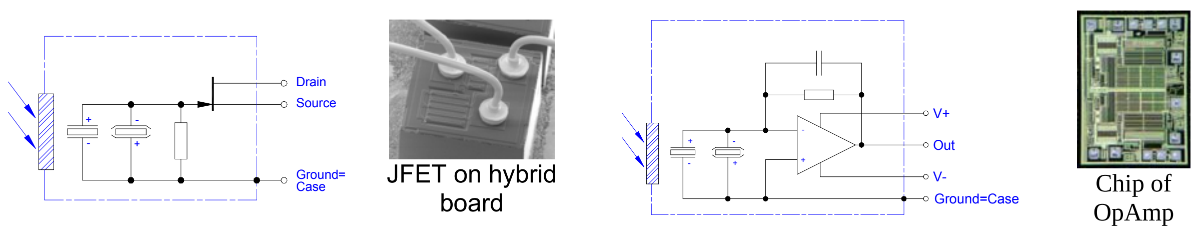
Advanced Features of InfraTec Pyroelectric Detectors

1. Pyroelectric Detectors with JFET source follower or integrated CMOS-OpAmp - A Comparison

In 2003 InfraTec added pyroelectric detectors with integrated CMOS Operational Amplifiers (OpAmp) to our established family of detectors with integrated Junction Field Effect Transistors (JFET). Advancements in analog Silicon based technologies have allowed us to replace the classic JFET design with a more complex amplification circuit for nearly all applications.
Well established JFET detector designs like the LIE-302, LIE-316 and LIM-222 have been enhanced with CMOS OpAmps as in the LME-341, LME-345 and LIM-262.

LME-316 with JFET (thermal compensated) LME-335 with CMOS-OpAmp (thermal compensated)



Voltage mode ***Current mode***

Fig.1: Examples of pyroelectric detectors with JFET (left side) and OpAmp (right side)

Detectors with JFET and OpAmp are distinguished by more than orders of magnitude in signal voltage. The fundamental difference you find is in the analysis of the pyroelectric signal. As a result you will get different frequency responses of signal and noise (response and typical parameters in figure 2).

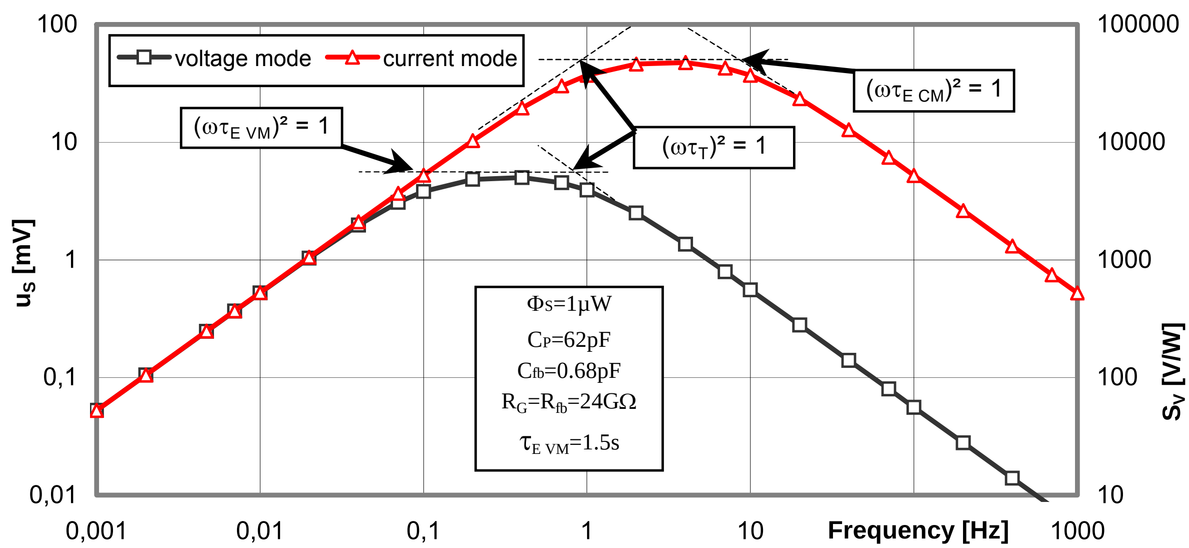


Fig.2: Frequency response of signal voltage U_S and voltage responsivity R_V of a pyroelectric detector with 2mmx2mm active sensing element

