

Application Note AN1

MINIATURE INFRARED GAS SENSORS GOLD SERIES

UK Patent App. No. 2372099A
USA Patent App. No. 09/783,711
World Patents Pending

SENSOR OVERVIEW



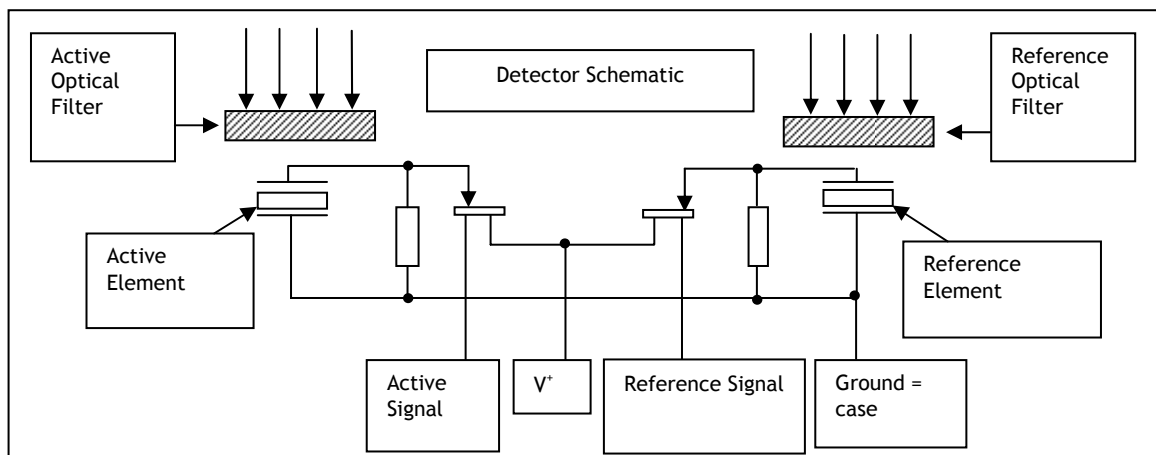
The Dynament Gold series of infrared sensors uses the well-established NDIR (Non Dispersive Infrared) technique to monitor the presence of gases and vapours via their infrared spectral signatures. The sensors comprise an **infrared light source**, a **dual wavelength infrared detector**, a **temperature sensor**, an **optical cavity** and a connector PCB within a **miniature housing** (world patents pending). Each of these component parts is discussed in order to provide an understanding of the sensor operation:

Infrared light source:

The infrared light source is a thin walled tungsten filament lamp rated at 5V/65mA with an MTBF of 100,000 hours. The thin wall of the lamp increases the emission of infrared wavelengths, particularly in the range 1-5 microns. The wall material effectively absorbs longer wavelengths. In operation the light source is typically pulsed at 4Hz with a 50% duty cycle in order to present light and dark contrast states to the dual wavelength detector. The life of the source can be extended by applying less than 5V during the on cycle and also by maintaining a small residual filament current during the off cycle which reduces inrush current at the start of the next on cycle.

Dual wavelength infrared detector:

The detector is a dual pyroelectric detector with each individual detector element optically filtered by integral windows to respond to specific bands of infrared radiation. The detector elements are individually buffered by on-chip FET transistors to provide a useable output. A schematic of the detector is shown below:



