Stanford Research Systems
Technical Note

Using the RGA Ion Counting Output

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ABSTRACT

The SRS Residual Gas Analyzers (both RGA100 and RGA120 series) can be optionally outfitted with an electron multiplier (EM) as a sensitive ion detector for use at partial pressures below 5×10^{-11} Torr. The EM detector can be paired with another optional add-on that we call the "Ion Counting Output." This option adds an RF connector to the RGA electronics control unit for easy and direct access to the EM output current. This output can be monitored for time-resolved measurements of a constituent gas, or for pulse counting of individual ions at very low partial pressures.

Introduction

This Technical Note describes steps for making measurements of the output current of the electron multiplier (EM)[1] of the SRS RGA. When ordering the RGA, if Options 1 (EM) and Option 3 (ion counting output) are specified, an SMB connector is provided on the RGA electronics control unit (ECU) which yields the ion current output of the EM. Option 3 also includes a shielded SMB-to-BNC cable for ease of interfacing with preamplifiers, oscilloscopes, digitizers, etc.

Two separate applications are discussed in this note:

1. Time-resolved monitoring of a gas species whose concentration *is detectable* by an analog scan.
2. Pulse counting of individual ions, for very dilute gas species.

[1]The EM is sometimes referred to as CDEM (continuous dynode electron multiplier) or CEM (channel electron multiplier), to contrast with a discrete dynode design.

Equipment

Time-resolved monitoring

1. **SRS RGA100** or **RGA120** with Options 1 (EM) and 3 (Ion Counting Output)
2. Oscilloscope (optional, but helpful)
3. **SR570 Current Preamplifier**
4. Digital Multi-Meter (DMM)

Pulse counting

1. **SRS RGA100** or **RGA120** with Options 1 (EM) and 3 (Ion Counting Output)
2. **SR445A - 350 MHz Preamplifier** or **SR446 - 400 MHz Preamplifier**
3. Oscilloscope (optional, but helpful)
4. **SR400 - Gated Photon Counter**

Procedure

Time-resolved monitoring

RGASoft provides a built-in "Pressure vs Time" mode (or alternatively, "Leak test" mode), which allows monitoring of a particular pressure vs. time. The time resolution (∼0.5 s) of these modes may not be sufficient for your application. If you need real-time monitoring of the partial pressure of a gas species, you can directly digitize the output signal available at the SMB connector of the ion counting output (Option 3).

The first steps below are provided primarily to help you "get your bearings." You will reproduce a mass spectrum (normally acquired in RGASoft) on an oscilloscope. Once you are confident that you are measuring a voltage that is proportional to the gas concentration at a particular mass, continuous digitization of that voltage signal is straightforward.

1. Connect to your RGA using **RGASoft** or our legacy RGA Windows application.
2. Collect a mass spectrum over a range that includes the gas species you wish to monitor, first using the Faraday Cup as the ion detector.
3. Set the y-axis of the mass spectrum in units of Amps. (Go to File » Preferences » Data » Units).
4. Perform CEM tuning.
5. Calibrate the CEM at a mass whose peak height is $>1 \times 10^{-13}$ A. This characterizes the gain of the CEM as a function of the applied high voltage.
6. Identify a smaller mass window that contains well-resolved mass peaks (e.g. 10 AMU –35 AMU in Fig. 1).
7. Set the scan speed to relatively fast (e.g. 22.22 AMU/s (NF 5)) so that it is easy to capture a full scan repeatedly on an oscilloscope.
8. Turn on the CEM. (Probe » Turn on CEM)
9. Start Analog scans with the CEM as the ion detector. An example scan is shown in Fig. 1.
10. Connect the SMB connector connector of the included SMB-to-BNC cable to the Ion Counting Output SMB connector on the RGA ECU. Connect the other end to the SR570 Current Preamplifier Input.
11. Adjust the SR570 Sensitivity (in Amps/Volt) to an appropriate level (using the measured Ion Current from the y-axis in the acquired mass spectrum). For example, at a Sensitivity of 50 pA/V, the 200 pA H_2O peak (mass 18) in Fig. 1 will produce a $\sim$4 V output. (Note that for low Sensitivity (small gain), the gain resistor used by the SR570 will be quite small. This represents a small input impedance as seen by the CEM signal source, and as a result the signal as measured by the RGA ECU and RGASoft will be attenuated).
12. Connect the preamplifier output to an oscilloscope input.
13. Adjust the oscilloscope timebase and input scale to bring the spectrum into view on the screen. An example spectrum is shown in Fig. 2. Note the similarities to the spectrum acquired in RGASoft (in particular the H_2O peak, plus OH and O fragment peaks at 18, 17, and 16, respectively, as well as the N_2/CO peak at 28).
14. Set the preamplifier filter to lowpass, with a cutoff frequency that won't attenuate signal changes on timescales of interest for your pressure monitoring application.
15. Verify that the measured peak heights on the oscilloscope match that from the RGASoft application (based on the oscilloscope scale, and the preamplifier Sensitivity factor).

