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(54) **Flame monitoring system**

(57) The invention relates to a flame monitoring system (20) for a combustion space (2) having a first ionisation sensor electrode (8) in said combustion space and a second electrode (3). The system comprises an AM signal generator (21) arranged to communicate an AM signal, comprising an amplitude modulation frequency (f_m), to said first electrode to generate a detection signal.

The system further has means (27,28,29,30,31,32) for monitoring a component of said detection signal, corresponding to said modulation frequency and indicative of a presence of a flame in said combustion space. Accordingly, a flame monitoring system is provided which is more robust against dirt and moisture within the combustion space (2).

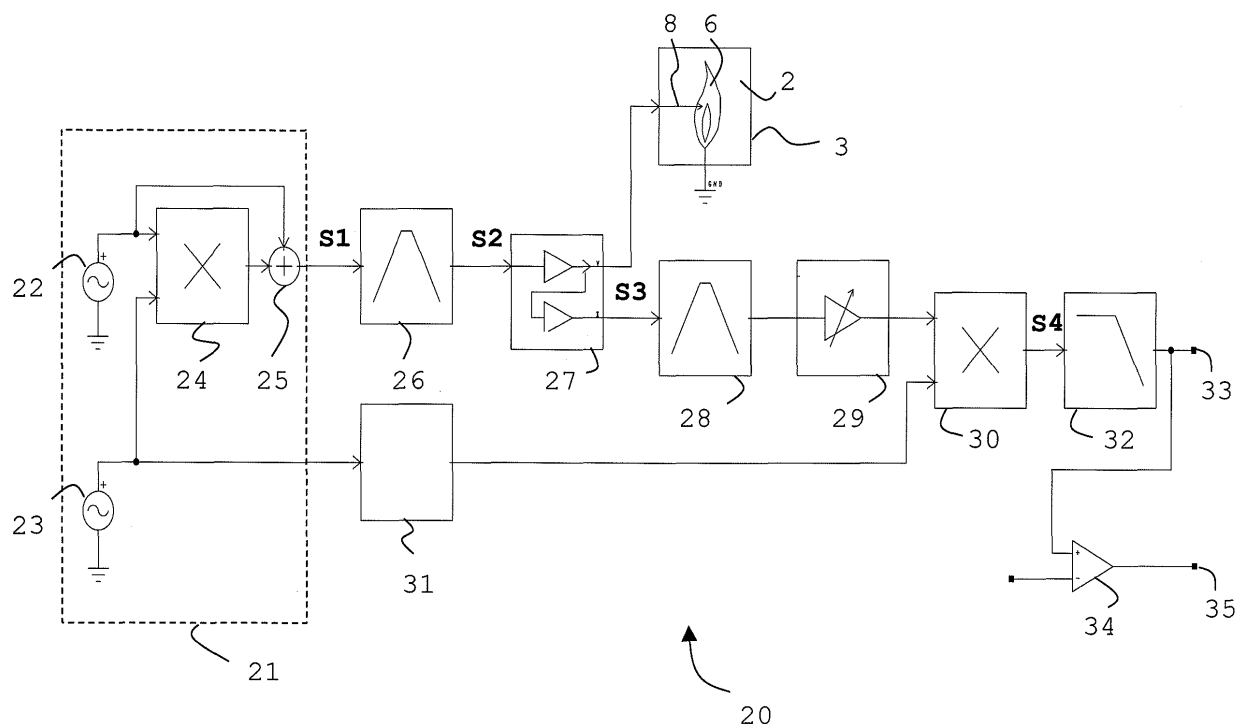


Fig. 2

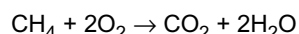
Description

FIELD OF THE INVENTION

[0001] The invention relates to a flame monitoring system for a combustion space having a first ionisation sensor electrode in said combustion space and a second electrode. The invention further relates to a combustion apparatus comprising such a flame monitoring system, a method for monitoring a flame in a combustion space and an automatic burner arranged to perform such a method.

BACKGROUND OF THE INVENTION

[0002] When gases are combusted in combustion devices used for heating purposes, such as central heating installations, water heaters, geysers and furnaces, carbon dioxide and water are formed when air is supplied, e.g. in accordance with the reaction



During such a reaction, free ions and electrons are released as a result of thermal and chemical ionisation processes.

[0003] This reaction can be monitored by a flame rod acting as an ionisation sensor that extends within a combustion chamber and is electrically isolated from the chamber by an insulator. The ionisation sensor utilises said free ions and electrons for detecting the presence of a flame. If an AC voltage is supplied to the ionisation sensor, the free ions and the electrons cause a rectifying effect on the applied signal resulting in a DC current.

[0004] Standardization committees have prescribed use of this rectifying effect if ionisation effects within the combustion space are used for flame monitoring. However, dirt and moisture within the combustion space may cause problems in the detection of the ionisation effect as these induce galvanic voltages that interfere with the detection signal. These phenomena of dirty and moist environments are particularly encountered when a combustion apparatus has not been used for a considerable period of time. As the combustion apparatus will only operate after a full check by the flame monitoring system, dirt and moisture may disturb the monitoring process and, consequently, start of the operation of the combustion apparatus may be not successful.

[0005] Accordingly, flame monitoring systems in practice operate with high voltage signals in order to obtain a detection signal level wherein the interference of the galvanic voltage does not obscure this detection signal. Such high voltage signals typically require use of a signal generator in combination with a transformer. Use of a transformer significantly increases the costs of the flame monitoring system. However, as a result of low parallel impedances also caused by the dirt and moisture, the current load capability of the generator-transformer combination is not very high.