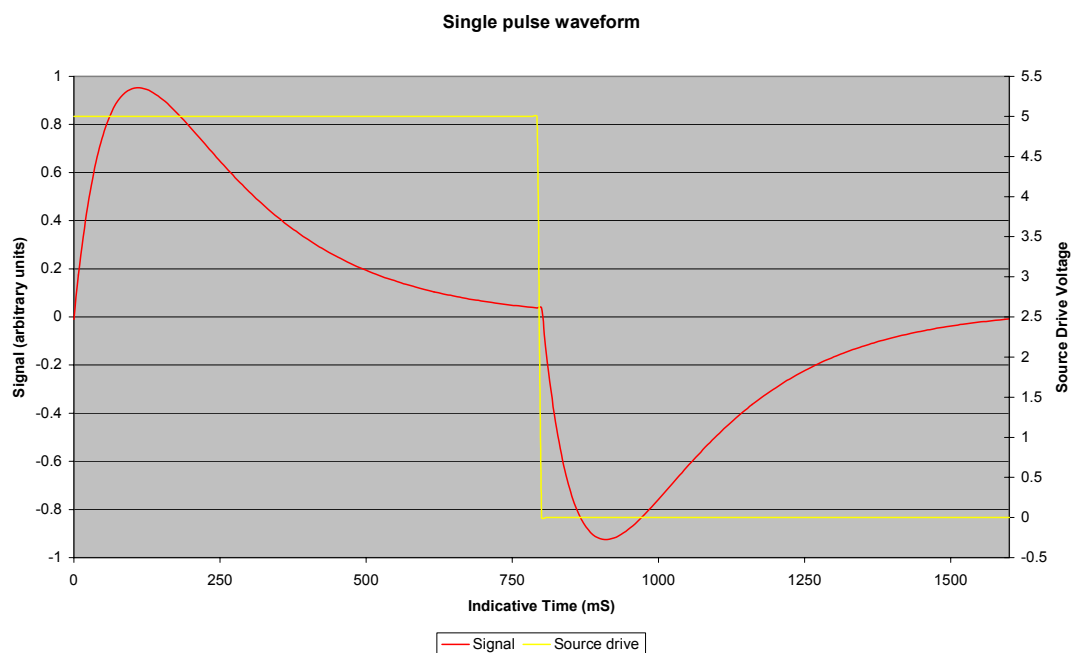
The optical filter associated with the active detector element transmits radiation within a band of infrared wavelengths that are absorbed by the target gases. The optical filter associated with the reference detector element transmits radiation within a neutral band of infrared wavelengths unaffected by target gases. The reference element therefore acts to monitor the throughput of infrared radiation and is used to compensate for any changes in incident radiation that are not caused by absorption due to the target gases. The reference element also provides a first means of temperature compensation.

Pyroelectric detectors respond to a CHANGE in incident radiation, hence the need to pulse the source on and off to provide light and dark states. The pyroelectric effect results in a charge generated on the surface of the individual detector elements when heated by incident radiation that has been transmitted through the integral optical filters. This charge is applied to the gate of the on-chip FET transistors which can be coupled to an external circuit to provide the signal. An internal high ohmic resistor connected across the pyroelectric element leaks the charge from the element surface to allow the detector to operate at useful frequencies. During the dark state of the source the charge on the pyroelectric element changes polarity as its surface cools.

The on-chip FET transistor, when operated in a source follower mode, provides a DC voltage pedestal of typically 0.6V - 1.0V on which is superimposed the detector signal. Current flowing through the on-chip FET transistors should be limited to the range 10 μ A to 20 μ A in order to minimise the possibility of power dissipation in the FET causing heat generation within the detector package.

