 that illustrate signals present

during the operation of the amplifying arrangement, in order to contextualize the proposed invention.

The amplifying arrangement 1 acts as an analogue-to-digital amplifier that effectively obtains amplified samples (i.e. a digital signal) of an analog or time-continuous input signal s_{in}. Of course, these amplified samples may be subsequently resolved into an analog signal, e.g. using a known digital-to-analogue converter (not shown), to obtain an analog amplification of the input signal s_{in}.

The modulating arrangement 2 receives the input signal s_{in} (e.g. from a radiofrequency sensor 6) and generates a modulated signal s_{mod}. The modulating arrangement 2 is adapted so that the modulated signal s_{mod} alternates between the input signal s_{in} and a reference voltage level V_{ref}. Thus, the modulated signal s_{mod} alternates between a voltage providing input signal information and a reference voltage level (i.e. providing no instantaneous input signal information). As will be later explained, the magnitude of the reference voltage level V_{ref} depends upon magnitude characteristics of the input signal s_{in}.

As illustrated, the modulating arrangement 2 may comprise a first input terminal 2a, adapted to receive the input signal s_{in}, a second input terminal 2b adapted to receive the reference voltage level V_{ref} and an output terminal 2c adapted to provide the modulated signal s_{mod}. Switching logic 2d is adapted to alternately connect the output terminal to the first input terminal 2a and then to the second input terminal 2b.

The switching logic 2d may, for example, comprise a single pole double throw or changeover switch 2d controlled by a switching signal s_s that controls the connection of the output terminal 2c. The switching signal s_s may be provided by a microcontroller, processor, oscillating circuit or other control unit (not shown).

The frequency at which the magnitude of the modulated signal alternates between a current magnitude of the input signal s_{in} and the reference voltage level V_{ref} (the "modulating frequency", "modulation frequency" or "second frequency") is larger than the frequency of the input signal s_{in} (the "first frequency" or "input frequency"). In this way, the input signal s_{in} is modulated or converted to form a modulated signal s_{mod} of a higher frequency, which contains information from the input signal s_{in}.

The duty cycle of the modulated signal may be in the region of 10-50%. In a simple embodiment, the modulated signal may have a duty cycle of around 50%, so that it switches evenly and regularly between a voltage level of the input signal and the reference voltage level. In other embodiments the duty cycle may be in the region of 10%, so that the modulated signal is held at the voltage level of the input signal s_{in} for 10% of the time and at

the reference voltage level V_{ref} for 90% of the time. The duty cycle of the modulated signal s_{mod} may be controlled to be any number between 10-50%, depending upon the embodiment. Of course, the duty cycle may, in some embodiments, be greater than 50%.

Figure 2 is a graph illustrating the relationship between the input signal s_{in} and the modulated signal s_{mod}. In particular, Figure 2 illustrates a voltage waveform for an example input signal s_{in} and a corresponding modulated signal s_{mod}, plotted along a same time axis.

The input signal s_{in} is of a first frequency and the modulated signal s_{mod} is of a second frequency (i.e. the "modulating frequency"). Here, the second frequency is between two and twenty times greater than the first frequency, for example, around ten times greater than the first frequency or about 4-8 times the first frequency. The second frequency should, to ensure proper signal reproduction by the analogue-to-digital converter, fulfill at least the Nyquist criteria with respect to the first frequency, as would be known by the skilled person. The second frequency may depend on different implementation requirements, such as required signal-to-noise ratio, the analog low pass filter roll-off and filter details in firmware, as would be well known to the skilled person.

By way of example, the first frequency may be in the region of 1-500Hz, e.g. around 200Hz, and the second frequency may be in the region of 1,500 to 2,500 Hz, and preferably around 2,000Hz. The value of the second frequency may depend upon the dominant frequency of the input signal s_{in}, as previously explained.

Preferably, the second frequency is at least 2,000Hz. This allows for improved ease and reduced cost for performing a low-pass filter on the modulated signal (if desired).

It will be clear that the magnitude or voltage level of the modulated signal s_{mod} alternates between a voltage level of the input signal s_{in} and the reference voltage level V_{ref}. In this way, the input signal s_{in} is effectively sampled onto the modulated signal s_{mod} at the modulating frequency, where the modulated signal is held at the reference voltage level in between samples. In other words, the modulating arrangement modulates a signal of interest (the input signal) onto a carrier signal of a higher frequency to produce the modulated signal s_{mod}.

Referring back to Figure 1, the amplifying circuit 3 is adapted to amplify the modulated signal s_{mod} to generate an amplified modulated signal s_a.

The amplifying circuit 3 may, as illustrated, be single ended or, preferably, have a differential input. A differential input allows for ease of biasing the modulated signal s_{mod} (e.g. as the modulated signal can be provided to one terminal and a biasing signal can be

provided to the other terminal). For example, a negative terminal may be adapted to receive the modulated signal s_{mod} from the modulating arrangement and a positive terminal may be adapted to receive a bias voltage s_{bias} for appropriately biasing the modulated signal s_{mod} (as later illustrated in Figure 6).

Biasing the modulated signal may be performed, for example, to position effective signal to be amplified (being a difference between the bias voltage and the modulated signal) in the middle of the available supply voltage range. This improves a positive and negative headroom of the amplifier. The voltage magnitude of the bias voltage s_{bias} may be based on, for example, the reference voltage level V_{ref} (e.g. if the blocking capacitor C_b is omitted).

The amplifying circuit 3 may comprise one or more operational amplifiers, and other amplifying logic (e.g. feedback resistor/capacitors and the like) for amplifying the modulated signal. Other suitable amplifying circuits for amplifying a modulated signal would be readily apparent to the skilled person.

The amplifying circuit 3 may be provided with a voltage supply or power supply V_{DD} and a ground voltage GND, as would be known to the skilled person.

In some (optional) embodiments, the amplifying circuit 3 applies a band-pass filter to the modulated signal s_{mod} before or during amplification. The band-pass filter would be adapted to pass a signal of the modulating frequency (i.e. the dominant frequency of the modulated signal). In particular, the band-pass filter may be centered at the modulating frequency. This improves a noise reduction of the amplifying arrangement.

The gain of the amplifying circuit may depend upon the characteristics or nature of the input signal s_{in}. However, embodiments of the invention may comprise an amplifying circuit having a gain between 50dB and 90db (e.g. a gain factor of approximately 500 to 30,000). Preferably, the gain factor is no less than 15,000 (around 83.5dB), and even more preferably no less than 20,000 (around 86dB).

Figure 3 is a graph illustrating the relationship between the modulated signal s_{mod} and the amplified modulated signal s_a. In particular, Figure 3 illustrates a waveform of an exemplary modulated signal s_{mod} and a corresponding amplified modulated signal s_a, plotted along a same time axis.