SUMMARY OF THE INVENTION

[0006] It is an object of the invention to provide a flame monitoring system of reduced vulnerability with respect to dirt and moisture within the combustion space.

[0007] To this end, a flame monitoring system for a combustion space is provided having a first ionisation sensor electrode exposable to a flame and a second electrode, said system comprising:

- an AM signal generator arranged to communicate an AM signal, comprising an amplitude modulation frequency, to said first electrode to generate a detection signal, and
- means for monitoring a component of said detection signal, corresponding to said modulation frequency and indicative of a presence of a flame in said combustion space.

[0008] By modulating the amplitude of the voltage signal, the ionisation effect of the flame can be detected, whereas the galvanic interfering voltage component, which is a DC signal, can be ignored from the detection signal, e.g. by filtering. Consequently, the level of the signal communicated to the ionisation electrode can be lowered significantly, which decreases the current load of the flame monitoring sensor in circumstances of dirt and moisture and obviates the need of a transformer. Further advantages include a lower level of RF emission and an improved selectivity with respect to external noise sources and a substantially maintenance free combustion apparatus. Still further, the detection rate of the flame monitoring system can be increased significantly.

[0009] It should be appreciated that the AM signal, comprising an amplitude modulation frequency, should be understood in the sense that the AM signal comprises a modulated carrier, the amplitude modulation frequency being the difference between the frequency of the carrier and the frequency of a side band of the AM signal. This difference corresponds to the frequency of the envelope of the AM signal in the time domain.

[0010] It should further be appreciated that the application of an AM signal should not necessarily occur continuously, but may be applied only once or a few or more times at e.g. the beginning of operation of a combustion apparatus. Also, the AM signal may be applied at regular intervals.

[0011] It should still further be appreciated that flame monitoring includes detecting the presence of a flame but may also include other forms of flame analysis, e.g. with respect to the gas mixture composition, the temperature of combustion and the power of the flame.

[0012] Flame monitoring systems as described above can be applied in combustion spaces, such as combustion chambers, gas cookers and open fires. In this respect it is noted that the composition of gas may vary from location to location. Further, there exists a trend wherein the hydrogen content of gas is increased. Other circumstances wherein an increased risk of moisture is encountered and wherein the invention can be applied includes the field of high efficiency boilers, in which a lot of water is produced during the combustion process. Moreover, the invention can be applied in diesel engines by using the glow plug for preheating as an ionisation sensor electrode.

[0013] In an embodiment of the invention, the combustion space is determined by a wall defined a combustion chamber and said wall of said combustion chamber constitutes said second electrode and wherein said first ionisation sensor electrode comprises a rod protruding inside said combustion chamber. Although also a burner bed may be applied as a second electrode, most burner beds nowadays are of a ceramic material. If the first electrode is a positive rod, electrons will migrate towards this rod. As the mobility of the positive ions is considerably less than the electron mobility, the large dimensions of the wall of the combustion chamber provides for a suitable second electrode for these ions. Consequently, a asymmetrical voltage-current curve is obtained. However, it should be appreciated that other embodiments of the second electrode with shapes different from the first electrode are possible as well.

[0014] In an embodiment of the invention, the flame monitoring system is arranged for feeding said AM-signal to and retrieving said detection signal from said first ionisation sensor electrode. This embodiment has the invention that the same electrode is used for application and detection of the respective signals.

[0015] In an embodiment of the invention, a filter is arranged between said AM signal generator and said first ionisation sensor electrode, said filter being capable of blocking signals having a frequency corresponding to said modulation frequency. As the part of the system that receives the detection signal is selective to the modulation frequency, it is advantageous to use a filter in case of analogue signal generation such that no frequency corresponding to the modulation frequency passes directly from the AM signal generator to this detection part of the flame monitoring system. In case of digital signal generation, such a filter may not be necessary.

[0016] In an embodiment of the invention, the means for monitoring said component of said detection signal comprises a band-pass filter, arranged to select said modulation frequency. A band-pass filter offers a well-known and readily available means for selection of the component of the detection signal, corresponding to the modulation frequency, and accordingly to filter out the contribution in the detection signal of the galvanic voltage. The amplifier arranged to receive said filtered component of said detection signal offers the advantage of amplifying the possibly relatively weak modulation frequency signal.

[0017] In an embodiment of the invention, said means for monitoring said component of said detection signal further comprises a demodulator having a first input for said component of said detection signal and a second input for a reference signal of said modulation frequency. In this embodiment, the DC component correlated to the modulation frequency is obtained by using a reference signal with a frequency identical to the modulation frequency. The DC component relates to the ionisation level within the combustion space and accordingly to the presence of a flame and possibly other aspects of the flame. A low pass filter may be used to get rid of RF components of the signal. Preferably, a delay means is provided between said AM signal generator and said demodulator to equate the phases of the detection signal and the reference signal.

[0018] In an embodiment of the invention, the system further comprises a comparator arranged to compare the DC component of said modulation frequency component of said detection signal with a preset threshold value. Accordingly, a requirement can be set for the level of the DC component to indicate a flame present situation.

[0019] In an embodiment of the invention, the AM signal generator is capable of transmitting a signal with a carrier frequency in the range of 1 kHz - 1 MHz, preferably in the range of 1-100 kHz, more preferably in the range of 40-60 kHz, such as 50 kHz, with a modulation frequency in the range of 0.1-10 kHz, preferably in the range of 4-6 kHz, such as 5 kHz. As the ionisation current has been found to be frequency dependent, wherein the ionisation current decreases with increasing frequency (possibly by the limited mobility of the ions) an upper limit for the carrier frequency exists. However, it is also advantageous to use a high carrier frequency to obtain sufficient frequency space for the band-pass filters which allows less complex filter arrangement. The chosen range represents a balance between these considerations.

