# A variable gain front-end electronics for drift chambers


*M. Panareo(a,b), G. Chiarello (c), F. Cuna(a,b), A. Corvaglia (b), F. Grancagnolo(b)*

(a) Dipartimento di Matematica e Fisica, Università del Salento, Italy

(b) Istituto Nazionale di Fisica Nucleare, Lecce, Italy

(c) Istituto Nazionale di Fisica Nucleare, Pisa, Italy

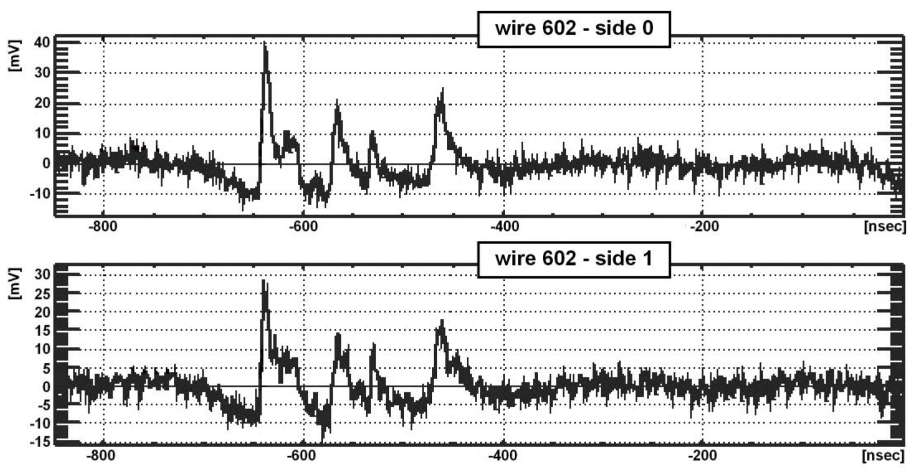


## ABSTRACT

The cluster counting/timing technique in a drift chamber allows to have a bias free impact parameter estimate. The application of this technique requires to measuring and counting the arrival times of each individual ionization cluster to a sense wire. The rise time of the signal from a cluster is approximately 1ns, therefore a readout electronic front-end with high linearity, low distortion and sufficiently high bandwidth is required. Furthermore, it would be useful for the readout electronics to be able to easily adapt its gain to the detector's operating point. The use of a variable gain amplifier (VGA) allows to meet the needs arising from the changed operating conditions of the detector. The market offers components capable of satisfying all these needs with dimensions compatible with high-density drift chambers. A high linear, low distortion, remotely controllable, about 1 GHz bandwidth and compact VGA is presented together with the measurements performed.

