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Multi-channel Flow Control System for the Hall A GEM

In the previously implemented gas flow monitoring system [1], used for the Hall A Gaseous Electron Multiplier (GEM) detector, flow monitoring is read out via a microelectromechanical system (MEMS) sensor. Flow control is done manually via rotameters, which are a combination of a needle valve with a flow indicator.

To control flow remotely, I selected compact proportional valves (SMC PVQ13 series). These proportional valves are controlled via current, which is not a native signal on a Raspberry Pi (RPi) single board computer (SBC), so an external digital-to-analog (DAC) chip is needed. At 24 VDC operations, the valves need up to 85 mA for full range. For the DAC, I chose an Analog Devices LTC2662 (five-channel, 16-bit, up to 300 mA) DAC [2] to provide the current signal to the valves. The RPi communicates with the DAC module via a serial peripheral interface (SPI). I programmed, using Python, the software running on the RPi. [3]

Two issues encountered were the lack of software for the DAC chip and the lack of available libraries for proportional-integral-derivative (PID) control in Python. The software for the DAC chip is used to set up, control, and read out the DAC chip, e.g. selecting the maximum output the chip uses. I solved the first issue by writing basic software (only the needed commands) for the DAC chip in Python allowing the setup and control of the chip in order to test its functionality.

The available Python libraries for PID are either quite basic (compared to LabVIEW) or intended to be used with very specific hardware setups. While the program I wrote for the PID control of the valve does work, in so far as changing the valve position to reach the desired flow set point, it is not robust enough to be put into production. Currently, the parameters selected for the PID control result in fast changes, thereby being unstable; stable operations require long time scales (minutes rather seconds) in order to reach the desired flow set point.

Going forward, the current plan is to try and test other values for the PID control and readback: faster/slower sample times, different initial PID settings. If I can find no appropriate combination using the existing Python software there is a LabVIEW toolkit that allows the RPi to be used as a target device; this toolkit should allow the use of the more advanced PID capabilities. Also, the driver for the DAC chip needs to be expanded to allow the use of more functionality of the chip.

[1] M. McMullen et al., *The Gas Flow Monitoring System for the Hall A BigBite Spectrometer's GEM Detectors*, DSG Note 2021-12, 2021.
[2] B. Eng et al., *Evaluation of an ADC Module to be Used with the Raspberry Pi Single Board Computer for the Hall A GEM Detectors*, DSG Note 2021-17, 2021.
[3] B. Eng and M. McMullen et al., *Multi-Channel Remote Gas Controls System for the Hall A Gas Electron Multiplier Detectors*, DSG Note 2021-39, 2021.