The complete multichannel readout system targeted for FET-based THz detectors

Terahertz radiation (1THz=10^{12}Hz) is often considered as the last range of the electromagnetic spectrum not fully utilized by the humanity, yet. The main reason of this state is caused by many fundamental difficulties related to the development of efficient radiation sources and satisfactory detectors. An engineering term *'terahertz gap'* has been formed several years ago and it concerns exactly this severe lack of practical technologies for generating and detecting the THz radiation. Presented readout system is one of the attempts to reduce this problematic gap.

One of the most promising solution dealing with the detection of THz radiation is a device called FET-based detector (FET – *Field Effect Transistor*). The main advantages of this type of sensor are: low fabrication costs, satisfactory parameters achieved in room temperature and ability of integrating detector and readout electronics within one chip.

Performed studies were targeted for the design of unique, complete readout system which provides the processing of signals generated by mentioned above transistor-based THz detectors.

1. Achievement description

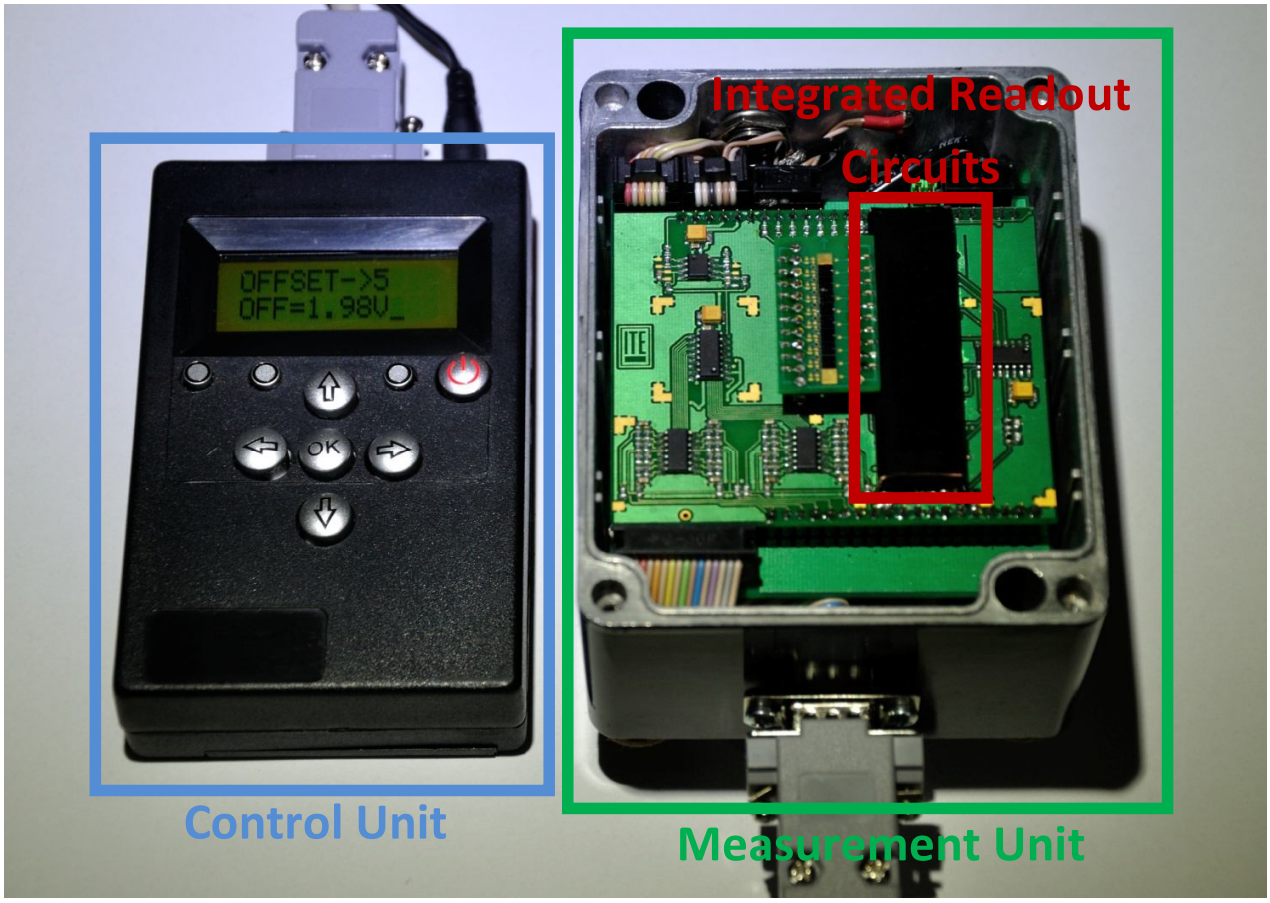
Registration and processing of the signal produced by FET-based THz detector are complicated and challenging tasks. They concern very low DC voltage signals (range of tens µV, 1µV=10^{-6}V), so the dedicated readout circuit must provide significant noise and interference reduction. Special attention must be paid to 1/f noise (one over f), because its root-mean-square value is inversely proportional to the signal frequency (so for DC this value is maximal).