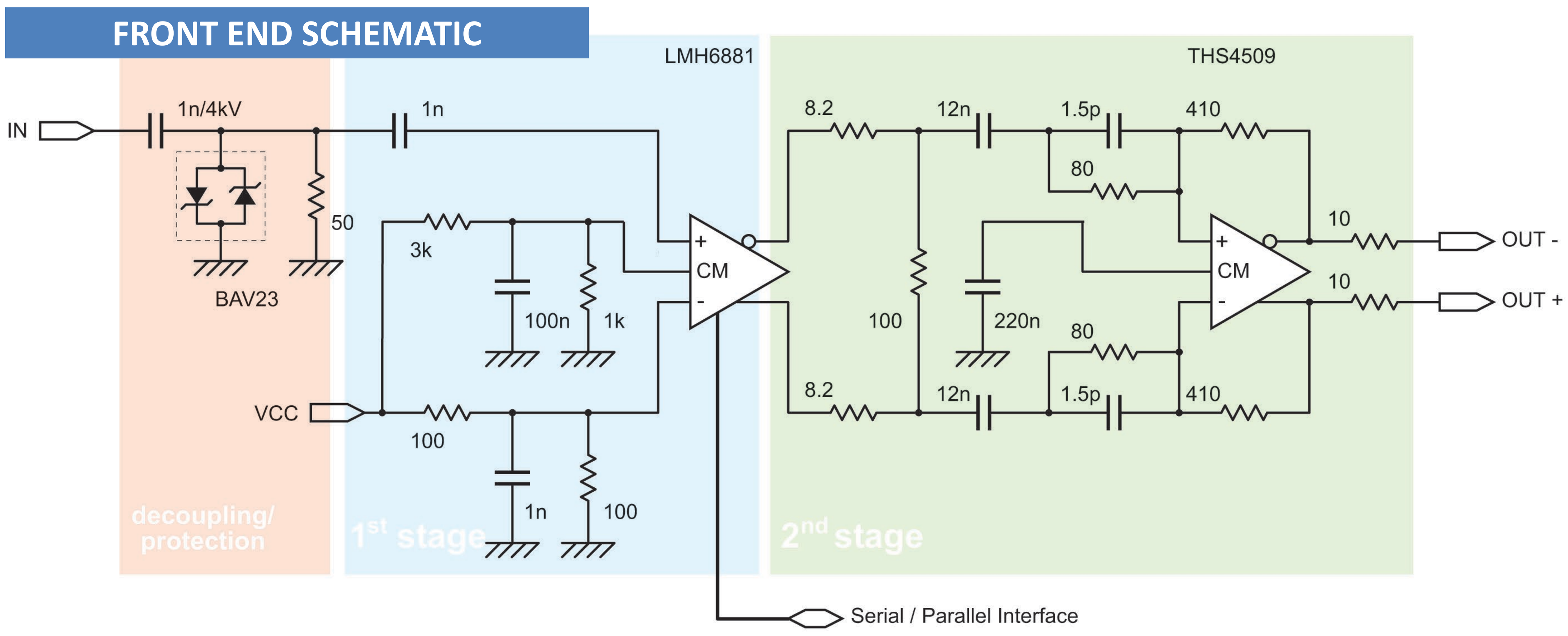

## THE CLUSTER COUNTING/TIMING TECHNIQUE

The cluster counting/timing technique in a drift chamber is a consolidated technique to obtain a bias free impact parameter estimate [1]. The application of this technique requires to resolve the cluster of avalanching electrons from each primary ionization event. This is done by digitizing the signal from the sense wire in the drift chamber and applying a suitable algorithm [2]. The rise time of the signal from a cluster is approximately 1ns, so front-end electronics with about 1GHz bandwidth are required. A high linearity and low distortion are also required to correctly identify the signal of each cluster.




Typical signal waveforms measured at both the ends of a drift cell in the MEG II tracking drift chamber [3].

## FRONT END SCHEMATIC




A readout channel based on commercial active components has been developed to detect individual ionization clusters in a drift chamber. The reading channel is characterized by a high linearity, low distortion, and a bandwidth adequate to the expected spectral density of the signal.

Furthermore, the readout electronics have been designed to have an easily variable amplification to have a signal that is always suitable for the digitizer, despite the changes in the working point of the detector.

The input network provides decoupling and protection, while signal amplification is realized with a double gain stage made from LMH6881 and THS4509, both from Texas Instruments:

- Variable gain LMH6881 is a high-speed, high-performance fully differential programmable amplifier with a bandwidth of 2.4GHz, a high linearity of 44dBm OIP3 and a low noise (2.3 nV/√Hz)
- The THS4509 is used as a second gain stage and output driver. It is a wide-band (1.9GHz), fully differential operational amplifier with a low noise (1.9 nV/√Hz) and low harmonic distortion (-75 dBc HD2 and -80 dBc HD3 at 100 MHz).

The slew-rate for both devices is of the order of 6kV/s therefore both devices are ideal for pulsed applications. The output driver consists of a fully differential amplifier; however, it is possible to convert the output to single ended by connecting an appropriate balun. The gain stage supports gain settings up to about 50dB with small accurate 0.25dB gain steps.

Specific compensation techniques have been implemented to modify the frequency responses of the second stage to obtain an overall bandwidth of the order of 1 GHz on the gain dynamics. Although the VGA can be also parallel programmed, in this application, where we assume that the gain is changed only infrequently, serial programming has been chosen. The serial interface is a generic 4-wire synchronous interface that is compatible with SPI-type interfaces that are used on many microcontrollers and DSP controllers. Since the used VGA is equipped with a chip select pin, it is possible to have different gains amplifiers in multichannel applications. The total current consumption for this device is 165 mA at a voltage supply of ±2.5 V / +5V.