You are now ready for continuous pressure-vs-time monitoring. Abort the scan. Set the Quadrupole Mass Filter (QMF) to filter at fixed mass using the "Mass Lock" command. For example, to monitor N_2 at 28 AMU send `ML 28`.

Now you can monitor the partial pressure continuously (either on the oscilloscope, or using a DMM or ADC).

Pulse Counting

For monitoring gas concentrations at very low partial pressures where ion detection events are rare and the gas peak is therefore buried in the noise floor of an analog scan, you can look for individual pulses at the electron multiplier output. This is a difficult measurement, owing to the presence of significant pickup of the RF drive of the QMF. Typical pulse duration is on the order of 50 nanoseconds (see Fig. 3b), so a fast pre-amplifier is essential. High gain of the CEM is also essential. (The gain of the CEM degrades with use, so a new CEM is advantageous for sensitive measurements).

An oscilloscope trace showing a single pulse event, with the RF pickup also very evident, is shown in Fig. 3. The below steps will describe how to obtain such a measurement.

1. Set the CEM voltage to 1900 VDC. This provides plenty of gain to ensure there is a measurable output signal.
   (a) Send command `HV1900`.
   (b) Check the returned value. It should be `0`. If not, check the error.
2. Tune the mass filter for the mass to be detected using the "Mass Lock" command. For example, `ML 84` for mass 84 (Krypton). This sets the RF amplitude to tune the QMF passband at 84 AMU.
3. Turn on the preamplifier and configure the input