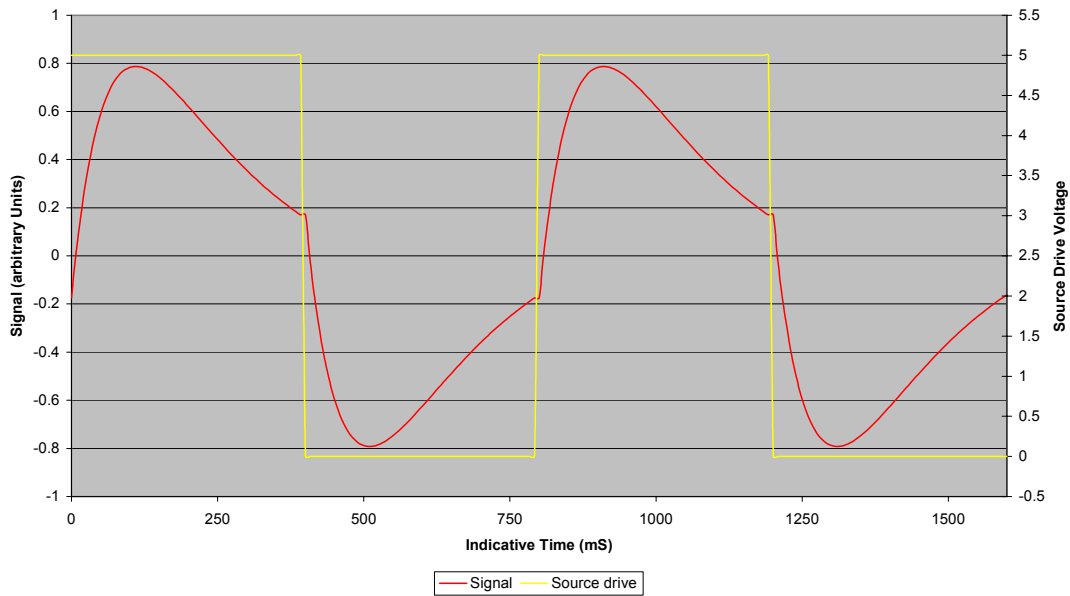
Signal characteristics

Typical waveforms of the detector signal as a function of the frequency of incident radiation are as follows:



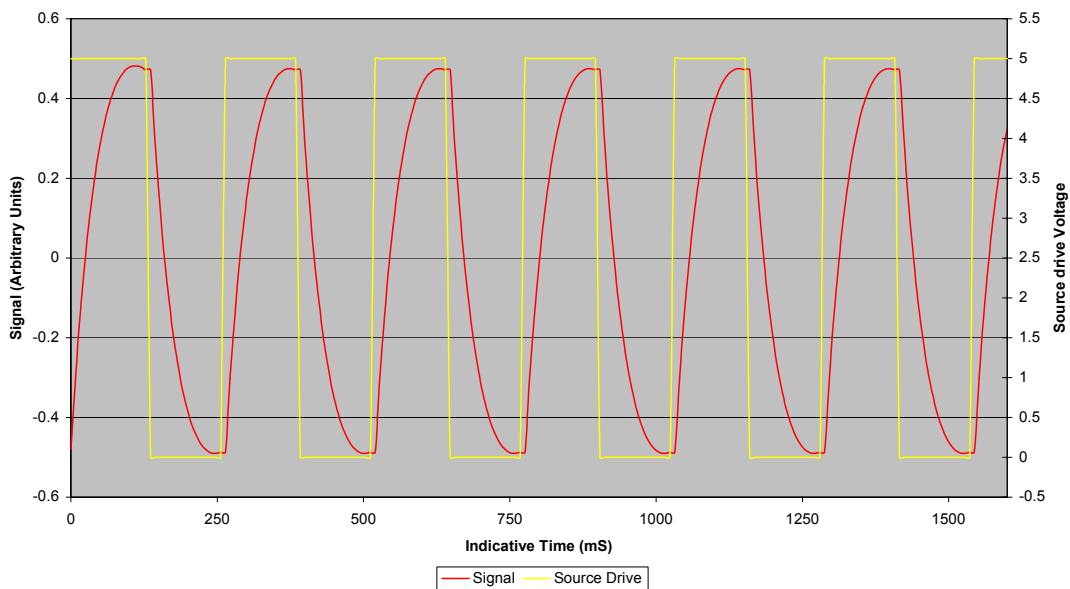
For a single pulse of incident radiation the signal reaches a maximum and then decays at a rate determined by the thermal and electrical time constants of the detector. When the incident radiation is subsequently removed, the signal follows the same characteristics but in the negative direction.

Slow frequency waveform



At a slow rate of change of incident radiation (typically less than 2Hz) the signal reaches a maximum value during the on cycle and starts to fold over as heat at the detector element surface starts to leak into the bulk, reducing the net temperature drop across the element. During the off cycle this process causes a similar signal in the negative direction. The peak-to-peak intensity is lower than that achieved with a single pulse of radiation since a repetitive cycle is maintained.

Standard frequency waveform



Increasing frequency of incident radiation prevents the detector reaching a saturation point and a waveform similar to a sine wave is produced. The peak-to-peak intensity reduces as the frequency increases since the heating and cooling effects on the detector elements occur in shorter timeframes.

The meaningful signal from the detector elements is related to the total integrated charge generated during the light and dark states. For a fixed frequency of incident radiation this simplifies to a measure of the peak-to-peak signal intensity.

