SENSORS AND SIGNAL CONDITIONNING

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Abstract

The general problem of sensor signal conditioning is approached from the point of view of separating the intrinsic sensor properties from those associated with inserting the sensor into a conditioning circuit. This gives rise to a check list of attributes which would be useful to localize problems which may arise in using sensing devices. A second part of the presentation provides a survey of traditional sensor conditioning techniques, going from simple analog op amp solutions to sophisticated digital technology using DSP and look up tables of correction coefficients. A final section covers the use of a promising new passive analog technology to adjust resistance values using Resistor. It is demonstrated that the Rejustor performance compares favorably to its digital counterpart, the digital potentiometer. It is concluded that the Rejustor could provide a simple and elegant solution to many sensor signal conditioning problems.

Key words: Sensor signal conditioning, detectors, Analog sensor signal processor, DSP

1.0 Introduction:

Science is the beginning of civilization, man has continuously engaged in converting the natural resources into useful products. Measurement systems comprises of sensors, transducers and signal processing devices. Today a variety of these elements and devices are available in the market. For a fire detection systems not only apply increasingly intelligent methods to detect fires but also imitate defined processes automatically and provide emergency services on the ground with important information. Early and reliable fire detection using appropriate detectors has top priority. The detection criteria for automatic detectors are determined by the combustion products produced by the fire. Multi- detectors is a great example of how fire detection technologies have evolved over the years. Designed to detect smoke, heat and/or CO, and hazardous gases multi-sensor detectors help reduce false alarms by comparing the inputs from the multiple sensors before deciding whether the source of the input is an actual fire or one of many false alarm conditions. Having been established for a number of years, multi-sensor detectors are now being used to replace existing smoke detectors, as well as being the first choice for installation in many new building projects.

The purpose of fire detection systems is to detect a fire in its earliest stage and activate the alarm. From its initial phase, a fire is subject to various conditions, which have different effects on its development. The interaction of fire cause, combustible material and air supply can produce a smoldering fire, an open fire or a combination of the two. The combustion process generates temperatures, fire gases and smoke. The latter can take a variety of forms, from invisible aerosols to black sooty smoke, depending on the combustible material and the progression of the fire. Fire detectors must be able to detect these different fire phenomena characteristics of the fire development quickly and reliably.

2. Multi-Detector Concept:

Multi-Sensor Detector: the use of multi-sensor technology has the potential to reduce certain types of commonly encountered false alarms. However, the extent to which this can be realized depends on the particular implementation of features designed to improve false alarm. The different multi-detector was categorized as follows:

- Basic: A detector that uses the signal from the heat sensor to enhance the signal from an optical sensor (to provide quicker warning for flaming fires) and contains no other design features specifically intended to improve resistance to false alarms;
- Intermediate: A detector that, in addition to performing the functions of a basic detector, has been designed to enable it to recognize and not respond to some types of false alarm sources, e.g. spike rejection that ignores a transient potential false alarm (e.g. from an aerosol spray).
- Advanced: A detector that contains significant design features that allow it to identify and reject false alarms, e.g. devices that have dual sensor detectors, backward and forward scatter optics, or advanced algorithms that enable it to perform complex background monitoring/ pattern recognition.

3. **Types of Fire Detectors**: The products generated by a fire depend on the burning material and levels of oxygen present. The types of smoke produced from different types of fires can be very broad in terms of their characteristics - i.e. optical density, buoyancy and colour. Smoke detectors are expected to respond to all types of smoke. Unfortunately, some of these smoke characteristics overlap with those of airborne particles produced from non-fire sources, such as steam, dust, aerosol sprays etc., the effects of which could be identified by smoke detectors as smoke from fires. A number of different detection technologies are applied. They include the following:

3.1: **Heat detector:** This detects high temperature above ambient value and higher rate of temperature rise. These are based on the changes with the increase of temperature due to heat - physical, chemical properties like expansion, variation of electric resistance/capacitance, reaching melting point, insulation failure, loss of magnetic property, occlusion of gases in solid. Heat detectors are made using metal, non-metal, bimetal, liquid or gases as medium for detection. Heat or Thermal type detectors are the most primitive types of autonomous fire detectors, dating back to mid-1800's.Most of these detectors are fixed temperature ones, which activates upon reaching a predefined temperature in the premises. Thermal detectors are reliable, inexpensive, easy to maintain, and have lower false alarm rate. But these detectors are slow, and by the time they reach predefined detection point, damage could already been underway. Therefore these detectors are limited use.

Fig 3: Heat Detector

3.2: **Fixed Temperature Type**: It is one of the most common types of heat detector. Fixed temperature detectors operate when the heat sensitivity eutectic alloy reaches the eutectic point changing state from a solid to a liquid.