[0020] In an embodiment of the invention, wherein said AM signal is an amplitude modulated voltage signal communicated to said first ionisation sensor electrode and wherein said system is arranged for modulating said amplitude in a linear part of an I-V transfer characteristic of said flames. It has been found that it is favourable to modulate the AM signal such that the linear part of the voltage current characteristic, e.g. above 4 Volts, is used for flame monitoring since

this produces repeatable results. Modulation by a few volts provides for a sufficient detection signal.

[0021] In an embodiment of the invention, the system comprises digital or hybrid implementations of said means for monitoring a component of said detection signal. By applying and programming one or more digital signal processors (DSPs) and/or using AD and/or DA converters, it is possible to implement one or more of the functions in a digital or hybrid device. This obviates the need of analogue filters.

[0022] In an embodiment of the invention, the system comprises one or more switched capacitor filters as these filters have well defined filter characteristics and obviates the need of external capacitors.

[0023] The invention also relates to a combustion apparatus comprising a flame monitoring system as described above. As mentioned above, operation of the combustion apparatus is often linked to the flame monitoring system. Only a positive detection signal triggers operation of the combustion apparatus.

[0024] The invention also relates to a method for monitoring the presence of a flame in a combustion space with a flame monitoring system comprising a first ionisation sensor electrode exposible to a flame and a second electrode, said method comprising the steps of:

- feeding an AM signal, comprising an amplitude modulation frequency, to said first electrode to generate a detection signal, and
- monitoring a component of said detection signal, corresponding to said modulation frequency and indicative of a presence of a flame in said combustion space.

[0025] By modulating the amplitude of the voltage signal, the ionisation effect of the flame can be detected, whereas the galvanic interfering voltage component, which is a DC signal, can be ignored from the detection signal, e.g. by filtering. Consequently, the level of the signal communicated to the ionisation electrode can be lowered significantly, which decreases the current load of the flame monitoring sensor in circumstances of dirt and moisture and obviates the need of a transformer. Further advantages include a lower level of RF emission and an improved selectivity with respect to external noise sources and a substantially maintenance free combustion apparatus. Still further, the detection rate of the flame monitoring system can be increased significantly.

[0026] Finally, the invention also relates to an automatic burner arranged to perform the above-described method.

[0027] The invention will be further illustrated with reference to the attached drawings, which schematically shows a preferred embodiment according to the invention. It will be understood that the invention is not in any way restricted to this specific and preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] In the drawings:

- Fig. 1 schematically shows a combustion apparatus comprising a flame monitoring system;
- Fig. 2 shows a block diagram of a flame monitoring system according to an embodiment of the invention;
- Fig. 3 shows a block diagram of a detailed part of the flame monitoring system of Fig. 2;
- Fig. 4 shows an example of an AM signal generated by the AM signal generator of Fig. 2, and
- Figs. 5A-5D show schematic representations of signals at various points in the block diagram of Fig. 2 for ease of understanding the embodiment of the invention.
- Fig. 6 shows a voltage-current signal transfer characteristic of a flame monitoring system according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0029] Fig. 1 schematically shows a combustion apparatus 1 comprising a combustion chamber 2 determined by a wall 3. A mixture of gas and air is introduced into the combustion chamber 2 via an inlet 4 through a burner bed 5. The combustion reaction is represented by a plurality of flames 6. A heat exchanger device H is positioned in the combustion chamber 2 above the flames 6 and exhaust gasses are output via an outlet 7.

[0030] The combustion reaction takes place at the surface of the flames 6 and free ions and electrons, indicated respectively by the "+" and "-" signs in Fig. 1, are produced. Electrons diffuse away from the flames 6 faster than the ions as their mobility is higher than the mobility of the ions. An electric field builds up until an equilibrium state is present.

[0031] A first ionisation sensor electrode 8 extends into the combustion chamber 2 and is isolated from the wall 3 of the combustion chamber 2 by an insulator 9. The ionisation sensor electrode 8 may extend into the flames 6, but e.g. also underneath the flames 6 in order to avoid exposure of the sensor electrode 8 to high temperatures. If a voltage is applied from a voltage source 10 to the ionisation electrode 8, the equilibrium state of ions and electrons is disturbed and a current will flow between the ionisation electrode 8 and the wall 3 of the combustion chamber 2, indicating the

presence of a flame. If no flame is present, theoretically no electrons and ions will be present and a current will not flow on application of a voltage (apart from capacitance effects).

[0032] However, dirt and moisture in the combustion chamber 2 may disturb this monitoring process in case these deposit on or in cracks of the insulator 9. A galvanic voltage may develop from moisture and dirt formed between the sensor electrode 8 and the wall 3 of the combustion chamber 2. This galvanic voltage interferes with the ionisation detection signal and may provide erroneous results. In conventional flame monitoring systems, consequently, the voltage of the AC voltage source is high, e.g. an effective voltage of 130 V, to obtain a detection signal of sufficient magnitude which can be distinguished from the interference signals. In practice, a combination of a signal generator and a transformer is required to obtain such a high voltage. However, since the dirt and moisture also provide for a parallel impedance between the ionisation sensor 8 and the wall 3, the current load of the transformer is limited as this parallel impedance may in extreme circumstances be as low as 10 k Ω . However also in less extreme circumstances parallel impedances below 1 M Ω may be encountered, which still implies a considerable current load for the combination of the signal generator and the transformer.

[0033] Fig. 2 shows a block diagram of a flame monitoring system 20 according to an embodiment of the invention. The components of the system 20 may all be integrated on a circuit board implemented as an application specific integrated circuit.

