High-stability high-voltage power supply for MRTOF†

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Achieving the highest possible mass resolving power in a multi-reflection time-of-flight (MRTOF) mass spectrograph requires very high-stability power supplies. To this end, we have developed a programmable high-voltage power supply that can achieve long-term stability on the order of parts-per-million. We have demonstrated that in the $\leq$1 Hz band the output stability is on the level of 1 part per million (ppm) during one hour, with only slightly more output variation across 3 days. We have further demonstrated that the output is largely free of noise in the 1 Hz–200 Hz band. We have also demonstrated settling to the ppm level within one minute following a 100 V step transition. Finally, we have demonstrated that when these power supplies are used to bias the electrodes of an MRTOF the measured time-of-flight is stable on the ppm-level for at least one hour.

In order to achieve a fast-settling, high-precision, long-term stable high-voltage power supply for driving our MRTOF, we have extended the concept laid out in the Voltage Multipliers, Inc, application note "AN-0300 - High Voltage Op-Amp Application Using Opto-Couplers,[1)]" which describes the use of infrared LEDs and high-voltage photodiodes to emulate an operational amplifier with up to 15 kV power supply span. A conceptual circuit diagram of our design, separated into functional blocks, is given in Fig. 1.

A crate of 16 power supplies was built to bias the electrodes of 50 cm MRTOF-MS in the E3 (KISS) vault. The voltages were adjusted until a time resolving power of $\frac{t}{\Delta t} \approx 250{,}000$ was achieved. Due to the lens voltage requiring a bias of 5 kV or more, we have thus far opted to use an NHR 42 60r high-precision $\pm$6 kV power supply from ISEG to bias this electrode.

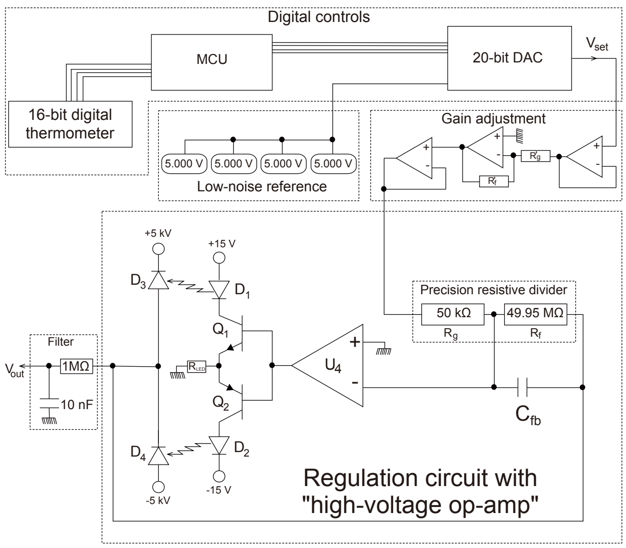

Fig. 1. Design of the high-voltage stabilization circuit.

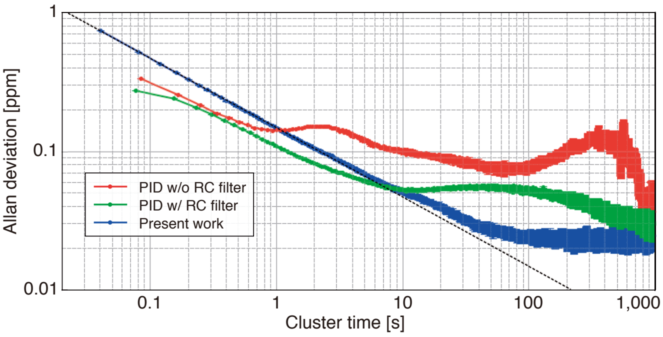

Fig. 2. Allan deviation from individual ion times-of-flight. The PID regulation without and with RC filter exhibit a slope approximating white noise to $\approx$1 s and $\approx$10 s, respectively. The dashed line indicates the trend expected for white noise. The Allan deviation curve switches to a flat line indicative of flicker noise at a level of $\approx$0.02 ppm, which coincides with the 0.1 ns raw bin width from the TDC.

Figure 2 shows the result of an analysis of time-of-flight data from a several-hours-long measurement using our newly developed power supplies with the MRTOF in E3 along with a similar analysis using pre-existing hours-long duration data from our full-size MRTOF-MS operated with a PID stabilization scheme. The data for the PID stabilization was obtained using a 30 ms cycle period, yielding a minimum Allan deviation[2)] sampling period of $\approx$80 ms. The data for the present system was obtained using a 15 ms cycle period, yielding a minimum Allan deviation sampling period of $\approx$40 ms. These analyses shows that in terms of long-term stability the voltage stabilization circuit of the present work exceeds the performance of our RC filter enhanced PID regulation system. Using our new power supplies, the MRTOF exhibits white noise in the ion time-of-flight over a much wider duration than with the PID-based regulation systems.

References

1) "AN-0300 - High Voltage Op-Amp Application Using Opto-Couplers," Voltage Multipliers, Inc, `http://www.voltagemultipliers.com/pdf/High-Voltage-Op-Amp-and-Linear-Regulator-App-Notes.pdf` .
2) N. El-Sheimy, H. Y. Hou, X. J. Niu, IEEE Trans. Instrum. Meas. **57**, 140–149 (2008).

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