Application Note DESA1: Infrared Sensor Preamplification

This application note discusses the power and drive requirements of an infrared sensor and the preamplification of the infrared sensor signals. A suggested sensor drive and preamplifier circuit is shown and the component sections are discussed. This application note is intended as a general guide to interfacing infrared sensors to external circuitry.

An infrared gas sensor comprises a radiation source and a radiation detector housed within an optical arrangement into which target gas diffuses. The radiation detector is a dual detector containing 2 detector elements that respond to radiation emitted by the radiation source. One detector element (the active) responds to radiation of wavelengths emitted by the radiation source that are absorbed by the target gas. The other detector element (the reference) responds to radiation emitted by the radiation source that is not absorbed by target gas. The radiation detector therefore provides an active signal (affected by target gas) and a reference signal (unaffected by target gas). The reference signal is used to compensate for changes in radiation intensity caused either by the radiation source (e.g. through ageing) or by changes in the optical characteristics of the optical arrangement (e.g. through neutral density contamination).

The radiation detector is a pyroelectric detector and therefore responds to changes in incident radiation, unlike a photometric detector that responds directly to incident radiation. The radiation is therefore chopped in order to generate changes in incident radiation at the detector. This chopping is achieved by pulsing the radiation source, which is a low power filament lamp. The lamp is typically driven by a square wave supply, which should be of a constant frequency and ideally a constant 50% duty cycle. Typical operating frequencies are in the range 2.0Hz – 4.0Hz, where the pyroelectric detector response is close to optimum.

The detector signals comprise a DC voltage pedestal upon which is superimposed a small oscillating signal in sympathy with the lamp chopping. It is important that the preamplifier gain be optimised for the frequency range of the lamp chopping. If the preamplifier AC response is optimised at higher frequencies then some differentiation of the signals occurs and this shows itself as a distortion in the signals. Typically the signals should have a sinusoidal shape. Any differentiation will show as a peak response decaying to a lower value before the next half cycle occurs. The larger the difference between the preamplifier frequency response and the chopping frequency the more this decay and distortion appears.

In the presence of target gas the active oscillating signal reduces as the target gas absorbs radiation detected by the active element, whereas the reference oscillating signal remains constant. In order to accurately monitor the signals there must be some amplification of the small oscillating signal without amplification of the DC voltage pedestal. The resulting signals can then be read directly via an A/D converter for example and used to obtain a measure of the target gas concentration. This is discussed in Clairair Application Note DESA2: Infrared Sensor Signal Extraction.

A suggested Infrared sensor preamplifier is shown below in Fig. 1 where both active and reference preamplifiers are essentially identical. In practice one may wish to adjust the individual signal gains to suit the target circuit. A simple means of chopping the source is shown where the input to the chopping is a digital signal of 50% duty cycle at the operating frequency. Each component part of the suggested circuit is explained below.

