Design of a Differential Safety Mechanism (DSM) Dedicated to the NSW Micromegas Wedges

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Outline

- Motivation and the baseline design
- Simulations and functional tests
- Design of an advanced version
- Conclusions
MOTIVATION AND BASELINE DESIGN
The motivation for designing the DSM

Our basic idea was to perform an indirect detection: measuring the pressure in the input gas line we could conclude about the pressure in the output gas line (essentially the pressure of the Quad).

- The Micromegas detectors operate with Ar+7%CO\textsubscript{2} gas mixture in a static pressure close to atmospheric (~1-3 mbar)
- Pressures levels above 10 mbar, can cause serious damages in the Micromegas Quads or Wedges.
- Only an active and early detection mechanism could protect the detectors.
- The safety bubblers or the conventional safety valves are both inappropriate in cases of blocking the gas line.
Operation principle of DSM

Unexpected blocking of the pipe at point $A_x$

\[ p_{\text{out}} \text{ [mbar]} \]

\[ t_0 \quad t_1 \quad t_2 \quad t \text{ [a.u.]} \]

$\Delta p = 7 \text{ mbar}$

$\text{DW: safe / released to atm.}$
BASIC FEATURES

- In the baseline design the operation is based mainly on: a) the precision differential pressure transducer and b) the voltage comparator and c) a set of solenoid valves (N.O./N.C.)
- Stand-by and activation warning by green and red LEDs.
- Activation test (confirm) and Reset buttons.
- Pressure setting regulation trimmer and monitor pin.
The basic core electronic schematic
Prototype design

A 3D model of DSM

A prototype PCB (the pressure sensor and the solenoid valve have not yet been placed on the PCB)

Solenoid valve: low power miniature, Normal Open (N.O.), 3-way, 3-positions
SIMULATIONS AND FUNCTIONAL TESTS
Electronic simulation using “Pspice”
Pressure settings models (for SM and LM type)

The pressures are developed across the two “impedances” in parallel (either ZSM or ZLM)
Overall test of prototype to a Micromegas Quad

- This test was essentially an emulation because we used two external solenoid valves N.O. and N.C. respectively (the miniature solenoid valve was not yet available).

- For blocking the line we use a shut-off valve. The MM Quad LM2-M38, due to its inherent elasticity, it presents a time constant during its overpressure (about 10 min).

- The obtained measurements (pressure rates and activation time) helped us to prepare a more precise setting models.
Response study based on electric equivalent circuit

Equivalent quantities

Voltage source (high resistance - current source like) ..... Gas pressure source (bottle) + flow control valve
Electric Current (slight decay close to the operation point) Gas flow rate corresponding to 23 L/h
Capacitor (C=2700 μF) ................................................................. Volume of the MM Quad
Voltage drop across R2 resistance ................................. Pressure drop across the impedance (two ZLM)
Voltage drop across R3 resistance ................................. Initial pressure in the MM Quad (around 1.3 mbar)
Time constant (RC=9.68 min) ................................................... Time constant pressurizing the MM Quad
Assumed activation voltage (5 V) ................................. Activation pressure (5 mbar)
Testing a produced prototype

- By this test we verified the validity of the settings, by means of flow rate / pressure relationship.

- We also measured the time response of the mechanism without any MM Wedge connected.
DESIGN OF AN ADVANCED VERSION
This version is based on a microcontroller which can manage the two input and one output signals. A mass flow sensor is also included in order to monitor the gas flow rate.
I. Detection of a slow rate rising of the gas flow rate, with respect to preset one, $r_q$, and a corresponding pressure rising rate, $r_p$.

II. Detection of a sudden increase of gas the flow rate (wrongly happened).

III. Detection of unexpected blocking of the gas output line.

IV. Other combinations of actions causing pressure rising.
Conclusions

- The high risk of damaging of the Micromegas Wedges at higher pressures has lead us to find a reliable solution to protect them.

- The Differential Safety Mechanism acts rapidly to any wrong action or intervention in the input or output of the gas line.

- Its electronic functionality has been simulated, emulated and validated in connection to real Wedges.

- We consider that it can be used reliably as a baseline safety setup in BB5 and B. 191 during the performance tests of the Micromegas Wedges.

Reference: ATL-COM-MUON-2021-03