[0034] It should be appreciated that although the following description is in terms of analogue electronics, the functionality of one or more of the components discussed may also be implemented as digital electronics by means of e.g. AD and DA converters and programmed digital signal processors (DSP's). In order to obviate the need of external capacitors, switched capacitors may be used. Of course, hybrid implementations are also possible. Digital or hybrid implementation may be advantageous as offsets of components and crosstalk between components can be avoided.

[0035] In Fig. 2, an AM signal generator 21 is formed by a first oscillator 22 for a carrier frequency f_c of 50 kHz and a second oscillator 23 for a modulation frequency f_m of 5 kHz. This signal is displayed in Fig. 4. In Fig. 4, $V_{tt,max} = 20$ Volts modulated around a value of 7,5 Volts between 5 Volts and 10 Volts. The carrier frequency signal and modulation frequency signal are fed to an AM modulator formed by a multiplier stage 24 and an adder stage 25 as shown.

[0036] As the multiplier stage 24 in practice may have a non-ideal characteristic, the spectral image S1 of the output signal, displayed in Fig. 5A, not only shows an amplitude modulated signal f_c at 50 kHz with side bands at 45 kHz and 55 kHz, but also a modulation feedthrough signal M of 5 kHz as well as higher harmonics and products of the carrier frequency signal and sidebands (not shown). A band-pass filter 26 is applied to obtain a clean AM signal, displayed in Fig. 5B as spectral image S2, in order to obtain a signal free of a 5 kHz component.

[0037] The clean signal S2 is fed to a combined driver/detector stage 27 that enables to communicate an amplitude modulated voltage signal S2 to the first ionisation sensor 8 and to obtain a detection signal with a spectral image S3 from this ionisation sensor 8.

[0038] Fig. 3 shows a more detailed scheme of the combined driver/detector stage 27 of Fig. 2. The stage 27 comprises four resistors R1, R2, R3 and R4 and a high gain operational amplifier O. R_L represents the ionisation sensor electrode 8. It is assumed that $R1/R2 = R3/R4$. As for a high gain opamp O, $V_+ = V_-$ is valid, the voltage applied to the ionisation sensor electrode 8 is $V_{RL} = V_{in} \cdot R4 / (R3 + R4)$. As this voltage is independent of the value R_L of the ionisation sensor electrode 8, the scheme of Fig. 4 represent a voltage source for this electrode 8.

[0039] If R_L is infinite, $V_{out} = 0$ independent of V_{in} . If R_L is finite and a current flows, this current is converted to a voltage according to $V_{out} = -V_{RL} \cdot R2$.

[0040] The detection signal S3 of the first ionisation sensor electrode 8 is represented in the spectral image of Fig. 5C. This detection signal S3 has a 5 kHz component as a result of the rectification property of the flame 6. This is illustrated in Fig. 6, representing the effect of the amplitude modulated voltage signal applied on the first electrode 8 on the current measured. The value of the detected DC current through the first electrode 8 changes with the frequency of the modulation signal, i.e. with 5 kHz, as a result of the asymmetric I-V characteristic. It is clear that the linear part of the I-V characteristic is used for reasons of reproducibility of the results. The amplitude of the detection signal S3 represents the degree of ionisation in the combustion space 2. The signal S3 further has a DC component E resulting from a galvanic interfering voltage and noise disturbances of the mains supply at 50 Hz and higher harmonics thereof. As can be observed, the component f_m at 5 kHz of the detection signal S3 to be analysed is located between lower frequency disturbing noise sources and the higher frequency AM signal.

[0041] As the modulation frequency component f_m at 5kHz is relatively weak as compared to the other signals, the signal S3 is fed to band-pass filter 28 and an amplification stage 29.

[0042] The resulting signal is subsequently fed to a first input of a demodulator stage 30. The demodulator stage 30 further has a second input for a reference signal of said modulation frequency of 5 kHz obtained from the oscillator 23. The reference signal is fed to a delay means 31, e.g. an all-pass filter, in order to match the phase of the detection signal at the first input and the reference signal at the second input of the demodulator stage 30.

[0043] The output signal S4, shown in Fig. 5D, of the demodulator stage 30 has a DC component that relates to the amplitude of the 5 kHz modulation signal and accordingly relates to the ionisation process triggered by a flame 6 in the

combustion space 2. Further, the output still may have one or more RF signals that are filtered from the detection signal by a low-pass filter stage 32. The bandwidth of the filter may be restricted to avoid interference from external noise sources resulting in a highly selective receiving section. As an example, the bandwidth of the filter stage 32 may be smaller than 5 Hz. As such a small bandwidth may result in a lower detection rate of the flame monitoring system, the bandwidth of the filter stage 32 may be increased to e.g. 500 Hz, 1 kHz or even 10 kHz.

[0044] The remaining DC component is a measure of the ionisation triggered by the flame 6 and is available at the output 33. The power of the combustion apparatus 1 may be obtained from the signal at this output if the composition of the gas mixture at the inlet 4 is kept constant.

[0045] A comparator 34 is applied to set a threshold value for this DC component to trigger a positive or negative flame monitoring signal at the output 35. This signal may be used to control start and operation of the combustion apparatus 1.

[0046] As previously mentioned, the invention may be implemented by analogue, digital or hybrid electronics. The invention is not restricted to the above described embodiment which can be varied in a number of ways within the scope of the claims. For instance, in order to avoid or reduce crosstalk between the transmitting part and the receiving part of the flame modulation system 20, both parts may be implemented on separate chips. The oscillator 22, 23 may be sine waveform oscillators but may also be embodied as triangular wave generators combined with a triangular-sine wave converter.

