level. While the input is below the threshold the comparator **56** keeps a charging capacitor clamped near ground through a diode. When the input exceeds the threshold the comparator **56** goes positive and allows the voltage of the charging capacitor **58** to rise. Its rate of rise is governed by the well-known RC exponential charging equation. The charging capacitor **58** voltage is applied to another comparator **57**, appropriately biased to the voltage that the charging capacitor **58** will reach in 8 μs. Thus, after an 8 μs time delay the comparator **57** output will go from HIGH to LOW.

The 8 μs delay comparator **57** and the slope-detection comparator **58** are combined in a NAND gate. The output of the NAND gate, then, is a signal that is low from the time the slope of the input envelope becomes zero until 8 μs after onset. If the input envelope does not peak within 8 μs, then there is no output from the NAND gate. Hence signals typified by FIG. **7** are ignored. The signal from the NAND gate may be considered a "tentative particle" indication.

FIG. **12** shows the circuitry of the Low Pass Filter, Flip-Flop, and Time Delay blocks of FIG. **9**. The circuitry to implement the process of waiting 200 μs after a tentative particle indication while checking for low-frequency components in the sensor signal will now be explained. Note again that a time-delay circuit based on the RC charge curve is employed. The values of the capacitor **70** and associated resistors as well as the comparator **75** bias are selected to give a 200 μs time delay. This timer is initiated by the "tentative particle" pulse from the circuit of FIG. **11**. At the end of the 200 μs pulse a short "time out" pulse to formed by timeout pulse circuit **76**. This function is implemented here using an inverter and a NAND gate so as to create a logical race condition. The timeout pulse circuit **76** reliably generates a negative pulse on the rising edge of an input signal, during the short time when both inputs to the NAND are HIGH.

The "tentative particle" pulse also sets a bi-stable flip-flop **80**. A simple implementation of a bi-stable flip-flop (comprising two cross-connected NAND gates) is shown. As mentioned previously, the output from the piezoelectric sensor is also applied to low-pass filter **81**, here implemented by an active-filter Sallen-Key circuit. The output of this filter is applied to a window comparator **82** biased somewhat above the noise level. If there is a low-frequency component in the piezoelectric sensor output then it will pass through the low-pass filter **81** and trigger the comparator **82**. This, in turn resets the flip-flop **80**. Finally, the 200 μs timeout pulse is ANDed with the flip-flop **80** output. If the flip-flop **80** has not been reset, then the output of the AND gate is an indication that a signal similar to that in FIG. **6** was received.

While the present invention has been described herein with regard to certain preferred embodiments, various modifications could be made without departing from the scope and spirit of the claims appended hereto.

For example, use of the invention is not limited to an internal combustion engine. Lubricants are also used as mechanisms for transmitting power, such as a transmission, a pipe system for oil pressure, such as a hydraulic servo system, industrial rolling, press working, etc. The invention could be used in all of these areas and more to sense particles in fluid.

Additionally, while piezoelectric sensors have been described herein, other types of sensors could also be employed. For example, electromagnetic-induction sensors and electrical capacitance sensors can be used. Further, light emitting diodes and phototransistors can be used to transmit and detect light off of a vibratile portion that makes contact with and is vibrated by particles in the fluid. Changes in the amount of light detected can be indicative of particle contact with the vibratile portion. Still further, the sensor element could take the form of a semiconductor element whose electrical resistance changes as particles make contact therewith.

What is claimed is:

1. A sensor device adapted to detect at least one of a particle and a bubble in a fluid, comprising:

a sensor element for converting an impact of a particle into an electrical signal, said electrical signal including a high frequency component; and

a circuit including (i) amplifier means for amplifying the magnitude of the electrical signal, (ii) envelope-detector means for forming an approximation to an envelope of the high frequency component of the electrical signal, (iii) rise-time-verifier means for detecting a rise time of the electrical signal so as to compare the rise time against a first predetermined value, wherein when the rise time is shorter than the first predetermined value, said rise-time-verifier means outputs the electrical signal, and (iv) detecting means for detecting presence of a low-frequency component of said electrical signal during a predetermined time interval, whereby when the low-frequency component is absent, the electrical signal is induced by a particle, and when the low-frequency component is present, the electrical signal is induced by a bubble.

2. A sensor device of claim **1**, wherein said detecting means includes a low-pass filter and a flip flop.

3. A sensor device of claim **1**, wherein said sensor element includes;

a diaphragm element having a sufficiently small mass for responding to a collision with a solid particle; and

an apparatus for converting vibration of said diaphragm element to an electrical signal so as to detect the vibration.

4. A sensor device of claim **1**, wherein said sensor element includes:

a detecting unit including a piezoelectric film consisting essentially of a first ceramic material, a first electrode coated onto at least a portion of the outer surface of said piezoelectric film, and a second electrode coated onto at least a portion of the inner surface of said piezoelectric film; and

a vibrating portion having a sufficiently small mass for responding to a collision with the solid particle and consisting essentially of a second ceramic material, said detecting unit being placed on said vibrating portion so that said second electrode is coated onto at least a portion of said vibrating portion;

wherein when one of a solid particle and a bubble in the fluid strikes one of said detecting unit and said vibrating portion, said piezoelectric film converts the vibration into an electrical signal.

5. A method for discriminating an electrical signal induced by a particle in a fluid from an electrical signal induced by a bubble, comprising the steps of:

detecting a rise time of a high-frequency component of the electrical signal so as to compare the rise time against a first predetermined value; and

detecting the presence of a low-frequency component of the electrical signal during a second predetermined time period,

wherein when the low-frequency component is absent then the electrical signal is induced by a particle, and