The amplifying arrangement here performs an inverting amplification to the filtered modulated signal to produce the amplified modulated signal. It will be appreciated that Figure 3 is not to scale, and that the amplification performed by the amplifying arrangement may differ (e.g. have a gain of no less than 15,000).

In the illustrated examples, a band-pass filter has been applied to the modulated signal s_{mod} before/during amplification, so that the filtered (amplified) modulated signal has only a narrow band of frequencies, including the modulating frequency. This helps reduce noise in the amplified modulated signal s_a.

Again referring back to Figure 1, the analogue-to-digital converter 4 is adapted to sample the amplified modulated signal s_a at the modulating frequency, and synchronized (i.e. in phase) with the portions of the amplified modulated signal that correspond to amplifications of the input signal.

In other words, when performing a first sampling process or operation, a sampling frequency of the analogue-to-digital converter is equal to the modulating frequency or "second frequency" of the modulating arrangement 2, where the samples are taken across portions of the amplified modulated signal that correspond to portions of the modulated signal that contain (instantaneous) information of the input signal.

Thus, the samples taken during the first sampling process or operation of the analogue-to-digital converter are amplified samples of the input signal s_{in}. In this way, the amplifying arrangement 1 can amplify the input signal.

Preferably, the analogue-to-digital converter 4 is adapted to sample the amplified modulated signal s_a at turning points of the amplified modulated signal (i.e. at a maximum or minimum points of each cycle of the amplified signal). This increases the resolution of the amplifying arrangement, ensuring that the points of the amplified modulated signal that represent the maximum amplifications of the relevant portions of the modulated signal corresponding to the input signal are sampled.

When sampling the amplified modulated signal s_a, it may be necessary to take into account a phase delay resulting from (the transfer function of) the amplifying circuit 3. Put another way, the amplifying circuit 3 may introduce a phase shift between the amplified modulated signal s_a and the modulated signal s_{mod}, such that amplified portions of the input signal s_{in} (in the amplified modulated signal s_a) are out of phase with the corresponding portions of the input signal s_{in} (in the modulated signal s_{mod}).

To take account of this phase shift by the amplifying circuit 3, the sampling by the analogue-to-digital converter 4 may have a same frequency, but be phase-shifted, with respect to the modulating of the input signal performed by the modulating arrangement 2 (as controlled by the switching signal s_s).

Preferably, this phase shift is determined experimentally. In other examples, the phase shift is determined by calculating a transfer function of the amplifying circuit (e.g. from known component values) and determining a phase shift of the amplifying circuit.

However, it is noted that for a modulated signal having a duty cycle of 50%, a phase shift of 90° is a reasonable estimation. In other words, the sampling by the analogue-to-digital converter may be 90° (or another values calculated as previously described) out of phase with the modulating by the modulating arrangement, in order to take account of a phase shift by the amplifying arrangement. The phase shift may therefore depend upon the duty cycle of the modulated signal (i.e. the proportion of the modulated signal that corresponds to the input signal s_{in} rather than the reference voltage level V_{ref}).

Without taking account of the phase shift, the sampling by the analogue-to-digital converter may be inefficient (i.e. not sampling at the greatest peak of the amplified modulated signal) and/or inaccurate.

Preferably, each sample taken by the analogue-to-digital converter during the first sampling process is timed to be at a center of a portion of the amplified modulated signal corresponding to a portion of the modulated signal corresponding to the input signal. For example, if a portion of the modulated signal corresponding to an input signal has a length of 0.5ms the sample taken by the analog-to-digital converter may correspond to a value of the amplified modulated signal 0.25ms into the corresponding portion of the amplified modulated signal.

Figure 4 illustrates a relationship between a sample result signal s_{adc} produced by the analogue-to-digital converter 4 and the amplified modulated signal s_a.

In particular, Figure 4 illustrates a waveform of an exemplary amplified modulated signal s_a, a sampling signal s_{samp} and a sample result signal s_{adc}. The sampling signal s_{samp} indicates timestamps or instances at which samples of the amplified signal s_a are taken.

The sample result signal s_{adc} indicates a value of a most recent sample. Thus, the sample result signal s_{adc} is a signal for which a voltage level is held at the voltage level of a most recent sample of the amplified modulated signal until a new sample is taken. Thus, the sample result signal s_{adc} represents the values of samples taken by the analogue-to-digital converter 4.

The samples taken by the analogue-to-digital converter (as shown by the sampling signal s_{samp}) are taken at portions of the amplified modulated signal that correspond

to an amplification of the input signal. In this way, the samples are considered amplified samples of the input signal s_{in}, or "amplified samples" of the input signal s_{in}.

The sample result signal s_{adc} is an analog representation of the samples of the input signal. Thus, the sample result signal s_{adc} can be considered to be an analog amplification of the input signal.

It will therefore be appreciated that, in some embodiments, there is further provided a digital-to-analogue converter adapted to: receive an output of the analogue-to-digital converter; and convert the output of the analogue-to-digital converter into an analogue output signal, the analogue output signal thereby representing an analogue amplification of the input signal.

In some embodiments, the digital information (contained in a digital signal output by the analogue-to-digital converter) is further processed (e.g. using a microprocessor 7) to interpret the digital signal(s), especially to derive presence or motion information and to classify moving objects. This post-processing may include digital filtering (e.g. averaging) of the gathered data and decimation (to reduce the amount of data). An analysis of the signal's frequency spectrum (for instance by FFT) may also be performed. Other post-processing steps will be readily apparent to the skilled person.

The present invention recognizes that an input signal for an amplifying arrangement may comprise a DC offset voltage (also known as a DC "pedestal voltage"). In particular, for RADAR sensors, this DC offset voltage is orders of magnitude larger than the AC component of interest in the input signal (e.g. $500mV_{DC}$ compared to $10\mu V_{AC}$). The removal of a DC component from such an input signal increases the relative proportion of the input signal s_{in} that contains the AC portion of interest, thereby enabling improved resolution of the input signal.

This DC offset voltage in an input signal could be accounted for by using a DC blocking or AC coupling capacitor. Such a capacitor is designed to block a DC component of a signal (e.g. the input signal S_{in}) prior to amplification. However, when a AC component of interest in an input signal is associated with very low frequencies (e.g. 1-500Hz), this results in the need for an large capacitor to avoid unwanted blocking/filtering of the AC component of interest.

Indeed, in a scenario where the reference voltage level is replaced with a ground voltage level (e.g. as used in a chopper amplifier) and without the use of a large DC blocking capacitor to remove a DC offset voltage of an input signal prior to modulating the

input signal, this could lead to a modulated signal that would result in amplifier saturation and/or reduced headroom (if conventional operational amplifiers were used).