High-speed layout design techniques have been implemented to ensure optimum stability and performance.

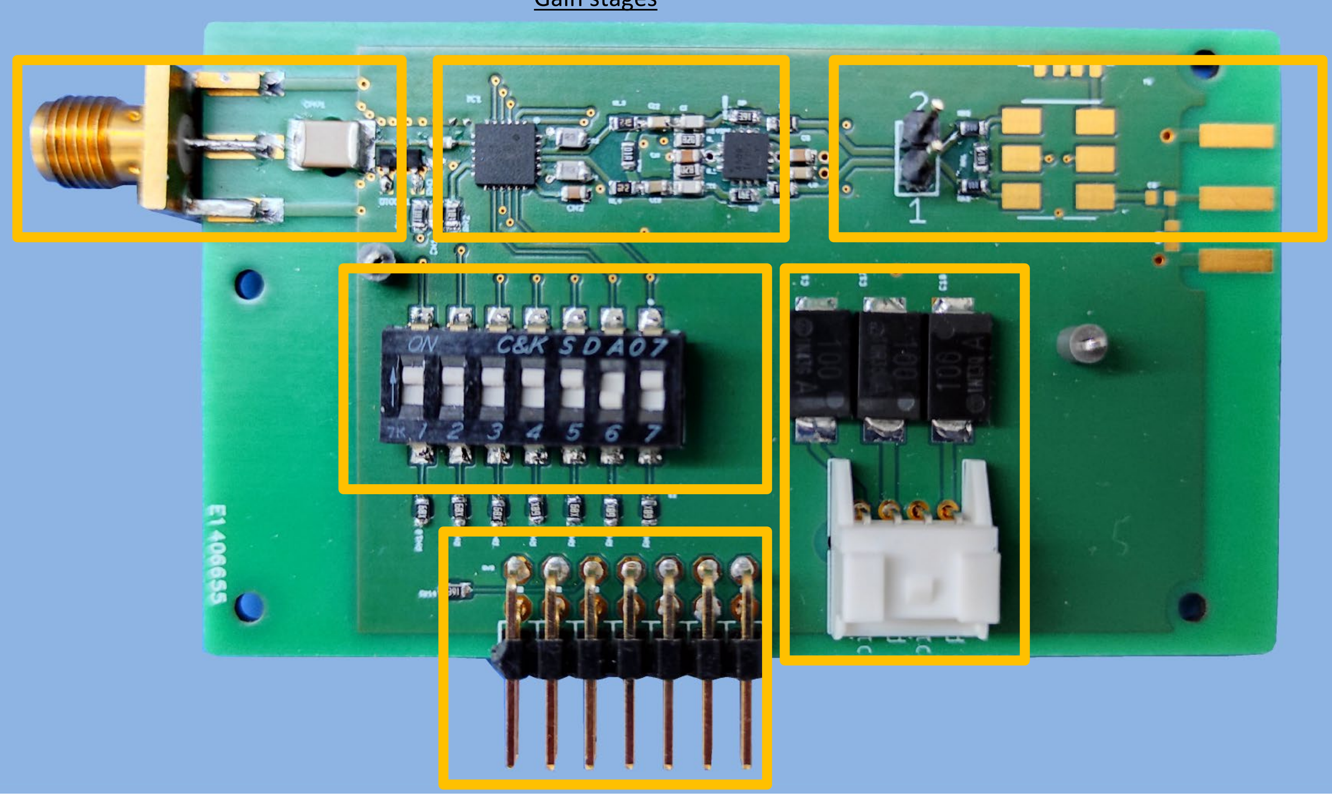
## THE LAYOUT

Gain stages

<u>Input</u>. Although the direct connection to the anode wire of a drift chamber is foreseen by using an appropriate decoupling capacitor, a layout compatible with an SMA connector has been designed for tests purposes.