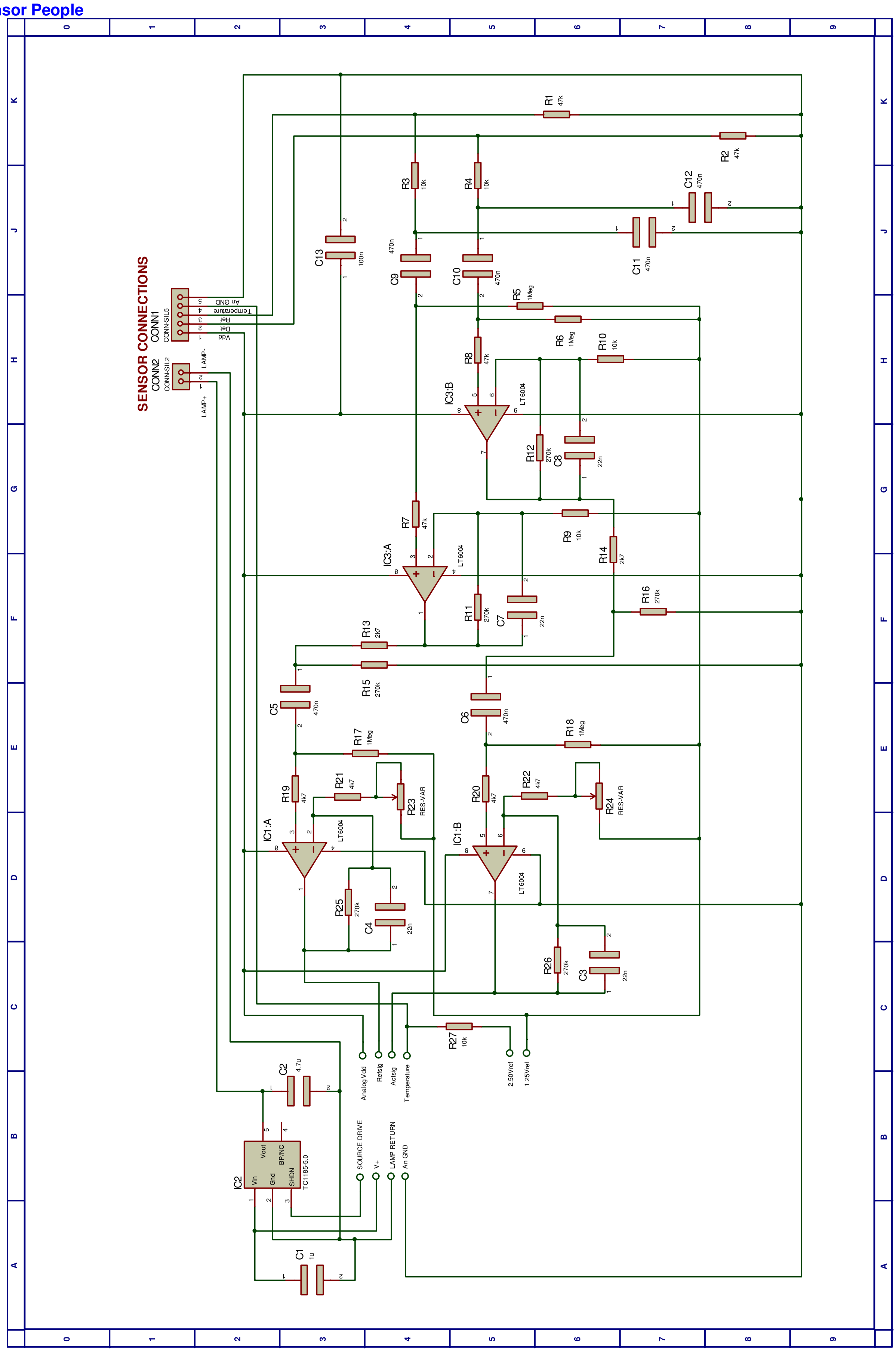

Fig.1: Suggested IR sensor preamplifier circuit

1) Sensor connections:

The sensor connections are comprised of 2 connectors, CONN1 and CONN2. They are separated to indicate that the lamp supply on CONN2 should be tracked separately from any other tracks to avoid lamp current generating noise in the amplifier circuit. Adopting a constant current regime for the lamp circuitry can also dramatically reduce lamp-switching noise. A suggested circuit to maintain a constant current for the lamp circuit and also provide the voltage references for the preamplifier circuit are shown in Fig. 2.

1a) Source drive:

The sensor source is driven directly from IC2, which is controlled by a source drive signal to turn IC2 on and off. There are many different regulator ICs with shutdown available and transistor switches to a regulated supply can also be used. The source drive signal should be a stable 50% duty cycle square wave with a frequency of typically 3Hz. Lower frequencies (down to 2Hz) will give larger sensor signals and higher frequencies (up to 4Hz) will give lower sensor signals. This is a characteristic of the pyroelectric detector contained within the sensor. The frequency response of the preamplifier is centred around 3Hz but will maintain the gain over the range 2Hz -4Hz to within 1% with negligible distortion of the signals. It is suggested that the sensor source be powered at 5V, lower voltages (down to 2.5V) can be used and the signal from the sensor will reduce as the source voltage reduces. It is important that the voltage drive to the lamp be stable and well regulated. It is also important that the duty cycle be an accurate 50% and does not vary, as any variations will show as cycle-to-cycle changes in the sensor signals. The lamp current returns via the LAMP RETURN connection and it is important that this be segregated from the amplifier tracking, ultimately returning to 0V at the incoming supply.

