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MULTIPLEXER FOR THE Em# ELECTROMETER

P. Sjöblom, A. Milan-Otero, A. G. Persson, MAX IV Laboratory, Lund University, Sweden

Abstract

Small currents need to be measured from a number of devices at a synchrotron and its beamlines. To meet this demand, MAX IV have joined a collaboration with ALBA to develop the Em# electrometer that will ensure low current measurement capabilities and seamless integration into our Tango control system. To further enhance the electrometer flexibility, a multiplexer has been designed with 8 individual inputs controlled by the electrometer and one output that is preferably connected to the Em# input. The multiplexer is suited for stronger currents than 10 pA and currents that needs to be monitored only at a low frequency.

ALBA Em# ELECTROMETER

The Em# electrometers has 4 independent channels that measure in the 1 mA to 100 pA in 8 ranges. Using the 1 nA range, 25 fA resolution has been demonstrated [1]. Each input has 5 2nd order analog filters from 0.1 Hz to full bandwidth. The 18 bit SAR ADC is operating at 400 kS/s and each channel has its own ADC.

The front panel of the electrometer, Fig. 1, presents a touch panel where currents can be read and filters and ranges can be changed together with other parameters.

The back panel of the electrometer, Fig. 2, contains the interconnections such as input current, output voltages, trigger signals, I/O signals, together with the internal NUC computer ports. In case of the low voltage version, current input connectors and proportional analog voltage output connectors are BNC while for the high voltage model, a connector for bias voltage up to 1 kV is present, the current input is triaxial and the analog proportional voltage connectors are omitted for safety reasons.

Figure 1: A touch panel is located at the electrometer front panel.

Figure 2: The back panel of the electrometer contains the interconnections such as input current, output voltages, trigger signals, I/O signals, together with the internal NUC computer ports.

MULTIPLEXER

Many devices produce large currents and only need low sample rate, which the performance of the electrometer exceeds by far. Other channels only need to be measured with long time periods in between. To make the electrometer more flexible and also meet those situations, KITS at MAX IV have developed a multiplexer, Fig. 3, with 8 independent input channels and one output channel after suggestions from the Veritas beamline.

The multiplexer is both powered by 5 V and controlled by the electrometer through its multipurpose HD26 SUBD IO interface. At most, an electrometer can control 4 multiplexers simultaneously and read its signals giving a system with 32 channels, but the number of multiplexers can be chosen freely. In case of a beam positioning device, where four currents are to be read simultaneously to calculate location, the four currents can be placed on the same channel number at different multiplexers, which means the electrometer does not need to change multiplexer channel to get a reading. The position can be calculated by the internal Em# FPGA and presented as a position variable and also fed to the analog voltage output with a PID loop also running in the Em# FPGA (under implementation).

The multiplexers are mounted in 19" frames and can easily be collocated with other patch panels from MAX IV [2]. The bias and address is chained to other cards by IDC10 flat cable, Fig. 4. A second grounded PCB is added on top of the main PCB to reduce EM interference with the surroundings.

CONTROL SYSTEM INTEGRATION

The Em# electrometer has been integrated into the control system in different layers, Fig. 5. As a first layer, we have the Tango CS [3] integration, for that purpose we are using

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Figure 3: The multiplexers are mounted in 19" frames and can easily be collocated with other patch panels from MAX IV.

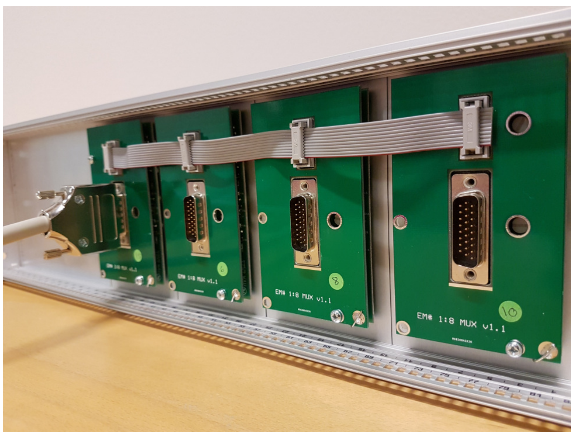

Figure 4: The voltage supply, as well as the address, is provided by the electrometer through a HD26 SUBD connector. The bias and address is chained to the rest of the cards by IDC10 flat cable. A second grounded PCB is added on top of the main PCB to reduce EM interference with the surroundings.

a generic Tango device server that supports SCPI communication. In that way, we have a Tango device server sending SCPI commands to the equipment and exposing them to the rest of the control system.

For higher integration and synchronization between equipment's in a system, we are using Sardana [4]. In the case of the Em# electrometer, the integration comes in a form of a Sardana Controller. This controller will handle the operations of the electrometer using the communication exposed to the control system by the Tango device server mentioned before.