In voltage mode the pyroelectric current, created in the single crystalline $LiTaO_3$ chip, charges the electric capacity. The resulting voltage is displayed by a simple Source follower (JFET, gate resistor and external source resistor).

In current mode the generated pyroelectric current is transformed by a Current-Voltage-Converter (OpAmp with feedback components, also named Trans-Impedance-Amplifier TIA). The frequency dependent conversion factor I/U is determined by the complex feedback components and is typically in the range of 10 ... 200 pA/V. While the thermal time constant τ_T (typically 150ms) as a measure of the thermal coupling of the pyroelectric element to its surrounding is effective in both operation modes, the electric time constant τ_E is determined by different components. In voltage mode τ_E is calculated as a product of pyroelectric chip capacity C_P and gate resistor R_G (typically 1.5s). In current mode τ_E is only determined by the feedback components R_{fb} and C_{fb} (typically 16ms).

Main differences between pyroelectric detectors with JFET and CMOS-OpAmp

- At common modulation frequencies between 1Hz and 10Hz in gas analysis and flame detection the detector will operate above the thermal and electrical time constant (1/f behavior of signal). The maximal responsivity is located beyond the normal modulation frequency range. Low-frequency disturbances up to some Millihertz will be transmitted. Detectors need settling times up to some 10 seconds.
- Detectors in current mode are mostly operated between both time constants and resultant cut-on and cut-off frequency. Here the signal voltage is on its highest level and stable over a broad frequency range, possibly over some hundred Hz. Low-frequency disturbances are one magnitude away from the cut-on frequency and will therefore by suppressed 10 times more compared to the voltage mode. The measuring signals are already stable after a few seconds.
- Due to the virtual short circuit of the pyroelectric element in current mode, an antiparallel connected compensation element does not lead to a reduction of signal and detectivity. Furthermore an incomplete illuminated pyroelectric element in current mode does not cause a loss of both signal and detectivity in contrast to the voltage mode.

Why we are using CMOS-Operational amplifiers?

CMOS technology combines technological and customer demands for a low supply voltage, low power consumption, Rail-to-Rail performance at output and low chip costs. Additionally the completely isolating gate (SiO_2) in the operational amplifier shows a better performance during operation at high temperatures as opposed to the JFET design. The current mode which earlier was only possible to apply in combination with very expensive OpAmps like OPA128 or AD549, can now be applied in applications for gas analysis and flame detection which were previously dominated both technologically and price wise by the JFET.

Comparison of the modulated output signal for detectors with JFET and OpAmp

The electrical time constant defines the form of the output signal in current and voltage mode. Identical time constants lead to the same signal form in both modes. In current mode we can work with a nearly arbitrary electrical time constant, which is an essential advantage. Therefore short time constants are preferred due to the resulting short settling time.

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Figures 3 to 6 show typical signal characteristics in order with decreasing electrical time constant.