- Thermal lag delays the accumulation of heat at the sensitive element so that a fixed-temperature device will reach its operating temperature sometime after the surrounding air temperature exceeds that temperature.
- The most common fixed temperature point for electrically connected heat detectors is 136.4°F (58°C).
- Technological developments have enabled the perfection of detectors that activate at a temperature of 117°F (47°C), increasing the available reaction time and margin of safety. This type of technology has been available for decades without the use of batteries or electricity.

3.3: **Smoke detector**: This detects level of smoke particles. Based on optical ability like obscuration, scattering variation in refractive index, photo electric properties, changes in conductivity of ionized air due to presence of smoke particles Smoke Detectors (Combustion Products) Property damage caused by a fire is directly related to the, Intensity of fire: The intensity of fire depends upon the time available for its growth, type and geometrical configuration of combustibles and ventilation. Duration of fire: The duration of fire depends upon the quantity of combustible and the point at which extinction process starts; Smoke or gas detectors, a relatively newer invention, became widespread during 1970's and 1980's. These detectors usually detect fire i early flaming or smouldering stages. These detectors can be of different types having different operation principles, namely-optical or photoelectric detectors, ionization detectors, air sampling detectors etc. Each of these types has specific applications in specific circumstances.

Photoelectric or Optical detectors include various components', mainly, a light source (usually an infrared LED), and a lense to coverage light rays into abeam, and a photo electrode. In normal condition, the light beam passes straight. But whenever smoke interrupts the path of light, scatters fraction of light into the photodiode, the smoke detector is activated. This method of detection can detect fire that begin with long duration of smouldering. This radioactive isotope emits alpha particles into an ionization chamber, which comprises of electrodes. The alpha particles ionize the air inside the chamber, resulting current flow between the electrodes, Now, whenever smoke particles from a nearby fire passes through the chamber, the ions get attached to smoke particles, and thereby interrupts the current flow between the electrodes, an activates the detector. This type of detectors is more suited flaming fire outbursts, unlike the photoelectric detectors, which responds better to smouldering stages.

Fig 1: Ionization-Smoke Detector

Ionization detectors might perform better where there is risk of fast flaming fire. Whereas photoelectric detectors react to cases of slow smouldering, like electrical or furnishing fire. Ionization devices are weaker in scenarios where air flow is high. Although ionization type detectors are cheaper than photoelectric ones, they have more chance of false alarm than the photoelectric detectors However, ionization based detectors have safety issues and possess threats to environment, because of americium-

241. Therefore, on the basis of performance and safety concern some countries have banned ionization based alarms, and different fire authorities and associations have reports not recommending use of these detectors. Air sampling detectors have applications in very sensitive area, as they can detect very fine smoke particles. These detectors are mostly air aspirating type systems. Generally they comprise a control unit, and a network of sampling tubes or pipes. The control unit consists of detection chamber, an aspiration fan, and necessary operation circuitry. Since this type of detectors are very sensitive and fast responding, they have applications in high-value and critical areas, such as, aesthetic galleries, archives', vaults, server rooms, high-tech organizations etc. However, these detection systems are complex and expensive.

Moreover, some combination smoke alarms include both ionization and photoelectric technologies in a single device. Some smoke alarms use a dioxide sensor or carbon for detection as well.

• Life risk is predominantly posed by hot toxic products of combustion, which travel faster and further than fire. The amount and speed of travel is directly proportional to the intensity of fire.

• In order to ensure life safety and reduce property loss there is a need to detect fire in an incipient stage, which will provide a reasonable interval of time for inmates to escape to a place of safety and extinguish the fire with minimum loss. Smoke detectors are ideally suited for such purpose.

• Smoke detectors basically work on two properties of smoke particle in air.

- Electric conductivity of ionised air varies with the density of smoke particles (aerosols).
- Visibility and path of light through smoky air is reduced, disturbed when compared to clean air.

• They are called ionisation type or optical type smoke detectors, respectively.

Ionisation Type Smoke Detectors It comprises of a chamber housing cathode and anode which are charged through battery source. The air between cathode and anode is ionised in the presence of radioactive elements. Air gets in through the filter to enter the chamber.

• Under the normal circumstances, pre-set current pass through the circuit. Under the fire condition, when smoke enters the chamber through filter by virtue of presence of smoke particles, the electric conductivity of air between electrodes reduces and current pass through circuit lowers down. The lowering of current after the predetermined value sends a signal for fire alarm.