As a final layer, we have developed a set of Sardana macros that help our users to perform some specific actions, for instance, select the operation mode for the multiplexer. These macros will trigger different operations through the Sardana controller. It's also possible to create macros that speak directly with the equipment. This scenario could be useful in cases were a functionality it's not important enough to be supported in the control system, but useful in a very specific and isolated situation, like for example, sending commands to the Em# GPIO ports.

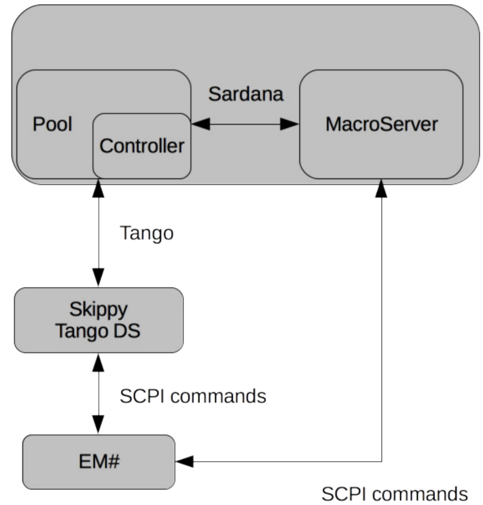

Figure 5: Diagram showing the control system architecture split in layers.

PERFORMANCE

The multiplexer shifts between signals without providing any glitches or spikes of its own as can be seen in Fig. 6 where a 1.6 nA and 3.3 nA signal are present on two channels and the multiplexer is switching between those two signals. The shift takes, in this case, about 500 ms, which is due to the charging of the cables and cut-off frequency of filter on the electrometer inputs as signals not under measurements are grounded through 300 Ohm by the multiplexer. The shunt resistance for signal under measurement is 2.6 MOhm while the series resistance is 0.3 Ohm. A 10 pA staircase shows in Fig. 7 that the multiplexer can be used if current levels are a few pA and stronger. Test currents are generated by a Keithley 2635B source meter.

A reference setup with equipment typical at MAX IV beamlines was used to collect a noise spectrum with and without the multiplexer to investigates its influence, Fig. 8. Without multiplexer, the noise was ±30 fA over a time period of 3 minutes and with a multiplexer ±50 fA during an equally long time period. The origin of this noise is most likely the input noise from the OP which through the capacitance in the cable creates a current, the electrometer is measuring. A 40 pA current offset, the dominating contributor is Analog devices multiplexer ADG708, is also introduced in the measurements, but this offset can be removed by the offset adjustment capabilities of the electrometer. A measurement over 10 hours shows in Fig. 9 ±1.2 pA variance, including long and short time drifting of the entire system. This longer variance with cycles of 20 minutes and hours, seems to be related to the offset contribution of the multiplexer, which in turn is temperature dependent. During noise and drift measurements, the input connector was shorted with a termination.

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The noise measurements over long time indicate that the multiplexer setup introduce more noise than what is possible to achieve when just the electrometer is present, but that the performance is anyhow in many cases well beyond what is needed.

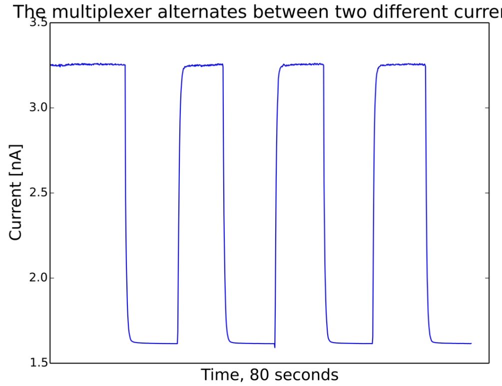

Figure 6: Switching between different inputs are made without spikes.

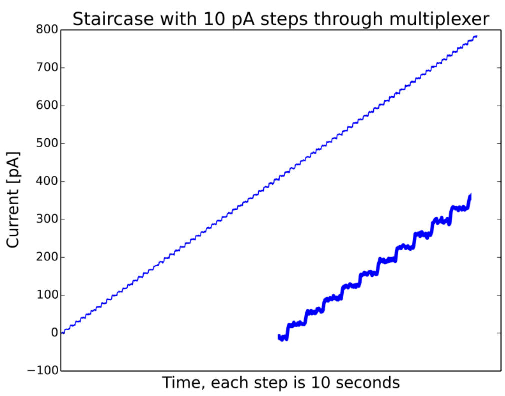

Figure 7: A 10 pA staircase measurement shows that the electrometer with a multiplexer resolve signals on a few pA.

CIRCUIT DESIGN

The designs major components are the ADG708 channel multiplexer from Analog Devices that routes the current on the input to the output and the 174HC138 demultiplexer, which allows the MOSFET 2N7002 to ground the other input signals that should not be measured, and hence not allowed to disturb the measurement. In Fig. 10 the schematics of the circuit is given.