Figure 5 illustrates an example modulated signal s_{cex} for a modulating amplifier, which signal is formed from an input signal s_{in} which has not undergone DC blocking nor uses the reference voltage level of the present invention. Such a modulated signal s_{cex} would significantly reduce resolution, as the range of the modulated signal s_{cex} is high compared to the range of the portion of interest of the modulated signal s_{cex} (i.e. those parts of the modulated signal corresponding to the input signal s_{in}).

The present invention proposes an improved method of accounting for the DC offset voltage, which enables the use of expensive and/or large components to be avoided.

In particular, the present invention proposes to modulate the input signal s_{in} to produce a modulated signal s_{mod} that switches between the input signal s_{in} and a reference voltage level V_{ref} (the magnitude of which is based on characteristics of the input signal). This is best illustrated by Figure 2.

The reference voltage level V_{ref} effectively modifies an average voltage offset of the modulated signal whilst also reducing the range of the modulated signal s_{mod}. In particular, the voltage range/swing of the modulated signal s_{mod} is reduced to more closely match the voltage range/swing of the input signal s_{in} (e.g., as illustrated in a comparison of Figure 5 to Figure 2). As this introduced voltage offset is based on the characteristics of the input signal, and preferably represents the voltage offset of the input signal, a voltage offset of the input signal can therefore be effectively copied across to the modulated signal.

The reference voltage level can thereby be held at a voltage offset of the input signal. The voltage offset of the input signal can be estimated by averaging the magnitude of the input signal. Thus, the magnitude of the reference voltage level may be held at an average magnitude of the input signal.

Referring back to Figure 1, the amplifying arrangement 1 therefore comprises a reference voltage level generator 5 adapted to generate the reference voltage level V_{ref}. The reference voltage level V_{ref} is connected to one of the two input terminals of the modulating arrangement 2 (here the second input terminal), whilst the other input terminal is connected to receive the input signal s_{in}.

In the illustrated embodiment, the reference voltage level generator 5 comprises a resistor 5a connected between the output terminal 2c and the second input terminal 2b. The reference voltage level generator 5 also comprises a capacitor 5b connected between the second input terminal 2b and a reference voltage GND (e.g. earth or ground). In

this way, the voltage across the capacitor 5b is the reference voltage level V_{ref}. The resistor 5a pulls the voltage across the capacitor 5b to a voltage level of the input signal. In particular, the resistor-capacitor pair 5a, 5b form a low pass filter having a long time constant. In particular, the time constant of the low pass filter may be much greater (e.g. at least 10 time greater) than a length of a time period for which the modulated signal is switched to the reference voltage level (i.e. the period between consecutive switches to the input signal). Thus, the reference voltage level V_{ref} (at the second input terminal 2b) can be assumed to be the average of the sensor signal s_{in} (including its pedestal / DC offset). Of course, there may be minor (but insignificant) variations in the magnitude of the reference voltage level as it discharges and charges.

Thus, when the modulating arrangement 2 connects the first input terminal 2a to the output terminal 2c, the resistor 5a begins to pull the voltage across the capacitor 5b towards the level of the input signal. When the modulating arrangement switches the connection, and connects the second input terminal 2b to the output terminal 2c, the voltage across the capacitor 5b is provide as the portion of the modulated signal s_{mod}, and the resistor 5a maintains the voltage across the capacitor. The process is iteratively repeated as the modulating arrangement switches back and forth between the two input terminals 2a, 2b.

Over time, this process results in the voltage across the capacitor 5b, i.e. the reference voltage level V_{ref}, approximately equaling the average voltage of the input signal s_{in}.

Thus, between samples of the input signal s_{in}, the modulated signal is held at an average voltage of the input signal s_{in}. This helps avoid an amplifier saturation and improve a resolution of the amplifying arrangement, as the relative variance of the modulated signal is substantially less than in a conventional modulating mechanism where the modulated signal is held at a ground level between samples of the input signal. In other words, the range of values in the modulated signal s_{mod} provided to the input of the amplifying circuit is reduced, meaning that the amplifier may apply a greater gain to the modulated signal s_{mod} without risking clipping or distortion in the amplified signal.

The reference voltage generator 5 thereby acts as pedestal cancelation circuity.

This arrangement is fundamentally different from a known sample-and-hold implementation for sampling the input terminal, as there is no intention to identify the instantaneous value of the input signal using the capacitor 5b – rather the reference voltage generator aims to store a value outside the bandwidth of interest.

The illustrated embodiment may be adapted by instead connecting the resistor 5a between the first input terminal 2a and the second input terminal 2b.

In other embodiments, the reference voltage level V_{ref} may be held, for example, at a minimum value of the input signal (including its DC offset) or at a maximum value of the input signal. This may be performed by analyzing the input signal using, for example, a microprocessor, and providing a suitable reference voltage level based on the analysis of the input signal.

The reference voltage level V_{ref} may be held at an minimum/maximum value of the input signal within a predetermined time period. That is, the input signal may be monitored for a predetermined period of time, and the reference voltage level may be generated to match a maximum/minimum voltage magnitude within that time period.

Thus, the reference voltage level V_{ref} is dependent upon characteristics of the magnitude of the input signal s_{in}. In particular, the reference voltage level V_{ref} may be held at an average of the magnitude of the input signal s_{in}. In other examples, the reference voltage level may be held at a minimum/maximum value of the input signal s_{in} or at a value halfway between the minimum and maximum values. Other suitable embodiments will be apparent to the skilled person.

In effect, the present invention proposes to use a reference voltage generator 5 to act as pedestal cancellation circuitry to account for an offset in the input signal s_{in}. In particular, the present invention proposes to set the reference voltage level based on magnitude characteristics of the input signal. In effect, this modifies a voltage offset in the modulated signal s_{mod} and the voltage range/swing of the modulated signal.

With continued reference to Figure 1, in preferred embodiments, the amplifying arrangement 1 comprises a blocking capacitor C_b, for blocking at least a DC component of the modulated signal (i.e. before amplification).

The proposed concept enables a smaller DC blocking capacitor, compared to the prior art, to be used to account for a DC voltage offset in the input signal. This is because the AC component of interest in the input signal has been effectively converted into a signal of a higher frequency in the modulated signal. Thus a smaller DC blocking capacitor (i.e. having a lower capacitance) can be used whilst avoiding unwanted blocking or filtering of the AC component of interest.

Moreover, the DC blocking capacitor may also be adapted to block low-frequency signals introduced by other noise components, such as mains noise and/or piezoelectric parasitic noise (e.g. introduced by the vibration of capacitors).