3.4: Beam Detectors (Heat and Smoke) these types of detectors are used as a beam of light projected at photo sensing receiver to detect physical changes which occur in the air above fire. Changes could be accumulation of smoke particles at ceiling level as well as disturbance caused by rising hot air or gas currents. It is a combination detector of heat and smoke.

• The system consists of an Emitter Unit producing light beam in infrared spectrum which is aligned to be sensed by receiving unit.

• An emitter and receiving unit are normally fixed in a convenient and readily accessible position on end walls. The emitter unit produces pulses of infrared light which approximately 4 micro seconds in duration and repeated 1000 times per second. The light leaves the emitter unit in form of a beam which spreads up to diameter of 1 metre over the path of 100 metres.

• At the far end of the system is a receiver unit, which by the use of a photo transistor, detects the presence of the infrared light beam. The received signal is then analysed for the presence of smoke and/or heat conditions for alarm.

Smoke Detection The light beam is used as a conventional obstruction type smoke detection system with directly illuminated receiver. When smoke drifts into the space between the emitter and receiver units, the brightness of the received light pulses is reduced and hence the phototransistor produces a smaller output.

• In a comparator circuit the brightness of the pulses at any given time is compared with the brightness of standard light for 10 minutes or so. When a reduction of more than 50% occurs within the duration of this 10 minutes interval, a smoke alarm is initiated.

• As build-up of drift on lenses etc. and small power losses due to misalignment of the beam occur over periods of days rather than minutes, these are automatically compensated for in the comparator circuit.

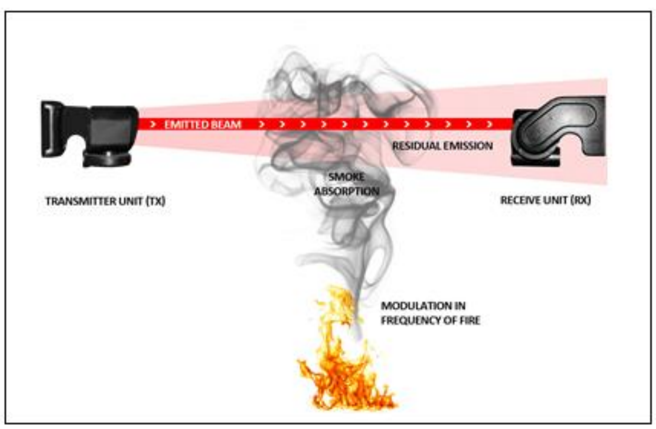

Fig 2: Beam (Smoke) Detector

3.5: Flame detectors:

The optical flame detector is a detector that uses optical sensors to detect flames. There are also ionisation flame Electromagnetic Radiation Fast Response Detector Conventional devices like heat and combustion detectors required a definite increase in the temperature of the atmosphere or production of visible or invisible aerosol. In the case of heat detectors, the rate of rise of temperature will be slow due to low energy level in the fire while combustion into the detector.

Flame type detectors are sophisticated equipment to detect the flame phenomena of a fire. These detectors have various types depending on the light wavelength they use. Such as, ultraviolet, near infrared, infrared, and combination of UV/IR type detectors.

UV detectors generally work with wavelengths shorter than 300 nm. This type of detectors can detect fires and explosions situations within 3-4 milliseconds from the UV radiation emitted from the incident. However, to reduce false alarm triggered by UV sources such as lightning, arc welding etc., a time delay is often included in the UV flame detector. The near infrared sensor or visual flame detectors work with wavelengths between 0.7 to 1.1 microns. One of the most reliable technologies available for fire detection, namely multiple channel or pixel array sensors, monitors flames in the near IR band. The infrared (IR) flame detectors work within the infrared special band (700nm – 1nm). Usually response time of these detectors is 3-5 seconds. Also, there is UV and IR combined flame detectors, which compare the threshold signal in two ranges to detect fire and minimize false alarms. Flame detectors are expensive and complex, through they provide very reliable and accurate response. They can operate in highly sensitive environment where other detectors can't be used. Aircraft maintenance facilities, fuel loading platforms, mines, refineries, high-tech industries etc., use these flame detectors for safety.

Fig : Flame Detector

3.6: Semiconductor Gas or Smoke detectors

These work by the principle of chemical reaction taking palace between gas from fire incident and semiconductor material present inside the sensor. The semiconductor material used in these sensors is metal oxides, generally, Tin dioxide (SnO_2). Tungsten oxide (WO_2), etc. Under normal circumstances, the surface potential from fire incidents diminish the oxygen surface density, and thereby reduce barrier potential to permit electron flow. The associated electrical circuitry detects the rise in conductivity dude to electron flow, and activates alarm to undertake necessary measures.