Nowadays, in many specialized laboratories, one of the commonly used method for very low DC signal measurement is *Phase Sensitive Detection* (PSD). Generally speaking, in this technique the useful signal is extracted from the background noise and other interferences by its modulation with some reference frequency and phase, and then all remaining signal components are filtered out, except mentioned reference frequency. With undisputed advantages of PSD, this technique has some fundamental restrictions. First - performing measurement is relatively slow. Second - there are THz sources that cannot be easily modulated. Third – PSD method de facto implicates single-channel architecture of the signal path. And fourth - phase sensitive detection requires synchronization between the transmitter and receiver modules, which causes several additional difficulties for readout system construction.

As the result of previously performed research and studies, the complete readout system has been designed and developed. It ensures the registration and processing of very small signals produced by FET-based THz detector, furthermore, the expensive and often troublesome phase sensitive detection technique is no longer required.

The system contains dedicated integrated readout circuits (IC) placed into the module called measurement unit, which operation is supervised from MCU-based control unit. All mentioned

devices have been fully designed and constructed in ICs & Systems Design Department (Z9). Picture placed below presents all system components - top cover of the measurement unit was removed for better visibility of its internal components.



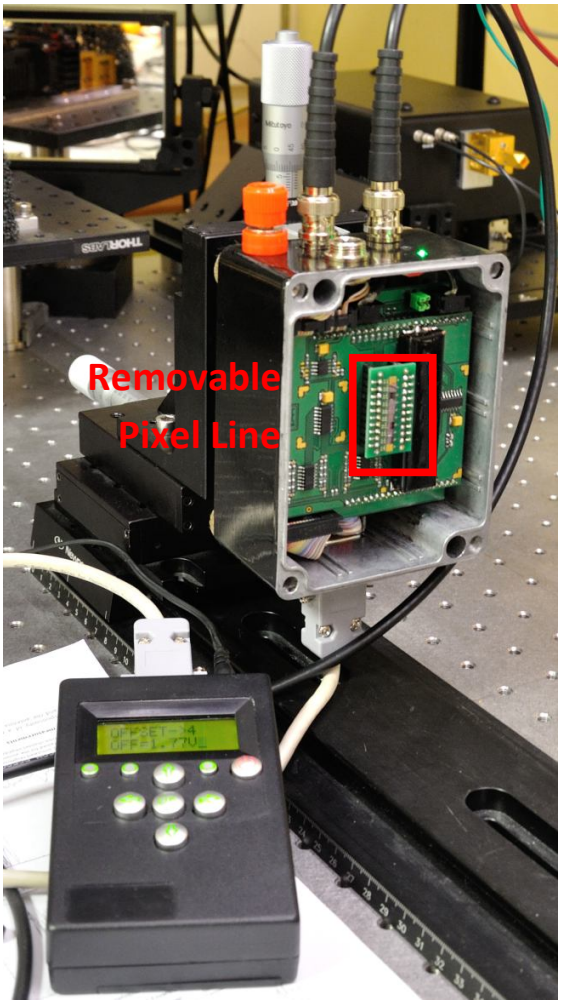
The most important part of the measurement unit are nine dedicated single-channel readout ICs, assembled using chip-on-board technique and covered within common shield. These circuits have been designed in ICs & Systems Design Department and fabricated in AMS C35 process (350 nm feature size) via *Europractice* MPW service.