Temperature effects

Temperature affects the operating point of the on-chip FETs, the sensitivity of the detector elements and the transmission characteristics of the integral optical filters. Rapid temperature changes can also result in transient responses from the detectors, noise and some signal hysteresis in extreme circumstances. The rate of change of ambient temperature should not be allowed to exceed 0.5°C per minute, the maximum rate of temperature change applied during sensor tests at Dynament.

The sensitivity of the detector elements increases with decreasing temperature, which is a fundamental characteristic of the lithium tantalate pyroelectric material used. Since both the active and reference elements are of the same size and thickness, the sensitivity changes due to temperature are similar for both elements and the reference element provides a good first means of compensation.

The transmission of the integral optical filters changes slightly with temperature and as a general rule, as temperature increases, the spectral characteristics of the optical filters will shift to longer wavelengths with some in band transmission loss. It is usual to use a reference optical filter with a spectral range close to that of the active optical filter to reduce offset effects caused by different spectral filter shifts.

The gate leakage current of the on-chip FETs increases substantially with increasing temperature. The common-source forward transconductance reduces as temperature rises at a rate of typically 0.01% per °C coupled with a corresponding increase in the pinch off voltage. The dual detector houses both on-chip FETs on the same substrate and therefore both FETs should experience the same temperature changes, reducing differences in active and reference FET characteristics as a function of temperature.

The external sensor connection pins are directly connected to the pyroelectric elements, the common FET drains and the individual FET sources. Sudden temperature changes at the pins can therefore be transmitted directly to the individual internal devices. In extreme circumstances (e.g. fast rate of change) this can cause transient signal changes and possible temporary collapse of the detector signals until the external pins and internal elements have thermally re-stabilised. It is therefore appropriate to insulate the external pin areas from direct temperature fluctuations, such as draughts and direct heating of the pins, in order to minimise this effect. In general, for a sudden rapid drop in temperature a negative charge generated on the detector elements pulls the FET gate voltage negative.

Temperature sensor

A temperature sensor is located adjacent to the dual pyroelectric detector. This allows for direct monitoring of the internal sensor temperature and provides the information needed to optimise additional temperature compensation for the sensor. The sensor is an NTC temperature sensor. The internal sensor temperature is typically 7°C - 10°C higher than ambient due to the heating effect of the light source.

Optical cavity (world patents pending)

The ultimate sensitivity of an NDIR sensor is described by the change in output of the active signal in the presence of target gas. This change is primarily dependent on the gas concentration, the absorbance efficiency of the target gas over the spectral range of the integral optical filters and the path length. The path length is defined by the optical arrangement and the optical cavity. The optical cavity also serves a number of other purposes:

It locates the internal components.

It provides a suitable path length within a small volume, which is appropriate for a rapid response time.

It is a compact design and enables a small sensor size, directly compatible with miniature electrochemical and catalytic gas sensors.

It is highly reflective to infrared radiation which results in a high signal level from the detectors and a corresponding enhancement in signal to noise ratio.

It is chemically inert

Miniature housing (world patents pending)

The sensor housing locates all the internal components, provides gas access to the optical cavity, provides a flame arrestor for use in hazardous areas (directly applicable to certified sensors) and seals the rear of the sensor. Connector pins protruding from the rear of the sensor provide electrical connections to the source, detectors and temperature sensor.

Gas accesses the optical cavity by diffusion through a sintered metal element, this element also forming the flame arrestor for certified sensors. The small internal volume of the optical cavity provides a good response time and this equally applies where a non-certified sensor is located behind an external flame arrestor (e.g. in a certified field head assembly).

The sensor housing is of the same size as standard miniature electrochemical and catalytic sensors, thereby offering an infrared capability to existing instrumentation with minimal physical changes needed to the sensor compartment.

The sensor housing is internally connected to the "0V" pin in order to form a Faraday cage to minimise externally induced noise. If the sensor is used in a circuit with a bias applied to the "0V" pin then the sensor should be isolated from any external housings.

The sensor housing is labelled with the sensor detail, serial number and all applicable certification information.



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