<u>Mode/Gain programming</u>. Through these dip switches it is possible to select the way to control the gain of the first stage, serial or parallel, in the 20dB ÷ 49dB range. In the parallel mode it is possible to select the gain of the first stage in 2dB steps, in the serial mode it is possible to vary the gain in 0.25dB steps.

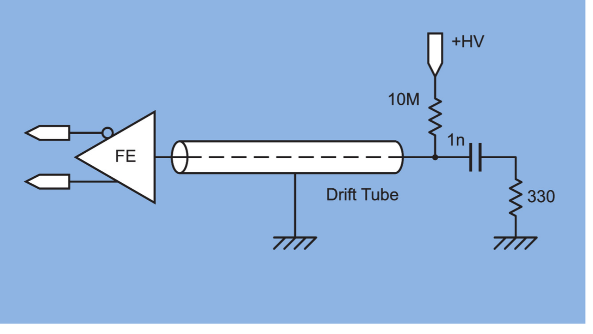
<u>SPI [4] connection</u>. For serial control of the gain of the device a SPI controller must be used



<u>Output.</u> The output signal is available in both differential and single ended form. The conversion is done with a broadband balun. In applications where a magnetic field is present, only the differential output will be used as shown in this picture

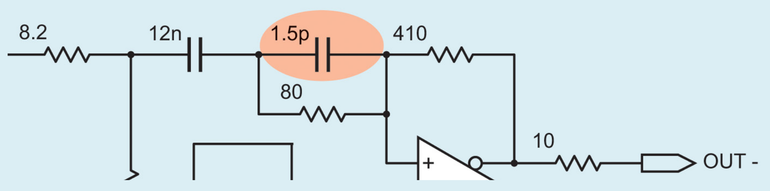
<u>Power supply</u>. In next versions of the device only one power supply will be used instead of a triple power supply

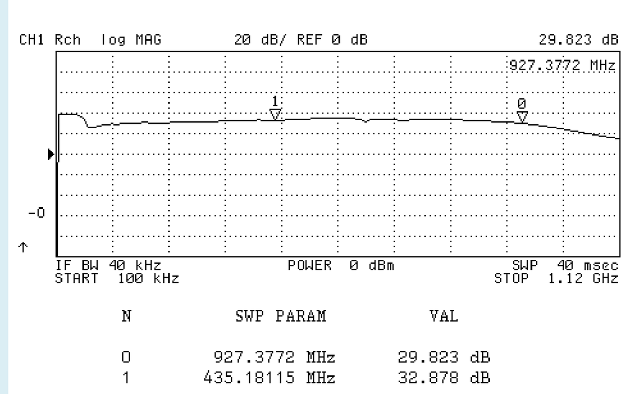
Direct connection to a test drift tube does not degrade the signal, despite the impedance mismatch between the drift tube and the front-end amplifier (the input impedance of the amplifier is 50Ω) since the impedance matching is done on the other end of the anode wire of the drift tube

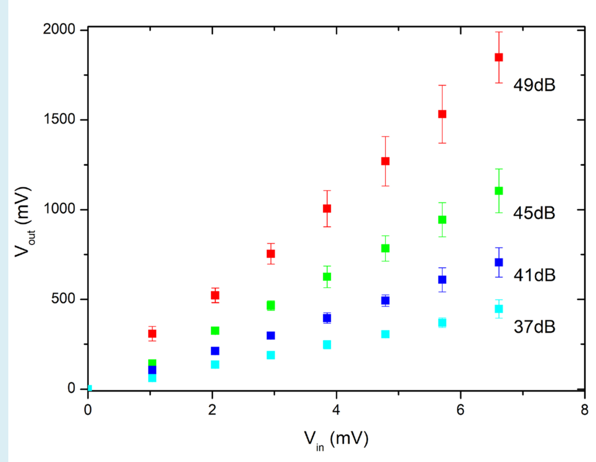



## PERFORMANCES

Bandwidth of the front-end is 1.0GHz. In order to balance the attenuation of the output cable, a pre-emphasis on the second gain stage can be been implemented by increasing the value of two capacitors. The pre-emphasis introduces a high frequency peak that compensates the output cable losses, preserving the total bandwidth.