[0047] Although the generation of sine wave signals is preferred because of the clean spectrum it produces, it should however be appreciated that other repetitive AM signals may be applied as well, including but not limited to triangular or block wave signals.

[0048] Further, a voltage controlled oscillator may be applied in order to exclude the comparator 34, which may cause offset, and to offer a frequency signal to an interface of an automatic burner that has a micro-controller for digital interpretation of this signal. A digital implementation for both the transmitter part and the receiver part may be obtained by using a DSP and a AD and DA converter. This implementation enhances flexibility of the flame monitoring system, as it is embodied by software. A hybrid embodiment may combine digital signal generation of the AM signal and analysis of the detection signal with an analogue intermediate part, such that e.g. the resolution of the AD and DA converters can be decreased. Still further, switched capacitor filters may be employed to avoid the need of external capacitors.

Claims

1. A flame monitoring system (20) for a combustion space (2) having a first ionisation sensor electrode (8) in said combustion space and a second electrode (3), said system comprising:

- an AM signal generator (21) arranged to communicate an AM signal, comprising an amplitude modulation frequency (f_m), to said first electrode to generate a detection signal, and
- means (27,28,29,30,31,32) for monitoring a component of said detection signal, corresponding to said modulation frequency and indicative of a presence of a flame in said combustion space.

2. The flame monitoring system (20) according to claim 1, wherein said combustion space (2) is determined by a wall (3) defining a combustion chamber and said wall of said combustion chamber constitutes said second electrode and wherein said first ionisation sensor electrode (8) comprises a rod protruding inside said combustion chamber.

3. The flame monitoring system (20) according to claim 1 or 2, wherein said system comprises means (27) arranged for feeding said AM-signal to and retrieving said detection signal from said first ionisation sensor electrode.

4. The flame monitoring system (20) according to one or more of the preceding claims, wherein a filter (26) is arranged between said AM signal generator (21) and said first ionisation sensor electrode (8), said filter being capable of blocking signals having a frequency corresponding to said modulation frequency.

5. The flame monitoring system (20) according to one or more of the preceding claims, wherein said means for monitoring said component of said detection signal comprises a band-pass filter (28), arranged to select said modulation frequency (f_m), and, optionally, an amplifier (29) arranged to receive said filtered component of said detection signal.

6. The flame monitoring system (20) according to one or more of the preceding claims, wherein said means for monitoring said component of said detection signal further comprises a demodulator (30) having a first input for said component of said detection signal and a second input for a reference signal of said modulation frequency.

7. The flame monitoring system (20) according to claim 6, wherein a signal delay means (31) is provided between said AM signal generator and said demodulator.
8. The flame monitoring system (20) according to one or more of the preceding claims, wherein said system comprises means (32) for retrieving a DC component of said modulation frequency component of said detection signal.
9. The flame monitoring system (20) according to claim 8, wherein said system further comprises a comparator (34) arranged to compare said DC component of said modulation frequency component of said detection signal with a preset threshold value.
10. The flame monitoring system (20) according to one or more of the preceding claims, wherein said AM signal generator (21) is capable of transmitting a signal with a carrier frequency (f_c) in the range of 1 kHz-1 MHz, preferably 1-100 kHz, more preferably 40-60 kHz, with a modulation frequency (f_m) in the range of 0.1-10 kHz, preferably 1-10 kHz, more preferably 4-6 kHz.
11. The flame monitoring system (20) according to one or more of the preceding claims, wherein said AM signal is an amplitude modulated voltage signal communicated to said first ionisation sensor electrode and wherein said system is arranged for modulating said amplitude in a linear part of an current-voltage characteristic of said flames.
12. The flame monitoring system (20) according to one or more of the preceding claims, wherein said system has a digital or hybrid implementation of said AM signal generator and/or said means for monitoring a component of said detection signal, corresponding to said modulation frequency and indicative of a presence of a flame in said combustion space.
13. The flame monitoring system (20) according to one or more of the preceding claims, wherein said system comprises one or more switched capacitor filters.
14. A combustion apparatus (1) comprising a flame monitoring system (20) according to one or more of the preceding claims.
15. A method for monitoring the presence of a flame (6) in a combustion space (2) with a flame monitoring system (20) comprising a first ionisation sensor electrode (8) exposable to a flame and a second electrode (3), said method comprising the steps of:
 - feeding an AM signal, comprising an amplitude modulation frequency, to said first electrode to generate a detection signal, and
 - monitoring a component of said detection signal, corresponding to said modulation frequency and indicative of a presence of a flame in said combustion space.
16. An automatic burner arranged to perform the method according to claim 15.