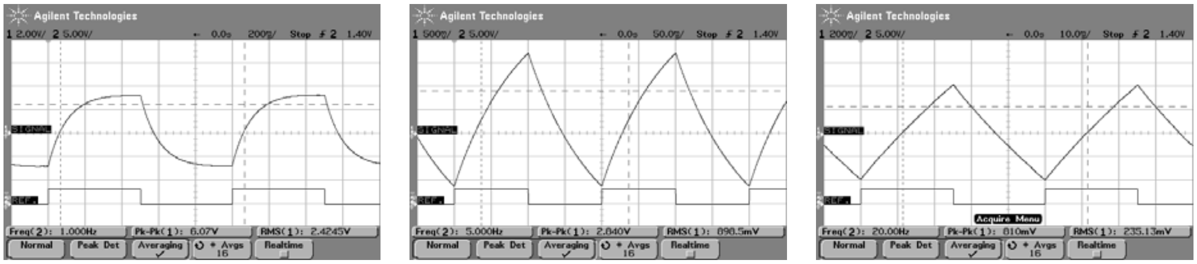

Fig. 3: LME-302 Voltage mode at 1Hz, 5Hz and 20Hz, thermal time constant 150ms, electrical time constant 5s

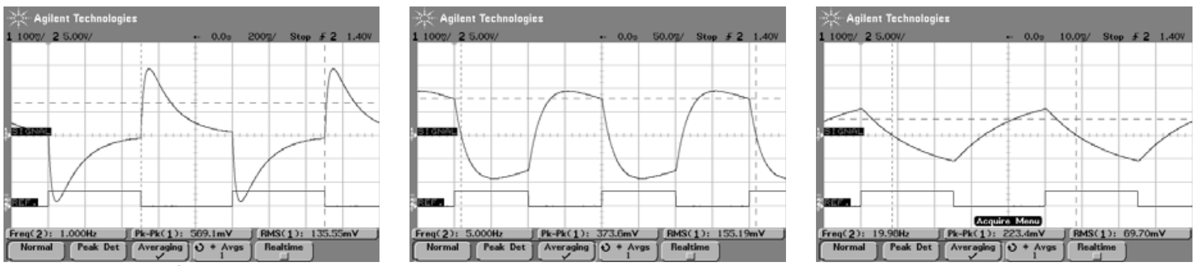

Fig. 4: LME-335 Current mode at 1Hz, 5Hz and 20Hz, thermal time constant 150ms, electrical time constant 20ms

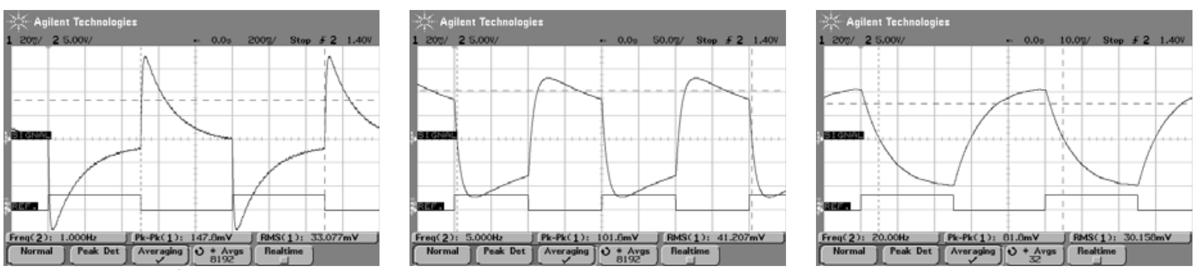

Fig. 5: LME-341 Current mode at 1Hz, 5Hz and 20Hz, thermal time constant 150ms, electrical time constant 5ms

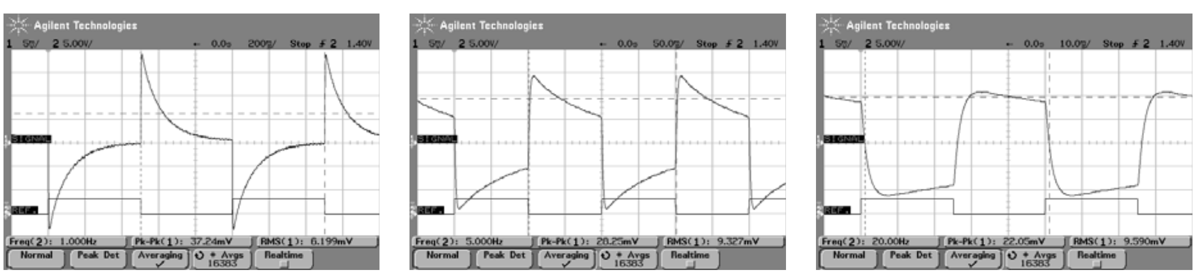

Fig. 6: LME-351 Current mode at 1Hz, 5Hz and 20Hz, thermal time constant 150ms, electrical time constant 1ms