Of course, the blocking capacitor may be omitted in some other embodiments. The proposed concept is still of advantage, as the range of the modulated signal is significantly reduced (e.g. and a DC offset could be taken into accounting by biasing with a differential amplifier). In some examples, such as previously described, the amplifying arrangement performs a filtering process on the modulated signal to account for the DC offset.

Figure 6 illustrates a circuit diagram of an amplifying arrangement 60 according to an embodiment of the invention.

The amplifying arrangement again comprises a modulating arrangement 2, an amplifying circuit 3 and a reference voltage generator 5. The analogue-to-digital converter has been omitted for the sake of clarity, but would be readily realized by the skilled person.

The amplifying circuit 3 comprises a cascading pair of operational amplifiers U1 and U2. Each operation amplifier U1, U2 comprises feedback logic R5-R7, C5-C7, and other components R4, C4, R8, designed to provide a bandwidth limited amplifying circuit. In other words, the feedback logic of the amplifying arrangement is designed so as to apply a band-pass filter on the modulated signal during/before amplification.

In particular, the amplifying circuit 3 illustrates a cascaded low-pass amplifier (associated with the operational amplifier U1) and high-pass amplifier (associated with the operational amplifier U2), with the two cut-off (roll-off) frequencies being centered at the second frequency (i.e. at the "modulation frequency"). In embodiments, the second stage has a gain of 1.

In the illustrated example, a coupling capacitor C4 may act to filter some low-frequency components from the amplifying arrangement (e.g. act as the blocking capacitor), and another capacitor C6 may act to filter some high-frequency components from the amplified modulated signal. Other methods and component arrangements of appropriately filtering the (amplified) modulated signal to thereby apply a band-pass filter on the modulated signal during amplification will be readily apparent to the skilled person.

In this way, the amplifying arrangement may filter and amplify the modulated signal to output an amplified modulated signal within a narrow range of frequencies.

It is particularly advantageous to use a cascading set of two operational amplifiers U1, U2, due to the typically large gain desired for amplifying an input signal, e.g. if the input signal s_{in} is of a low amplitude/magnitude. However, any number of operational amplifiers (i.e. at least one) may be used in some other embodiments, e.g. where the input signal has already undergone amplification.

The amplifying arrangement 60 may further comprise a first low-pass filter 61 to remove high frequency content from the modulator output (i.e. the modulated signal) prior to amplification. This can help reduce noise in the amplified modulated signal s_a. Here, the low-pass filter 61 comprises a passive low-pass filter formed of a resistor-capacitor pair R3, C3 that couples high-frequency components to a reference voltage, e.g. ground, as is well known in the art.

The cut-off frequency of the first low-pass filed 61 can be determined by various implementation requirements, such as the value of the first frequency, expected higher frequencies not of interest, such as those introduced in the input signal and disturbances, desired roll-off steepness of the low-pass filter and filter design details.

In the illustrated example, a negative terminal of a first operational amplifier U1 is adapted to receive the modulated signal s_{mod} from the modulating arrangement and a positive terminal of the first operational amplifier U1 is adapted to receive a biasing signal. This can be used to account for the voltage offset in the modulated signal introduced by the reference voltage level.

The amplifying arrangement may further comprise a second low-pass filter 62 to remove high frequency content from the input signal s_{in} prior to modulating by the modulating arrangement 2. This helps further reduce noise. Preferably, the cutoff frequency of the second low-pass is below the modulating frequency of the modulating arrangement, as this allows noise reduction of the input signal that could not be possible after modulating the input signal (i.e. as this would entirely filter the modulated signal). As before, the second-low pass filter may comprise a simple passive filter formed of a resistor-capacitor pair R1, C1.

The skilled person will be readily able to derive a method of amplifying an input signal based on any above described amplifying arrangement. That is, each aspect of an amplifying arrangement may be represented as a step in a method of amplifying an input signal.

However, for the sake of improved clarity, Figure 7 illustrates a flow chart summarizing a method according to an embodiment of the invention.

The method 70 comprises a step 71 of receiving the input signal.

The method 70 further comprises a step 72 of generating a reference voltage level having a magnitude based on one or more magnitude characteristics of the input signal.

The method 70 then moves to a step 73 of generating a modulated signal that alternates between a current voltage level of the input signal and the reference voltage level at a second frequency, the second frequency being greater than the first frequency.

Subsequently, the method performs step 74 of amplifying, using an amplifying circuit, the modulated signal to thereby provide an amplified modulated signal.

The method 70 then performs step 75 of performing a demodulation operation comprising sampling the amplified modulated signal at the second frequency and synchronized with portions of the amplified modulated signal corresponding to amplifications of the input signal, to thereby obtain amplified samples of the input signal.

Of course, the method may further comprise further processing the amplified samples of the input signal (e.g. performing averaging, digital filtering, recognition of motion and so on).

Figure 8 illustrates a sensing arrangement 80 according to an embodiment of the invention.

The sensing arrangement 80 comprises a transmission circuit 81 adapted to transmit an electromagnetic wave 89a. Preferably, the electromagnetic wave 89a is a radiofrequency electromagnetic wave.

The sensing arrangement also comprises a sensing circuit 82 adapted to receive a reflection 89b of the transmitted electromagnetic wave and determine a difference in frequency between the transmitted electromagnetic wave and the reflection of the transmitted electromagnetic wave.

The sensing circuit 82 is adapted to output a sensing signal s_{in} (i.e. the input signal for the amplifying arrangement) having a frequency equal to the difference in frequency.

Thus, the transmission circuit and sensing circuit can act as a motion detection system or a Doppler detection system, which detects motion based on the Doppler Effect.

The principle of the Doppler Effect is well known: when electromagnetic waves 89a are transmitted towards a moving object 85, then the reflected waves 89b undergo a translation in their frequency. This translation amount is directly proportional to the speed of the object as well as the frequency of the transmitter. Thus, the presence of a translation in the reflected waves is indicative of motion in the vicinity of the sensing arrangement.

The offset in frequency, caused by reflection from a moving object, can be measured by the sensing circuit, according to well-known principles. Subsequently, this measured frequency offset forms the basis of information regarding the speed of the object and leads to motion sensing. This offset frequency is typically made available in the form of a sensing signal, which is a signal alternating at the “Intermediate Frequency” – being the

difference between the frequency of the transmitted electromagnetic wave and the reflected electromagnetic wave.

The transmission circuit 81 and the sensing circuit 82 together form a sensing module 81, 82. Other sensing modules could be employed by the skilled person.