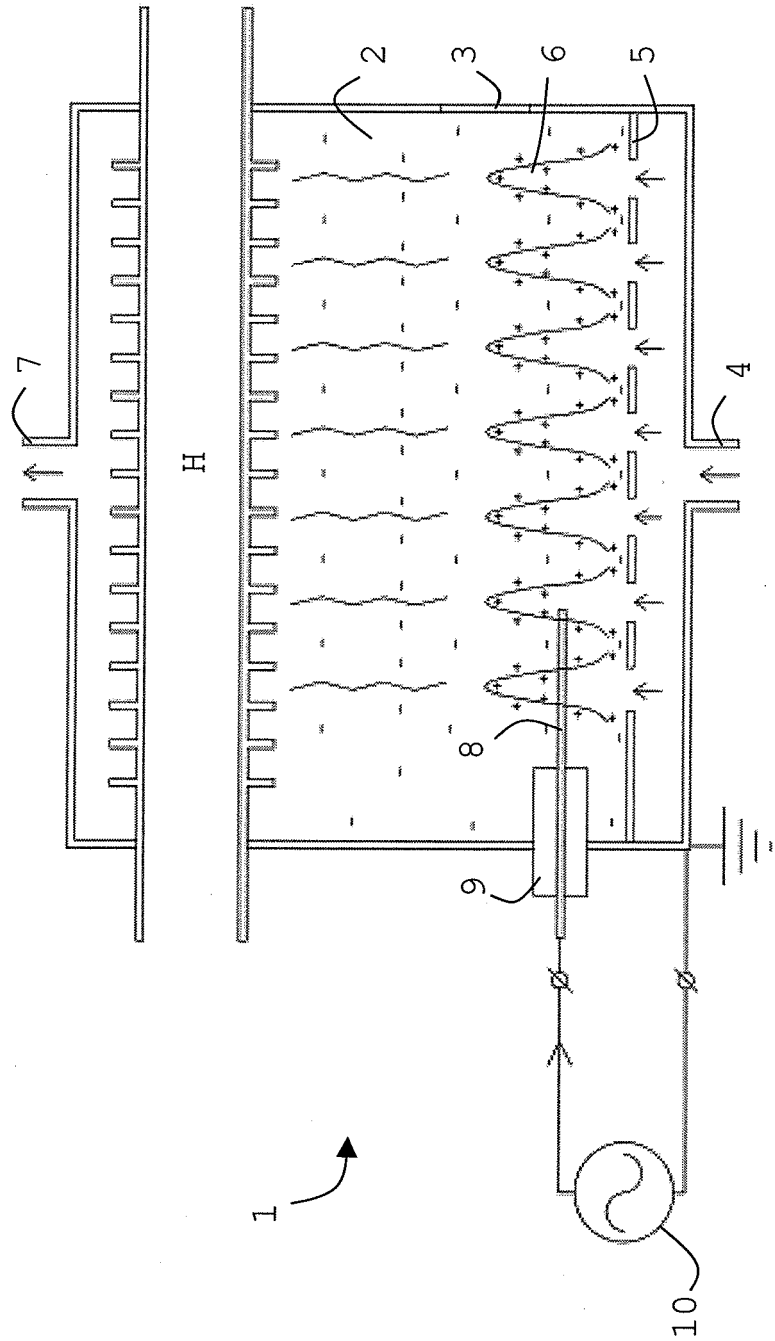


Fig. 1

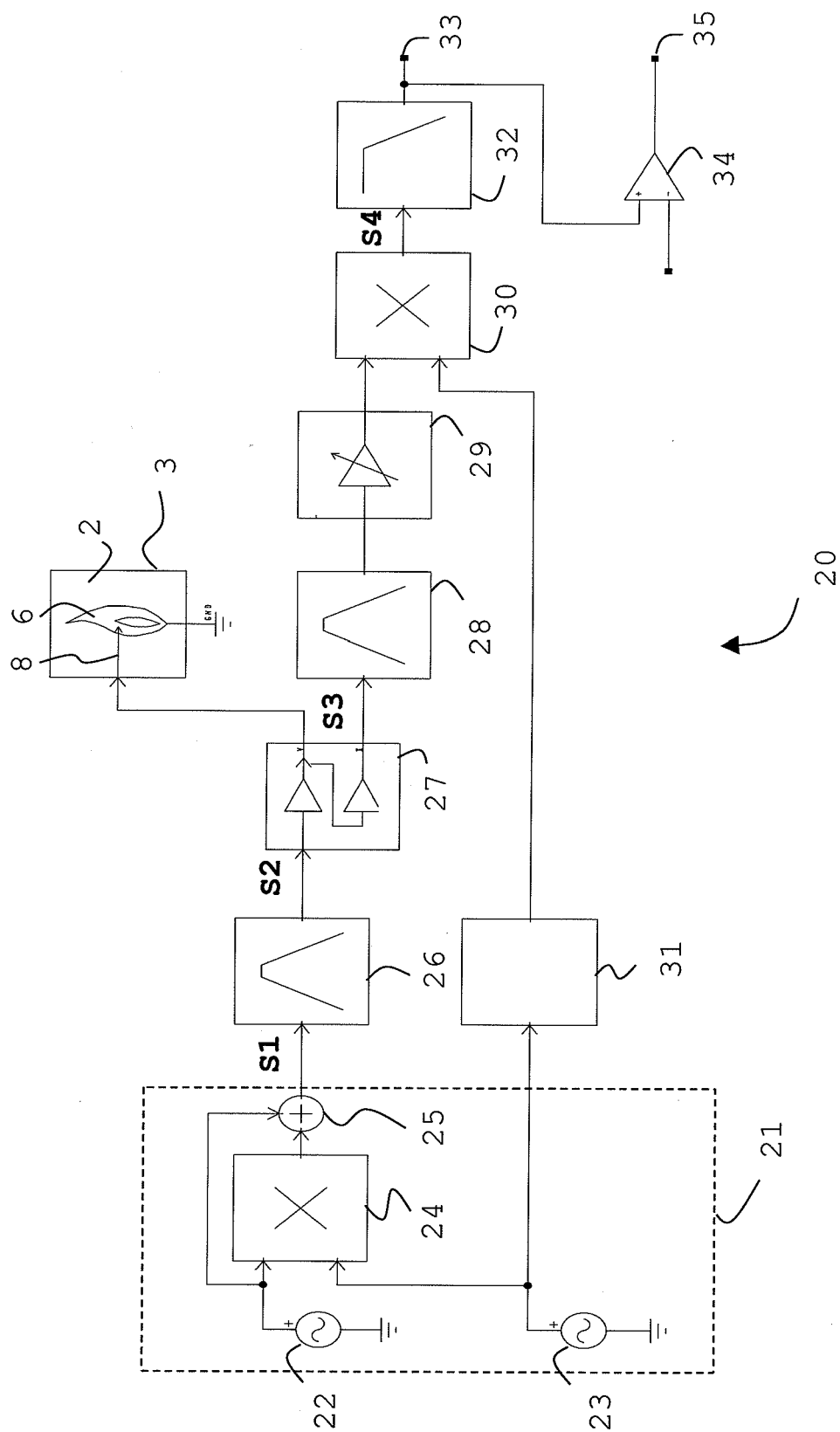


Fig. 2

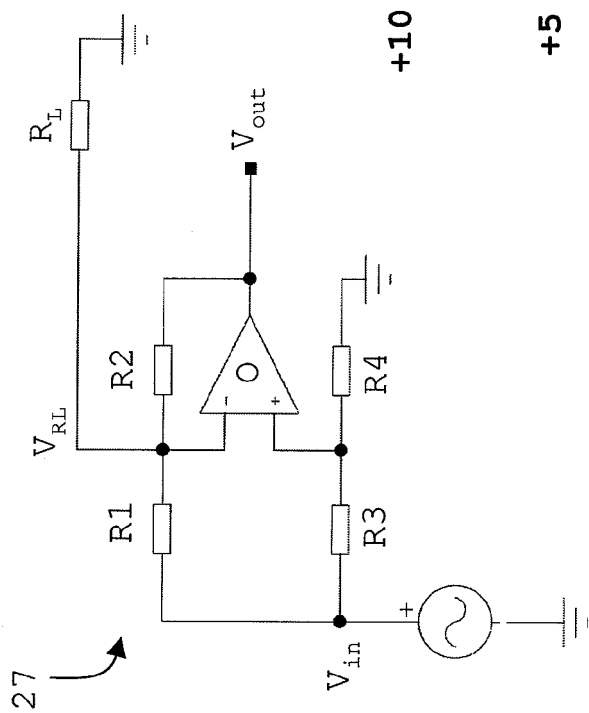


Fig. 3

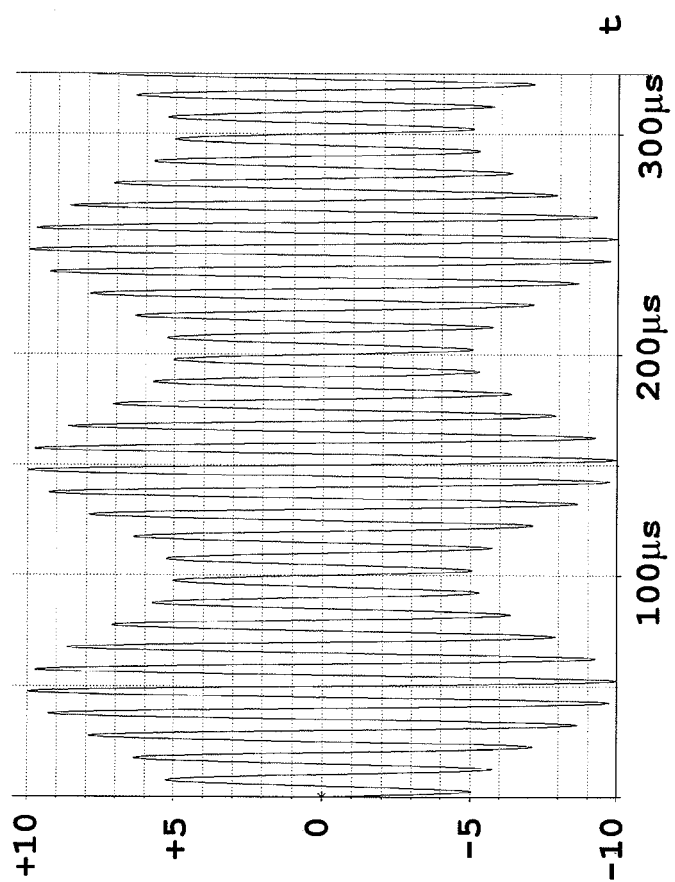


Fig. 4

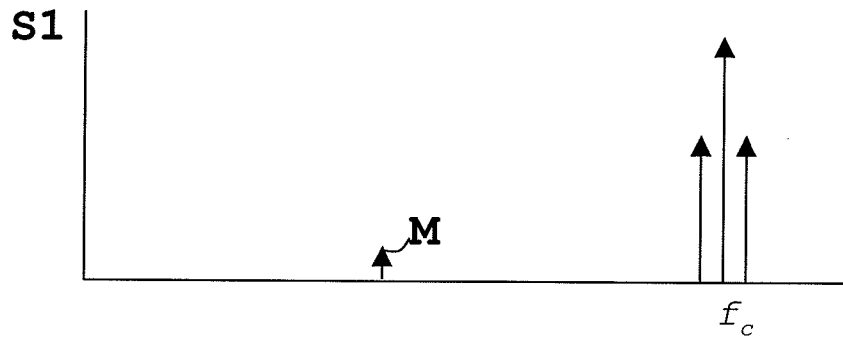


Fig. 5A