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Feedback Resistor Influence to Responsivity (signal), Detectivity (signal-to-noise ratio) and Stability of the operating point for a detector with integrated OpAmp

In accordance with voltage mode detectors the Ohm rating of the integrated resistor leads to opposite detector properties:

- A large resistor results in a high signal and an increased detectivity since the noise only increases the square root of the resistor value. In contrast an amplifier stage after the detector would increase signal and noise by the same ratio.
- A small resistor increases the stability of the DC operating point, therefore a thermal compensation is often not necessary for R<10Gohm.

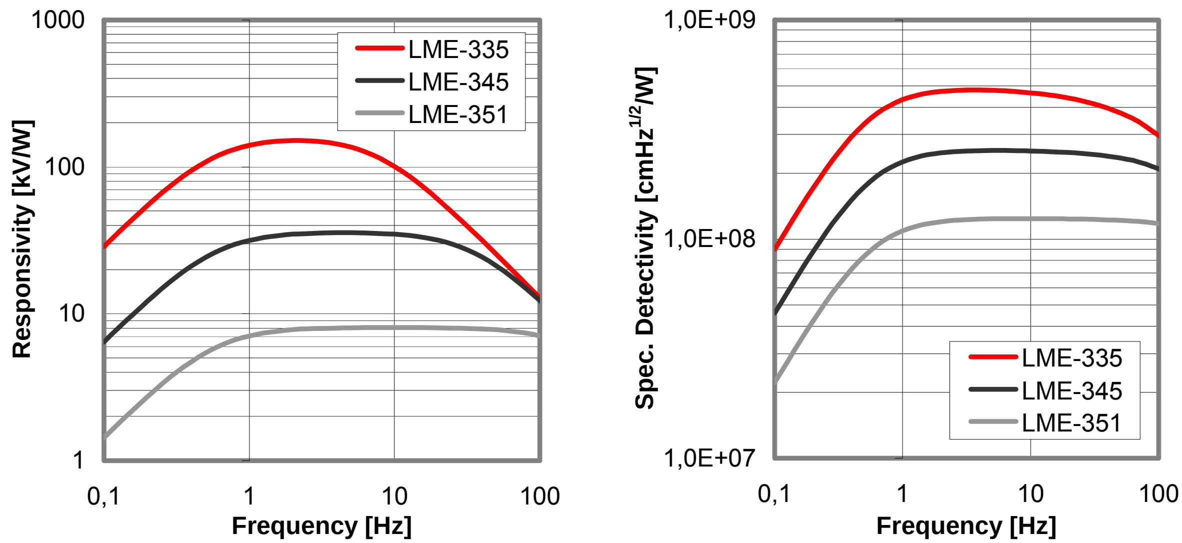

Fig 7: Frequency response of responsivity (signal) and detectivity (signal-to-noise ratio) as a function of the feedback resistor; LME-335 (100GOhm), LME-345 (24Gohm), LME-351 (5GOhm)

Power supply for InfraTec CMOS OpAmp detectors

We use mainly a split power supply ±2.2V ... ±8V for our detectors. Principally a single supply (4.5V ... 16V) is also possible, for this version the TO39-housing of our single detectors is located on Reference potential (mostly U/2).
For customized detectors we can also integrate different operational amplifiers, which can be operated either with a very small supply voltage (single supply +2.2V) and isolated detector housing or with very supply high voltages and a high dynamic range (split supply ±13V).

InfraTec can assure the availability of detectors with JFET source follower and CMOS-OpAmp for many years to come. The technical advantages will however accelerate the trend to use the current mode OpAmp detectors.