The inputs are protected by BAV99 diodes from FAIRCHILD with 1.5 pF total capacitance. The capacitance is selected to be low to minimize the induced noise.

LEDs indicates which channel is in use, which will aid the user to determine if connections are made to the correct port.

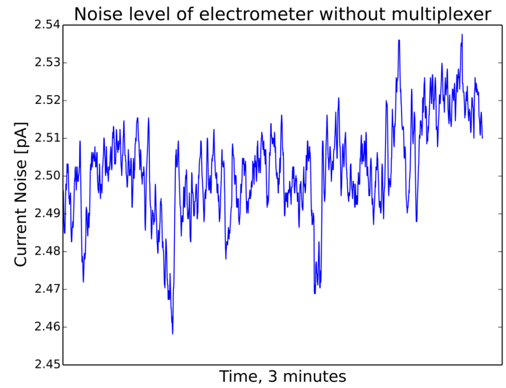

Figure 8: Without multiplexer, noise was ±30 fA over a time period of 3 minutes.

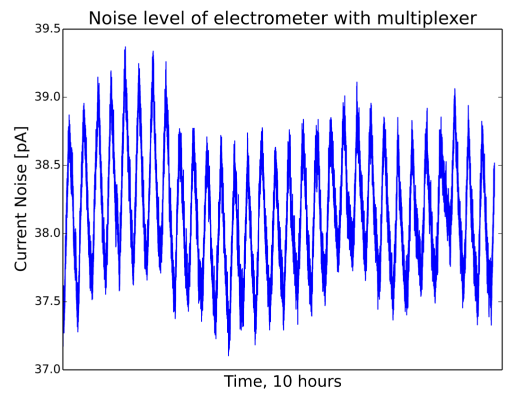

Figure 9: With a multiplexer, the noise was ±50 fA during the same time period. A measurement over 10 hours shows ±1.2 pA variance, including long and short time drifting of the system.

The ICM555 is connected as a oscillator and runs for a half clock cycle before getting stuck on negative voltage, which is used for the in the ADG708 VSS connection.

The multiplexer uses an address with three bits, A0, A1, A2, which is enough to address all the 8 channels. The address is fed into the comparator LP339, which is controlling the ADG708.

Analog and digital grounds are separated, but in the end, a choice was made to not separate the individual analog grounds on a single multiplexer. However, as a Em# can control up to four multiplexers, some flexibility is given as each of the cards will have separate analog ground. The digital ground is common for several multiplexers controlled by the same Em#. Between digital and analog ground is also two fast ES1F diodes located to protect the circuit from sudden high voltages.

The design is only intended for non-biased measurements and hence only exist with BNC connectors while the high voltage version of the electrometer has triaxial connectors.

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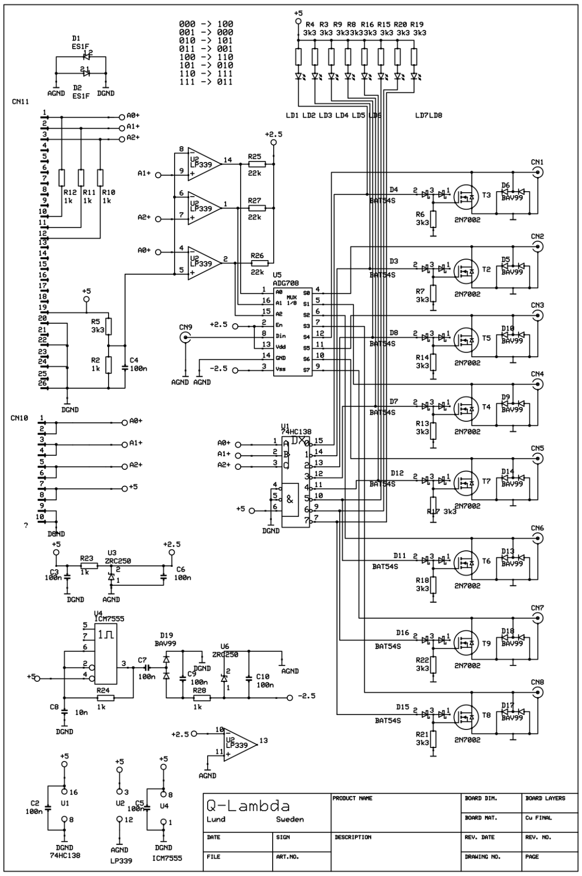

Figure 10: Schematics of the multiplexer.

The difference in connector types should prevent users from exposing high voltages by mistake.

CONCLUSION

A 8 channel multiplexer suited for currents stronger than 10 pA is developed and to be controlled by the Em# electrometer and its control system. The electrometer can control up to 4 multiplexer simultaneously and thereby creates a 32 channel system, which can be located next to other MAX IV patch panels.

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[3] TANGO.org website: `http://www.tango-controls.org`

[4] SARDANA.org website: `http://www.sardana-controls.org`