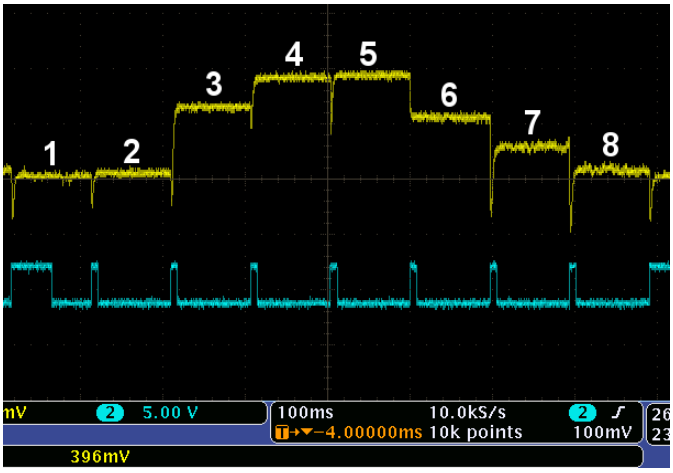
The readout system supports 8-element pixel line of FET-based THz detectors, assembled on separate, removable PCB. This allows easy replacement of the detector set, towards different needs of the research to be performed (e.g. different substance to be detected).

The user interface of the control unit is provided by two-lines character LCD and a keypad, allowing to select and modify settings of measurement program, executed on built-in ATMega 32 MCU (Atmel). Data exchange between measurement and control units features full galvanic separation for interference minimization. The control unit can also play a role of the interface between PC

running application developed for use with NI LabVIEW™ and measurement unit. For this kind of operation it is fitted with USB transceiver. One of predefined operation modes can be selected by user: manual pixel selection and automated scanning. Additionally, control unit can generate triggering signal for the oscilloscope, which synchronization while more complicated measurements.

The picture below presents the readout system during measurements performed at Institute of Optoelectronics of Military University of Technology (top cover of measurement unit was removed for better visibility). On the right side an exemplary signal obtained at the system output is shown, with THz beam centered in-between the fourth and fifth pixels.





2. Application (including the information about moving into production)

Presented system is one of the measurable results obtained during the THzOnLine project. All studies aimed at readout system development were performed as a part of this project. Described device is a complete system that supports readout of 8-element pixel line of FET-based THz detectors. Due to the modular design (removable PCB) the set of detector can be easily replaced toward different needs of the experiments to be performed. One of the main advantages of presented system is the fact that it can fully replace the expensive phase sensitive detection (lock-in) equipment.

3. Scientific, economic and social significance

First, the complete multichannel readout system was an important milestone for THzOnLine project. The device itself is an unique circuit solution providing registration and processing of the signals from FET-based THz detectors without the necessity of using the PSD.

Moreover, proposed solution, especially the designed integrated circuit, is a very universal readout device. It can be used in many future systems, performing a role of readout circuit for signal sources other than the mentioned THz detectors. Described IC has a great potential to play an important role in processing of very small, low-frequency signals, where PSD technique is commonly used nowadays. Very good example of this kind of applications are noise measurements, experiments performed in very low temperature (cryogenic) or registration of many biomedical signals.

4. Sources of funding

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5. Authors of the achievement

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