The sensing arrangement further comprises any previously described amplifying arrangement 1, 60, 80. The amplifying arrangement 1, 60, 80 receives, as the input signal, the sensing signal output by the sensing circuit 82.

For typical transmitted frequencies that are used in Doppler detection systems and for typical speed of human motion, this frequency of the sensing signal is between 1 and 500Hz. As previously described, it is difficult to process and amplify such low frequencies, due to 1/f noise, large component sizes, susceptibility to distortion from mains (50/60Hz and their harmonics), and susceptibility to vibration, thermocouple effects and microphonic pickup. Moreover, the received signal strength of the reflected electromagnetic wave, and therefore sensing signal, is usually very weak. The received power of the reflected signal is typically in the order of nanowatts hence the output of the sensing arrangement is preferably amplified by 50~80dB or more. The combination of high amplification while avoiding 1/f noise and the other noise sources mentioned before at low cost can be challenging.

However, the above-described embodiments provide suitable amplifiers for amplifying the low-power, low-frequency sensing signal of such sensing arrangements.

Thus, proposed embodiments enable a signal generated by a Doppler detection system to be amplified for further processing (e.g. motion detection, object identification, speed analysis and so on).

In some embodiments, the sensing arrangement 80 further comprises a switching arrangement 83 adapted to selectively provide power V_{DD} to at least the sensing circuit. In other words, the power supply V_{DD} to the sensing module 81, 82 may be pulsed. The frequency of the pulsing may be identical, and in phase, with the switching frequency s_s. This helps reduce power consumption of the sensing arrangement 80.

Thus, in preferred embodiments, there is proposed a sensing arrangement comprising an amplifying arrangement herein described and a sensing module adapted to generate a sensing signal for amplification, the sensing signal carrying information of interest at the first frequency. The amplifying arrangement receives the sensing signal output by the as the input signal.

Preferably, a power supply for the sensing module is selectively switched (by a switching arrangement) in phase with the modulating of the modulating arrangement and at

the first frequency. In particular, the sensing arrangement may be adapted to only provide the power supply to the sensing module when the modulating arrangement provides the input signal as the modulated signal. This significantly reduces a power consumption of the overall sensing arrangement. In particular, as a duty cycle of the modulated signal is reduced, so the power consumption of the overall sensing arrangement is also reduced. A more power efficient and therefore cost effective sensing arrangement can thereby be provided.

In other words, the sensing arrangement may further comprise a switching arrangement adapted to selectively provide a power supply for the sensing module based on the first frequency (of the amplifying arrangement). In particular, the switching arrangement may provide the power supply to the sensing module when the modulated signal is at a current voltage level of the input signal.

Thus, input signal modulating and power supply cycling (for the sensing module) can be synchronized, which makes the proposed sensing arrangement highly efficient.

Variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or other unit may fulfil the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. A computer program may be stored/distributed on a suitable medium, such as an optical storage medium or a solid-state medium supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems. Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. An amplifying arrangement (1) for amplifying an input signal (Sin) of a first frequency, the amplifying arrangement (1) comprising:

a reference voltage level generator (5) adapted to generate a reference voltage level (Vref) having a magnitude based on one or more magnitude characteristics of the input signal (Sin);

a modulating arrangement (2) adapted to receive the input signal (Sin) and generate a modulated signal (Smod) that alternates, at a second frequency, between a current voltage level of the input signal and a reference voltage level, the second frequency being greater than the first frequency;

an amplifying circuit (3) adapted to amplify the modulated signal to thereby provide an amplified modulated signal (Sa); and

an analogue-to-digital converter (4) adapted to perform a demodulation operation comprising sampling the amplified modulated signal at the second frequency and synchronized with portions of the amplified modulated signal (Sa) corresponding to amplifications of the input signal, to thereby obtain amplified samples of the input signal,

wherein the modulating arrangement (2) comprises:

a first input terminal (2a) adapted to receive the input signal (Sin);

a second input terminal (2b) adapted to receive the reference voltage level (Vref);

an output terminal (2c); and

switching logic (2d) adapted to alternately connect, at the second frequency the output terminal (2c) to the first input terminal (2a) and the second input terminal (2b), to thereby generate the modulated signal (Smod) on the output terminal (2c),

wherein the reference voltage level generator (5) comprises:

a capacitor (5b) connected between the second input terminal (2b) and the reference voltage level (Vref); and

a resistor (5a) connected between the output terminal (2c) and the second input terminal (2b), so that a voltage level at the second input terminal (2b) is held at an average of the input signal (Sin),

the amplifying arrangement (1) further comprising a filter arrangement (Cb) connected between the modulating arrangement (2) and the amplifying circuit (3), wherein the filter arrangement (Cb) is adapted to filter at least a direct current component from the modulated signal (Smod).

2. The amplifying arrangement of claim 1, wherein the reference voltage level generator is adapted to generate the reference voltage level having a magnitude equal to an average magnitude of the input signal.

3. The amplifying arrangement of claim 1, wherein the reference voltage level generator is adapted to generate the reference voltage level based on a maximum and/or minimum magnitude of the input signal.

4. A sensing arrangement comprising:

an amplifying arrangement according to any of claims 1 to 3,

a sensing module adapted to generate a sensing signal for amplification, the sensing signal carrying information of interest at the first frequency; and

wherein the amplifying arrangement receives the sensing signal output by the as the input signal.

5. The sensing arrangement of claim 4, wherein the sensing module comprises:

a transmission circuit adapted to transmit an electromagnetic wave;

a sensing circuit adapted to:

receive a reflection of the transmitted electromagnetic wave;

determine a difference in frequency between the transmitted electromagnetic wave and the reflection of the transmitted electromagnetic wave; and

output a sensing signal having a frequency equal to the difference in frequency.

6. A method for amplifying an input signal of a first frequency, the method comprising:

receiving the input signal;

generating a reference voltage level having a magnitude based on one or more magnitude characteristics of the input signal;

generating a modulated signal that alternates between a current voltage level of the input signal and the reference voltage level at a second frequency, the second frequency being greater than the first frequency;

amplifying, using an amplifying circuit, the modulated signal to thereby provide an amplified modulated signal; and

performing a demodulation operation comprising sampling the amplified modulated signal at the second frequency and synchronized with portions of the amplified modulated signal corresponding to amplifications of the input signal, to thereby obtain amplified samples of the input signal.

7. The method of claim 6, wherein the step of generating the reference voltage level comprises generating the reference voltage level so that the voltage swing of the modulated signal is no greater than the voltage swing of the input signal.

8. The method of claim 6 or 7, wherein the step of generating the reference voltage level comprises generating the reference voltage level having a magnitude based on an average magnitude of the input signal.