These semiconductor sensors have wide range of applications for their advantageous features. They are small, compact, inexpensive, easy to install and maintain. These metal oxide type detectors are aptly used to detect fire incidents involving combustible gas, LPG, methane, propane, alcohol, carbon monoxide etc, of their reliability. These features make this detector best suited for our purpose and hence we opted for it in our system

• This shows that combustion detector can operate only when the fire develops into such a size as to produce sufficient energy to accelerate the products of combustion through the layer of warmer air in the vicinity of a detector.

• Therefore, there has to be a time lag necessarily between the incidence of fire and detection. Experimental data available also indicate that the response time of these detectors range between 40-300 seconds depending on the distance between source of fire and detector and the nature of material involved in the fire detectors, which use current flow in the flame to detect flame presence and thermocouple flame detectors.

Advantages of multi-detectors

High Current Capability, Low Cost, Familiar "Low-Tech" Sensing, Sensor all kinds of materials, Long life, Longest sensing range, Very fast response time, Resistant to harsh environments, Very predictable, Long life, Easy to install, Detects through some containers Can detect non-metallic targets, Senses all materials.

Signal Conditioning:

In simple terms, Signal conditioning is a process of data acquisition, and an instrument called a signal conditioner is used to perform this process. This **instrument** converts one type of electrical or mechanical **signal** (input-**signal**) into another (output-**signal**). Signal conditioning operations:

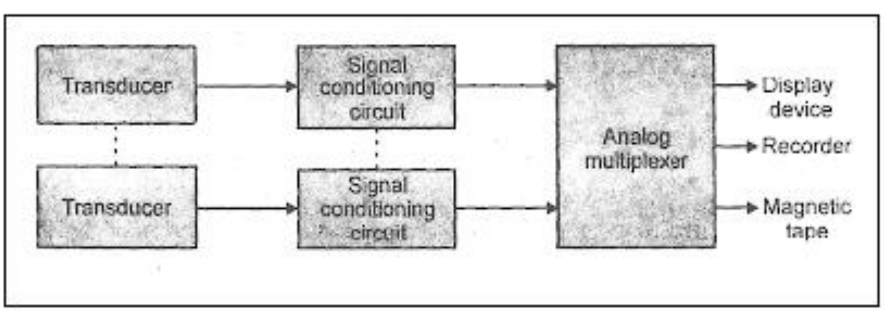

Fig: Signal Conditioning system

Input signals:

1. Non-linear,
2. High Amplitude
3. Low Amplitude
4. Noisy
5. Analog
6. Non-isolated

Output signals:

1. Linearization
2. Attenuation
3. Amplification
4. Noisy Free
5. Digital
6. Isolated

Signal conditioning system enhances the quality of signal coming from a sensor in terms of;

1. Protection: To protect the damage to the next level of the control system from the high current or voltage signals,
2. Right Type of Signal: To convert the output signal from a detector into the desired form i.e. voltage or current,
3. Right level of the signal: To amplify or attenuate the signals to a right / acceptable level for the next element,
4. Noise: To eliminate noise from a signal,
5. Manipulation: To manipulate the signal from its non-linear form to the linear form.

Conclusions:

A fire sensor system based on the simultaneous detection CO, CO_2, and smoke concentrations, is demonstrated. The rates of increase of these three components are used in the fire alarm algorithm to determine the presence of a fire. The algorithm monitors the rate of increase of smoke level, and when this rate exceeds its threshold rate, the rates of increase of CO and CO_2 and Hazardous gases concentrations are checked. When either the rate of increase of CO or CO_2 concentration exceeds its threshold rate, a fire alarm is initiated. The fire detection system was found to perform better than a smoke detector operating alone. In cases where the smoke detector did not alarm, the algorithm was able detect the fire**.** Fire detection using smoke and gas sensors detected the fire in a much shorter time. The nuisance sources did not cause the fire detection system to generate false alarms. An advantage of the fire alarm algorithm is that the signal to noise ratio for the temporal derivatives of measurements improves more rapidly with increasing time window length than does the signal to noise ratio for the mean of data points within the time window; this allows the alarm threshold to be set at a more sensitive value without causing noise-generated false alarm. A second advantage is that the alarm point is insensitive to constant offsets in the gas concentration measurements. Although, the fire detection system was originally conceived to be deployed in cargo compartments of aircraft, it can also be applied to buildings, ship compartments, submarines, living compartments in space, and concealed cavities used for running electrical wires and plumbing. Future work will focus on the improvement of the minimum detection of CO and CO_2 concentrations by using separate lasers for each chemical species, and selecting stronger absorption lines where these two chemical species do not overlap.

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