The lamp is rated at 5V, 60mA but there will be an inrush current whenever the lamp is turned on of up to 120mA. This inrush current can be reduced by supplying the lamp with a low voltage (less than 0.5V) during the off period in order to keep the lamp coil warm. This will reduce contrast and result in a reduction in sensor signal size but will extend the life of the lamp. Alternatively the LAMP RETURN connection can be made to a constant current point as shown in Fig.2 which, although drawing current continuously, removes current pulses at the expense of a slower lamp heating time.

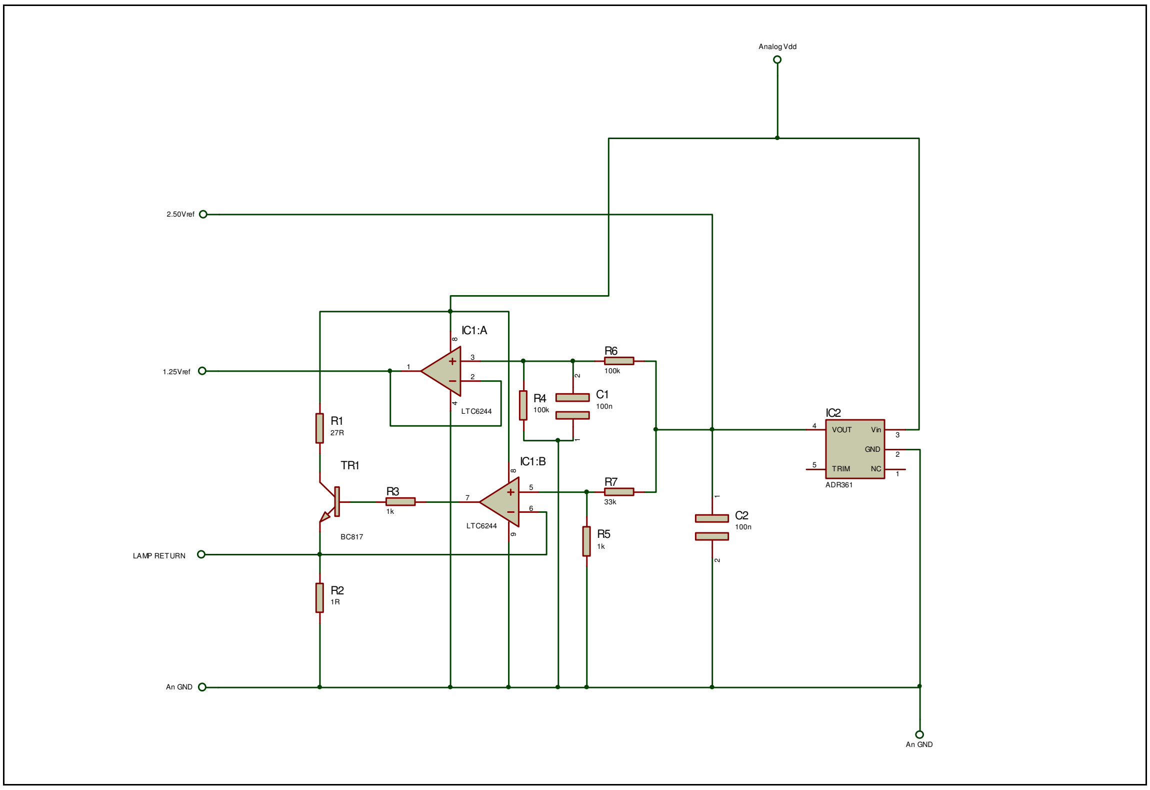

Fig.2: Suggested IR source constant current circuit and reference generator.

The supply current to the complete circuit will reflect the source drive current and if a number of circuits are connected to the same power supply via a common power cable there can be phasing of current demand from the supply that is likely to show as low frequency seemingly random ripple on the final output signals. This can also be removed by returning the LAMP RETURN connection to a constant current point as shown in Fig.2.

1b) Sensor power:

The power supply to the sensor is derived from the circuit analogue Vdd and the circuit analogue ground. The Vdd supply should be well regulated and the analogue ground should be segregated from any digital ground.