9. The method of claim 8, wherein the step of generating the reference voltage level comprises generating the reference voltage level having a magnitude equal to an average magnitude of the input signal.

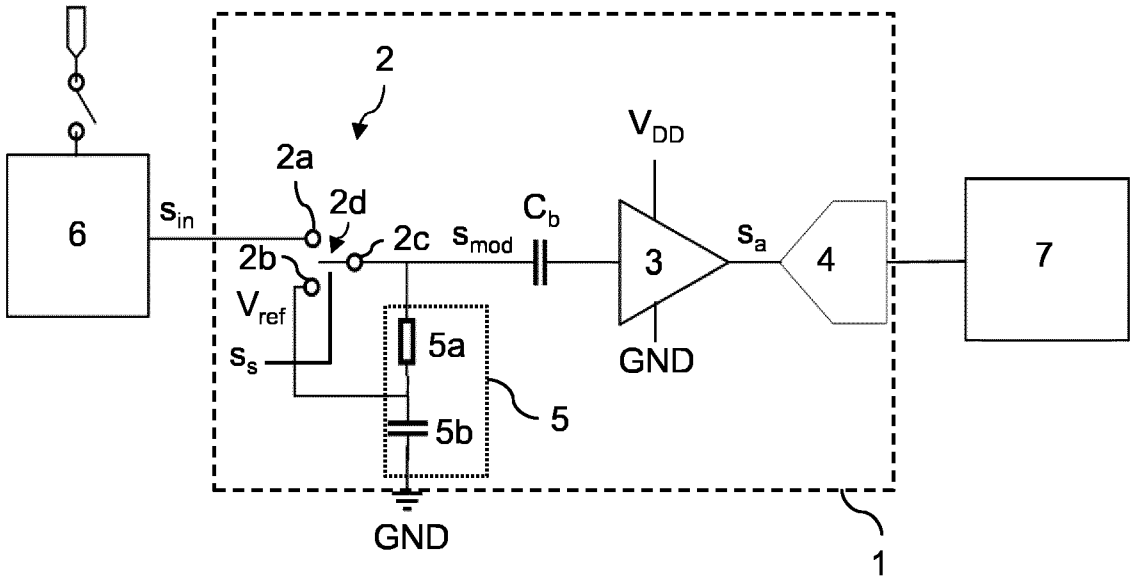
2
2a
2d
2b
2c
V_{DD}
C_b
s_{in}
s_{mod}
s_a
V_{ref}
s_s
5a
5b
5
GND
GND
6
3
4
7
1