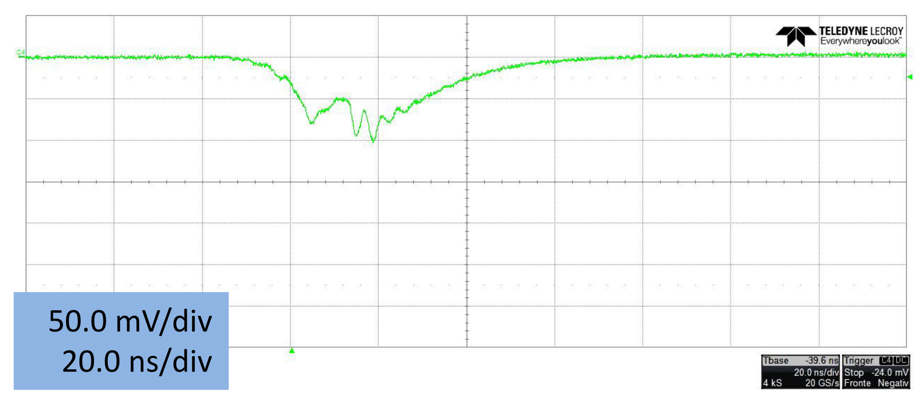




Linearity for each channel of the front-end board has been measured:

- Gain ($V_{out}/V_{in}$) is variable from 20dB to 49dB (mid-band) on a 100 Ω load
- Mean non-linearity is order of 1 % ($V_{in}$ in the range 2mV ÷ 10mV)

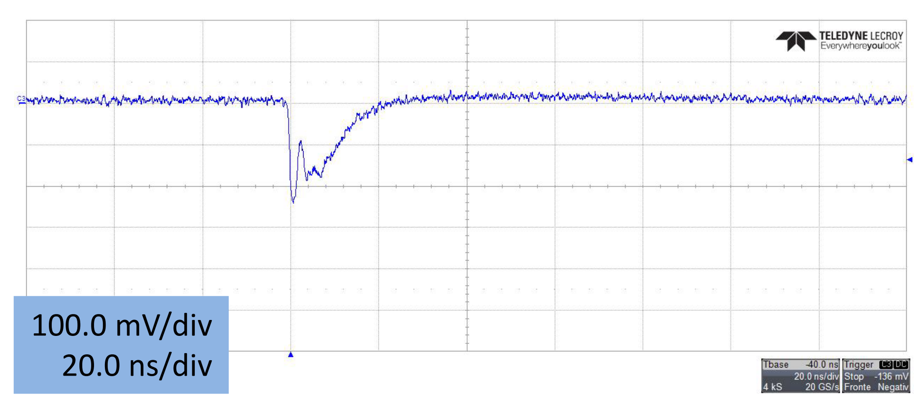
Output noise level measured is less then 2.5mV on a 100 Ω resistive load.

Typical signal from a ø 8mm drift tube, 30cm long, equipped with a ø 20µm W wire and 85% He – 15% isobutane gas mixture biased at 1200V. The signal is acquired with a 4GHz – 40GS/s oscilloscope on 50Ω load.



50.0 mV/div
20.0 ns/div

Typical signal measured with the presented frontend board in differential mode on a 100Ω load ad 22dB gain. Signal saturates at about 1500mV.



100.0 mV/div
20.0 ns/div

## REFERENCES


1. G. Cataldi , F. Grancagnolo and S. Spagnolo, Cluster counting in helium-based gas mixtures, Nuclear Instruments and Methods in Physics Research A 386 (1997) 458-469.
2. F. Cuna et al., Simulation of particle identification with the cluster counting technique, arXiv:2105:07064.
3. M. Panareo et al., The front-end electronics for the drift chamber readout in MEG experiment upgrade, Journal of Instrumentation, Volume 15, Issue 07, pp. C07009 (2020).
4. The Serial Peripheral Interface (SPI) is a synchronous 4-wires serial communication interface usually used in embedded systems. The SPI interface uses the following signals: clock input (CLK), serial data in (SDI), serial data out (SDO), and serial chip select (CS).



email: marco.panareo@le.infn.it