1c) Temperature signal:

The temperature signal is derived from an internal 3k NTC thermistor, which is connected between the temperature pin of the sensor and the analogue ground pin of the sensor. It is suggested the temperature connection be to a 2.50V reference via a 10k resistor, the subsequent voltage at the temperature pin of the sensor then being dependent on the thermistor resistance. The thermistor has a beta value of 3450 +/- 3.5% and a resistance of 3.0kΩ +/-5% at 298°K. The change in resistance of the thermistor with temperature can be modelled with a 10k resistor in series to a 2.5V reference to generate a voltage/temperature relationship such as:

Temperature (°K) $= \text{beta} / (\ln \{ R_{thermistor}[T°K] / R_{thermistor}[298°K] \} + \text{beta} / 298)$

where $R_{thermistor}[T°K]$ is the thermistor resistance at temperature T°K and $R_{thermistor}[298°K]$ is the thermistor resistance at 298°K

Temperature (°K) $= 3450 / (\ln \{ 10 \times V_{temp} / (3 \times (2.5 – V_{temp})) \} + 11.577181)$

where V_{temp} is the voltage appearing at the temperature pin of the sensor.

1d) Active and reference signals:

These are the active and reference signal outputs from the sensor. The signals should be loaded to analogue ground via 47k resistors (R1 and R2 in the attached circuit) although if a -5V supply is available in the circuit they can be connected to -5V via 390k resistors. The active and reference signals comprise a DC voltage pedestal on which is superimposed the low level AC signal which we need to amplify, this AC signal being in sympathy with the source drive. The load resistors set the current draw from the signal outputs in the region of 15 - 30 micro amps. It is important that the analogue ground here and within the preamplifier circuit be clean and noise free.

2) Signal amplification:

There are a number of variations on low frequency AC amplifiers, some give better performance than others when used for amplifying the signals from IR sensors. In particular, tolerance to noise pickup and temperature variations are very important. Fig. 1 shows a suggested 2-stage amplifier.

2a) First stage:

This is an AC coupled non-inverting amplifier. The sensor signals pass through initial high frequency filtering formed by R3/C11 (reference) and R4/C12 (active); this is to reduce high frequency interference that may be picked up in the cable between the circuit and the sensor. Any noise induced at the sensor cable will otherwise be subject to amplification. The signals are then AC coupled via C9/R5 (reference) and C10/R6 (active) to a 1.25V reference voltage. This reference is chosen as the mid scale point of a 2.5V referenced A/D converter into which the outputs can be digitised. If a different A/D reference voltage is used then it should be divided by 2 and that level used for the reference point of the amplifiers. This allows the signals to swing equally above and below the reference voltage. If the amplified signals exceed the reference voltage they will clip both against analogue ground and the A/D reference. If an amplifier reference voltage is used which is not half the A/D reference level then care must be taken that the amplified signals do not clip either analogue ground or the A/D reference. Note that if only one of these limits is reached then such clipping can avoid detection since the A/D result does not reach maximum counts.

The gain of the first stage is set by R11/R9 (reference) and R12/R10 (active), the frequency response being set by the AC coupling and C7 (reference) and C8 (active). The first stage gains are set to a nominal value of 28, varying a little with frequency and centred at around 27.8.

2b) Second stage:

The outputs of the first stage are AC coupled to the second stage via R13 (reference) and R14 (active). The second stage is essentially the same circuit as the first stage but with a variable gain element shown as R23 (reference) and R24 (active). It is advisable to have a means to adjust the gain in order to obtain the maximum signal size in zero grade air without the signals getting too close to analogue ground or the A/D reference voltage at their minimum and maximum values. A digital potentiometer with EEPROM data storage is recommended, the digital potentiometer being controlled by a circuit processor and the start-up value loaded directly from the EEPROM within the digital potentiometer. Note that changing the gain of the second stage as per the suggested circuit does not affect the frequency response of the second stage. The outputs of the second stage then form the active and reference signals that can be connected directly to an A/D converter.

3) Signal conversion:

A typical change in signal for a hydrocarbon sensor monitoring methane is 10% when exposed to 100%lel methane. In order to resolve to 1%lel methane a change in signal of less than 0.1% must be measured which requires a minimum 12 bit A/D resolution. The active signal size should be optimised by the second stage gain adjustment such that the peak of the signal in zero gas is at least 90% of the A/D reference level and the trough is not greater than 10% of the A/D reference level. The effect of temperature on the gain circuits can be roughly balanced by using the same gain setting for the reference as for the active, although the effect is minor compared to the effects of temperature on the detector itself. Therefore the reference gain can be set to the same as the active gain or it can be set to optimise the reference signal such that the peak of the signal in zero gas is at least 90% of the A/D reference level and the trough is not greater than 10% of the A/D reference level.