FIG. 1

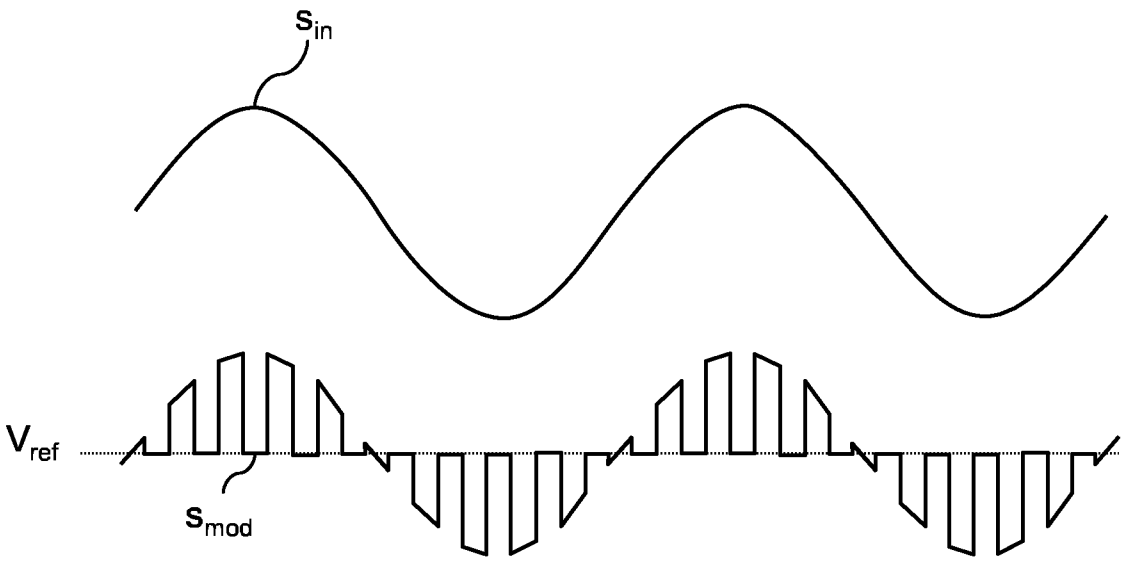
s_{in}
V_{ref}
s_{mod}

FIG. 2

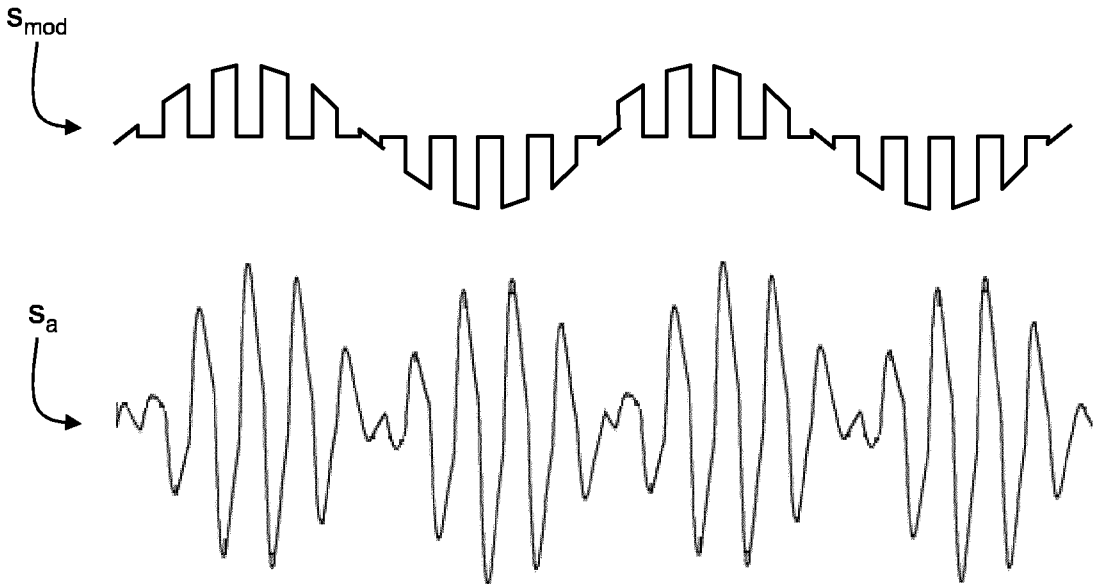

FIG. 3

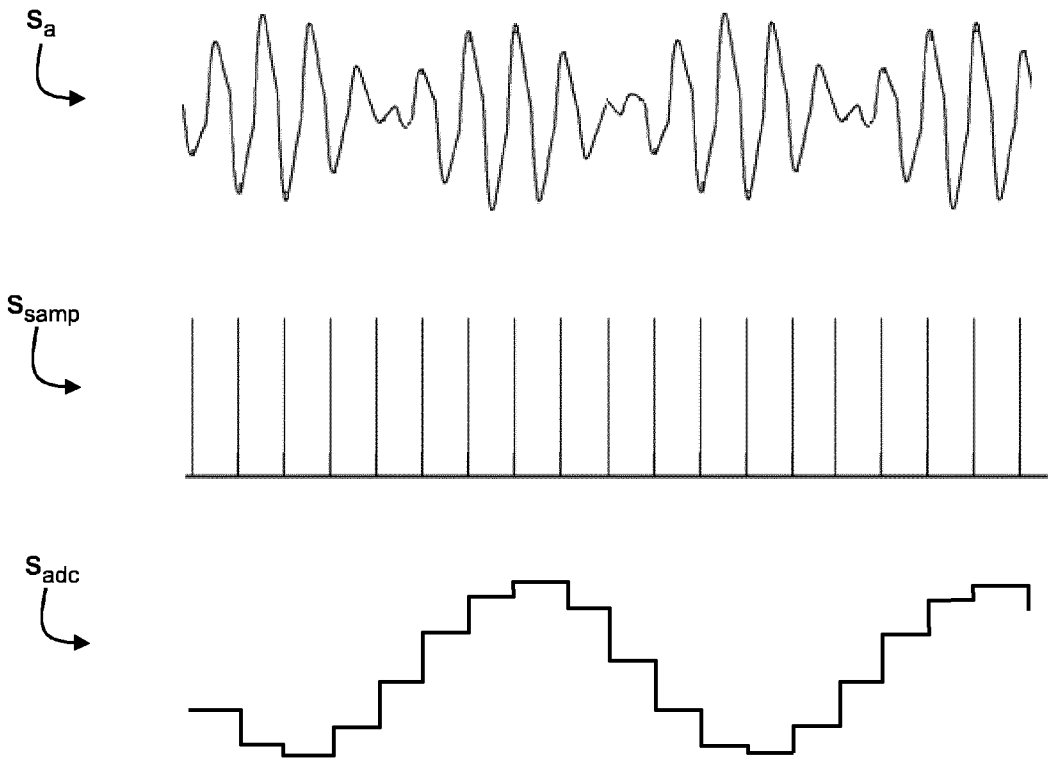

FIG. 4

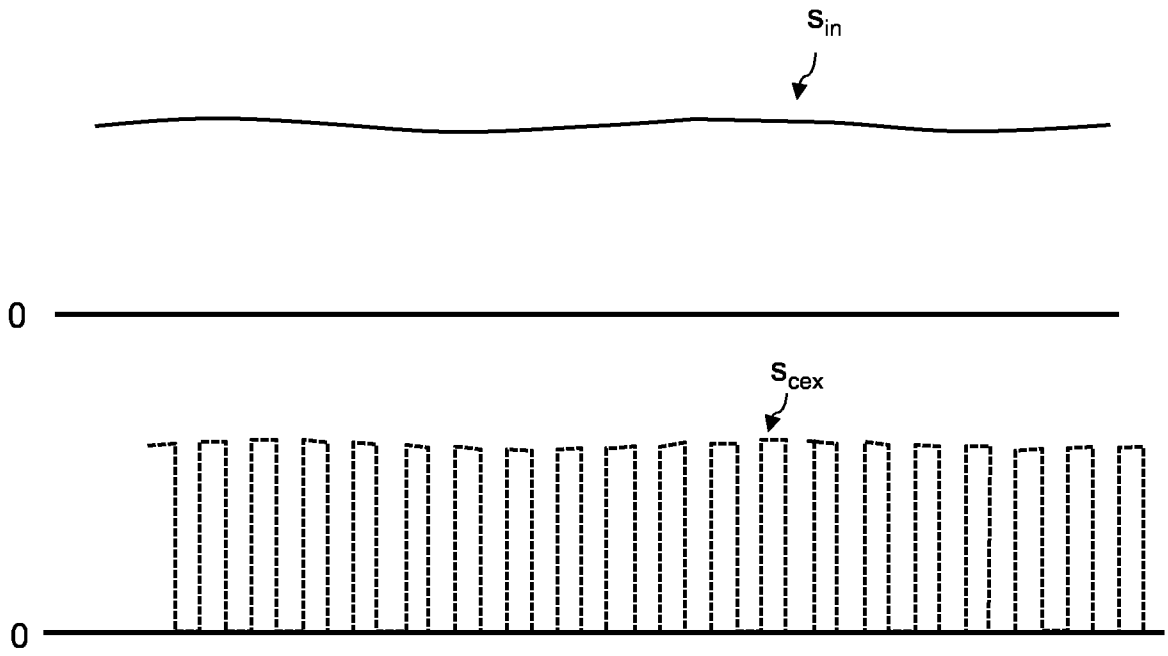
s_{in}
0
s_{cex}
0

FIG. 5

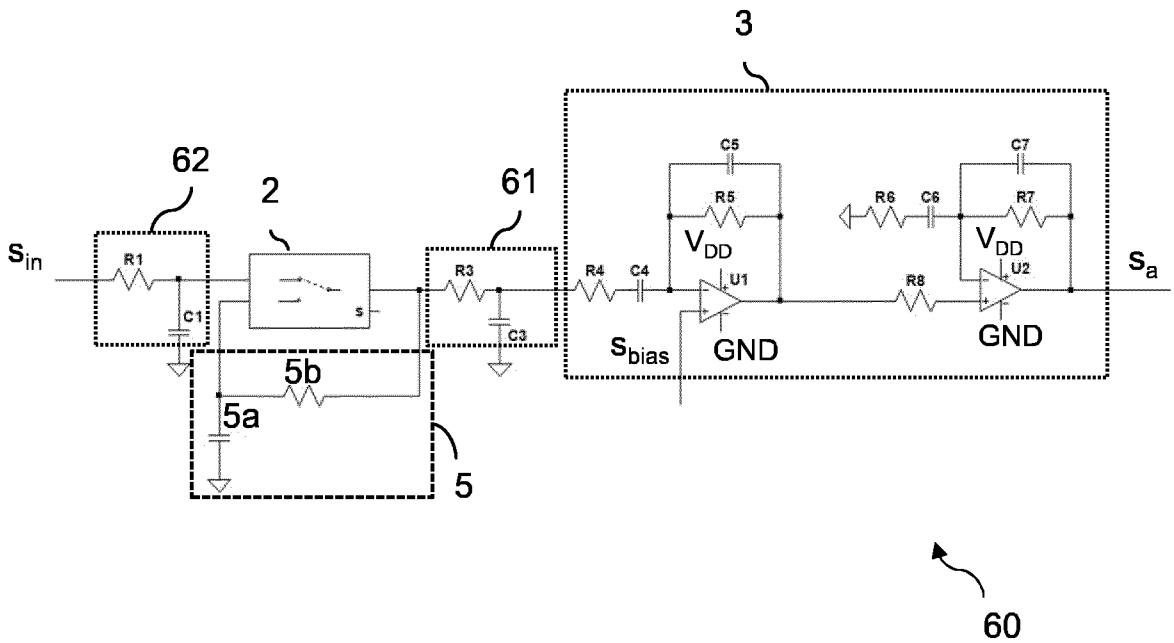
3
62
2
61
s_{in}
R1
C1
R3
C3
5b
5a
5
R4
C4
C5
R5
V_{DD}
U1
s_{bias}
GND
R6
C6
C7
R7
V_{DD}
U2
R8
GND
s_a
60

FIG. 6

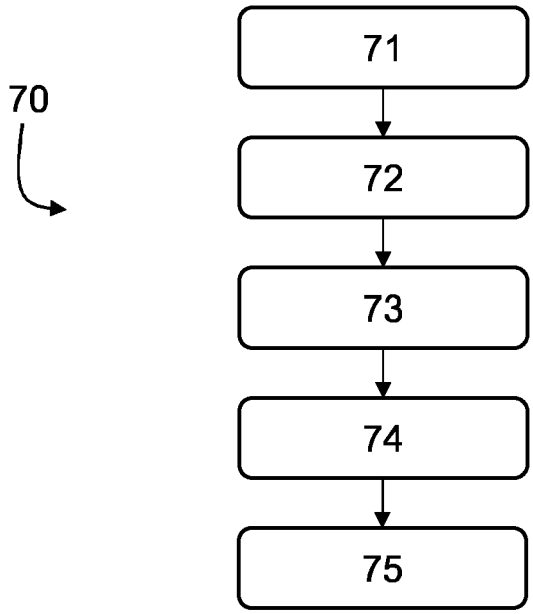

FIG. 7

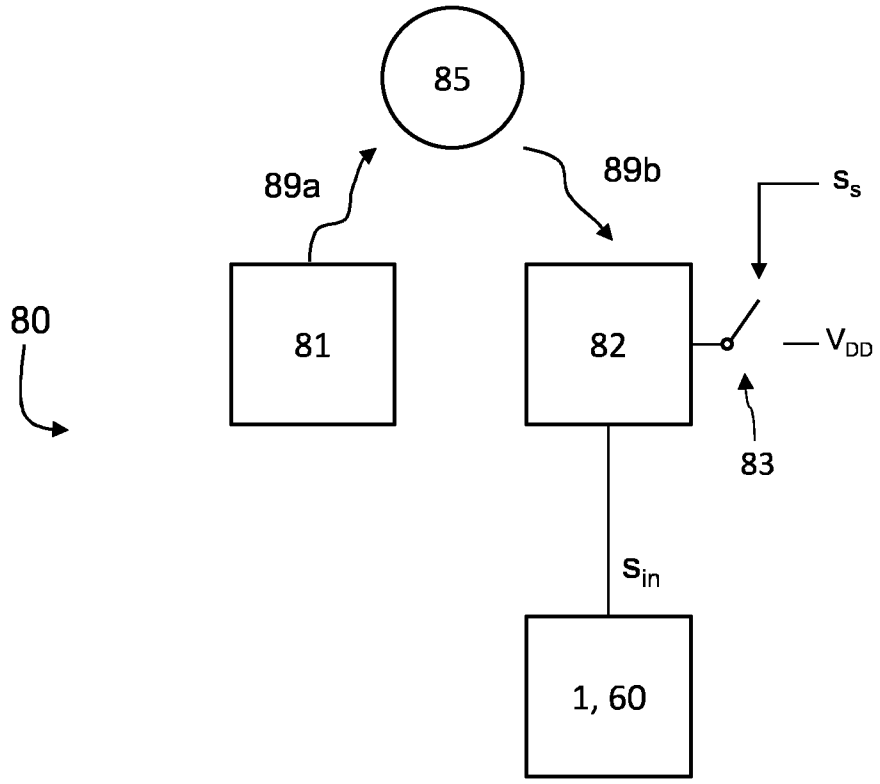

FIG. 8

NTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/073251

A. CLASSIFICATION OF SUBJECT MATTER
INV. H03F1/02 H03F1/32 H03F3/30 H03F1/26 H03F3/187
H03F3/38 H03M1/08 H03M1/12
ADD.
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)
H03F H03M

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)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02/065644 A2 (QUALCOMM INC [US]) 22 August 2002 (2002-08-22)	6
A	figures 7A,7B	1-5,7-9

A	BAGHERI AREZU ET AL: "56-channel direct-coupled chopper-stabilized EEG monitoring ASIC with digitally-assisted offset correction at the folding nodes", 2014 IEEE BIOMEDICAL CIRCUITS AND SYSTEMS CONFERENCE (BIOCAS) PROCEEDINGS, IEEE, 22 October 2014 (2014-10-22), pages 659-662, XP032701819, DOI: 10.1109/BIOCAS.2014.6981812 figures 2,3,7 page 2, left-hand column, line 33 - page 3, left-hand column, line 13	1-9

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[X] Further documents are listed in the continuation of Box C.

[X] 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

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"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
30 September 2019	09/10/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Jespers, Michaël

2

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	RONG WU ET AL: "A 20-b $\pm$ 40-mV Range Read-Out IC With 50-nV Offset and 0.04% Gain Error for Bridge Transducers", IEEE JOURNAL OF SOLID-STATE CIRCUITS, IEEE SERVICE CENTER, PISCATAWAY, NJ, USA, vol. 47, no. 9, 1 September 2012 (2012-09-01), pages 2152-2163, XP011457912, ISSN: 0018-9200, DOI: 10.1109/JSSC.2012.2197929 figure 6 page 2155, right-hand column, line 4 - page 2156, right-hand column, line 5 -----	1-9

2

NTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2019/073251

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