Fig. 5B

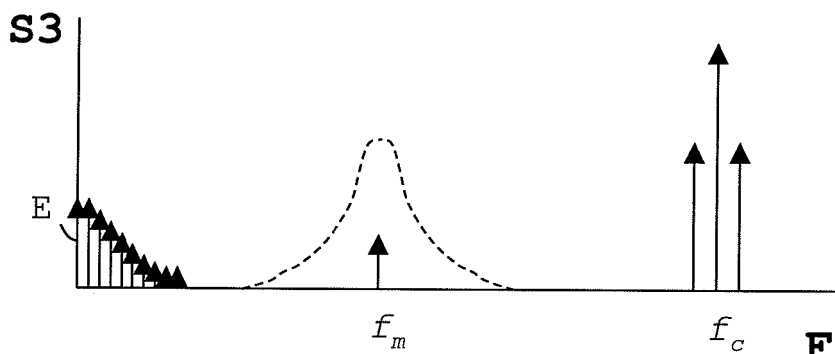


Fig. 5C

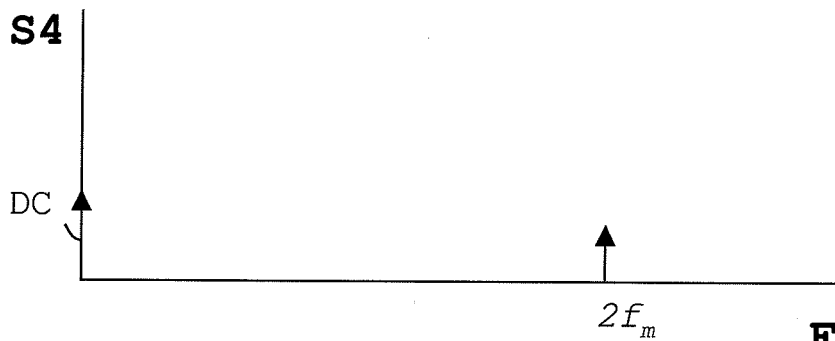


Fig. 5D

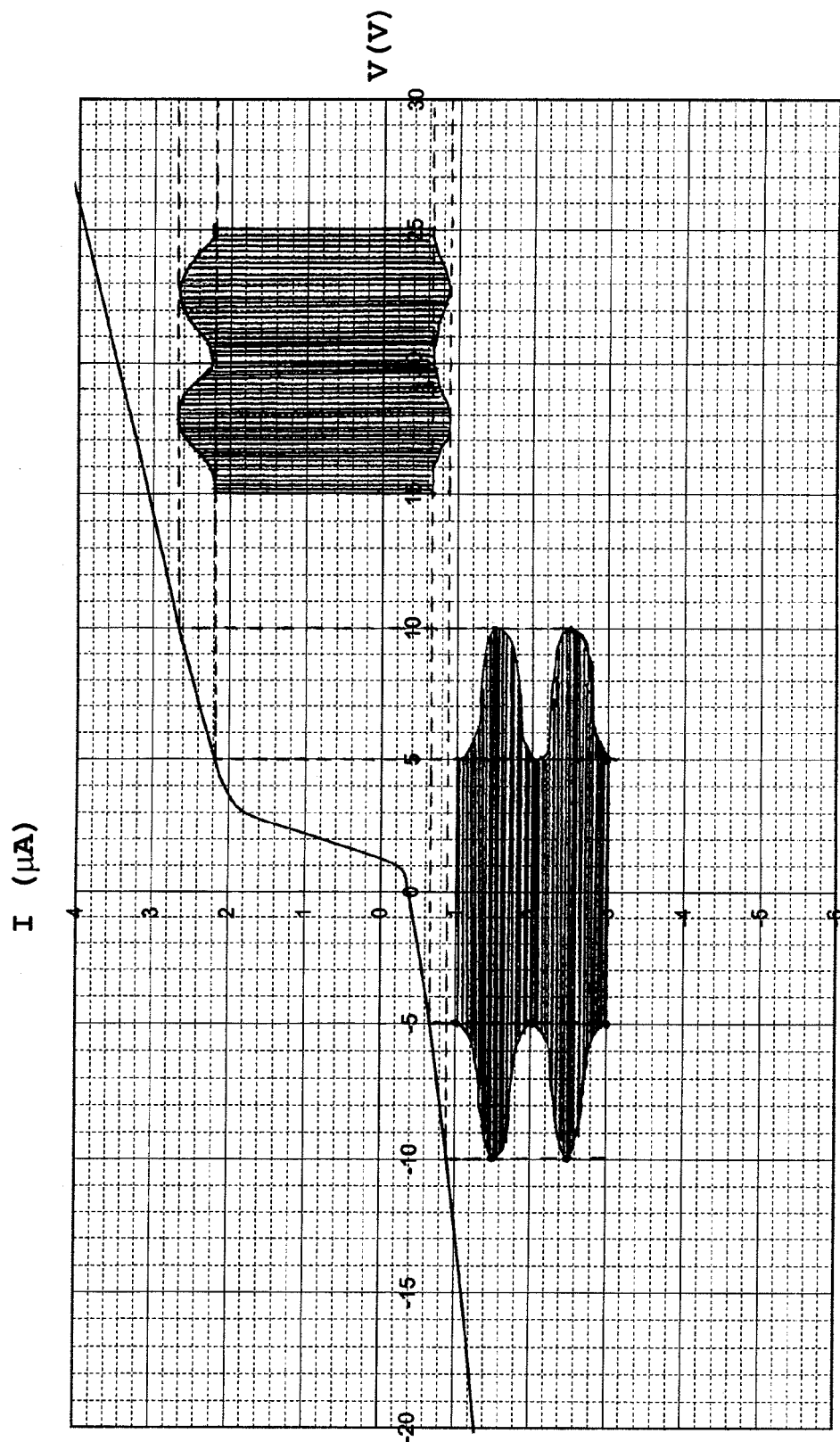


Fig. 6



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 10 6090

DOCUMENTS CONSIDERED TO BE RELEVANT			
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Place of search Munich		Date of completion of the search 21 October 2005	Examiner Gavriliu, C
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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