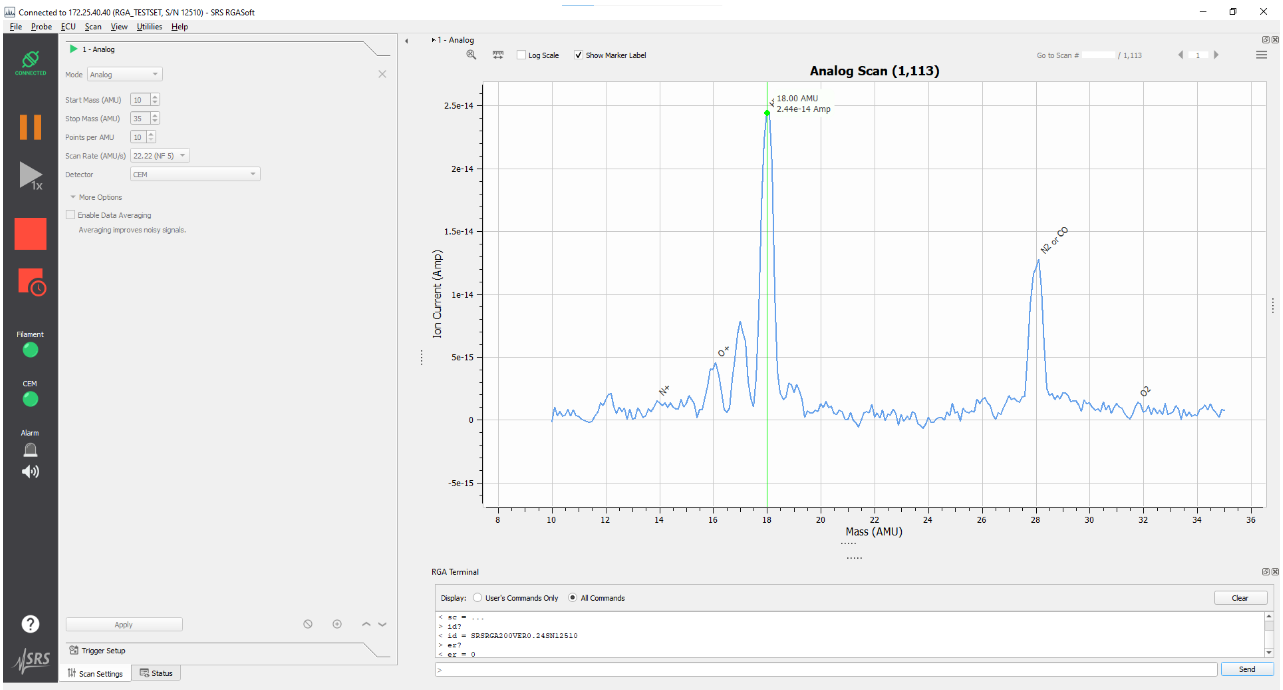


Figure 1: Example spectrum from RGASoft. Start Mass = 10 AMU. Stop Mass = 35 AMU. Points per AMU = 10. Scan Rate = 22 AMU/s. Detector = CEM.

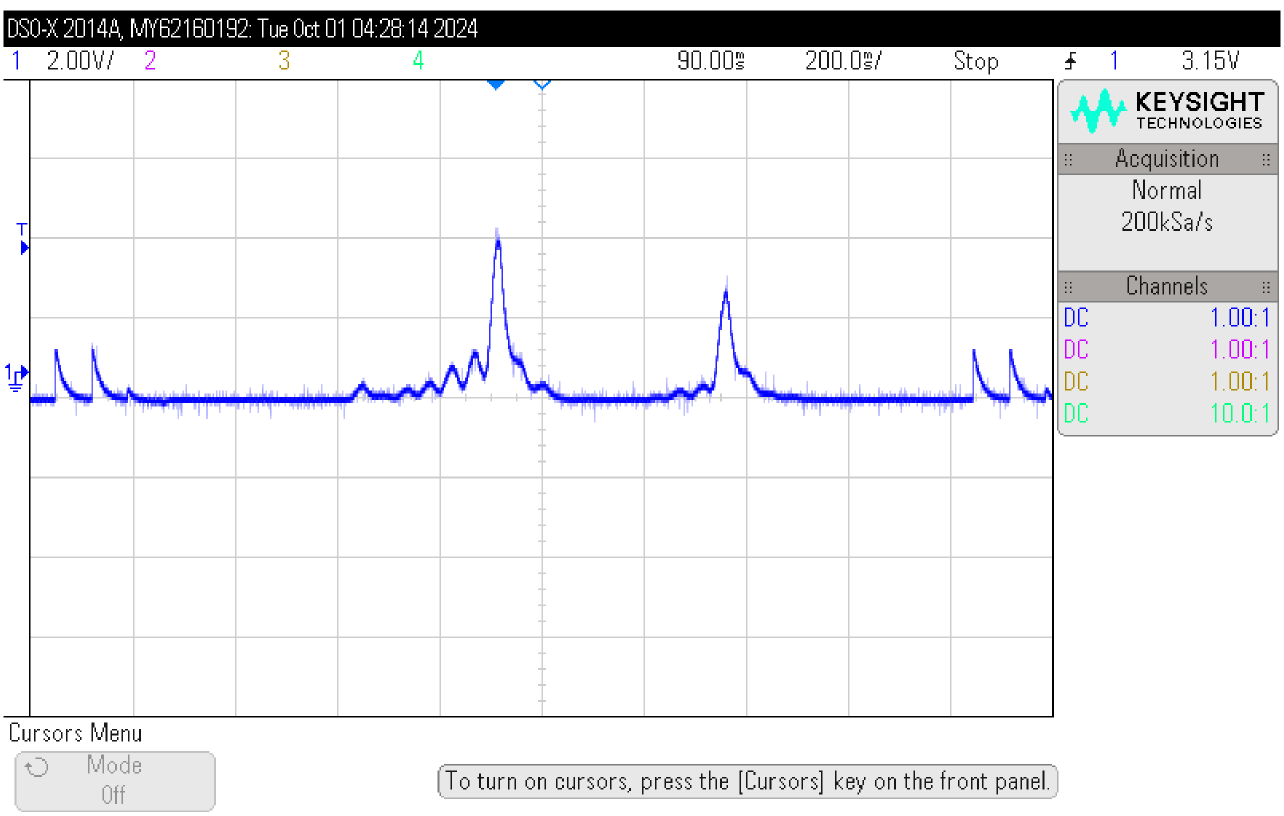
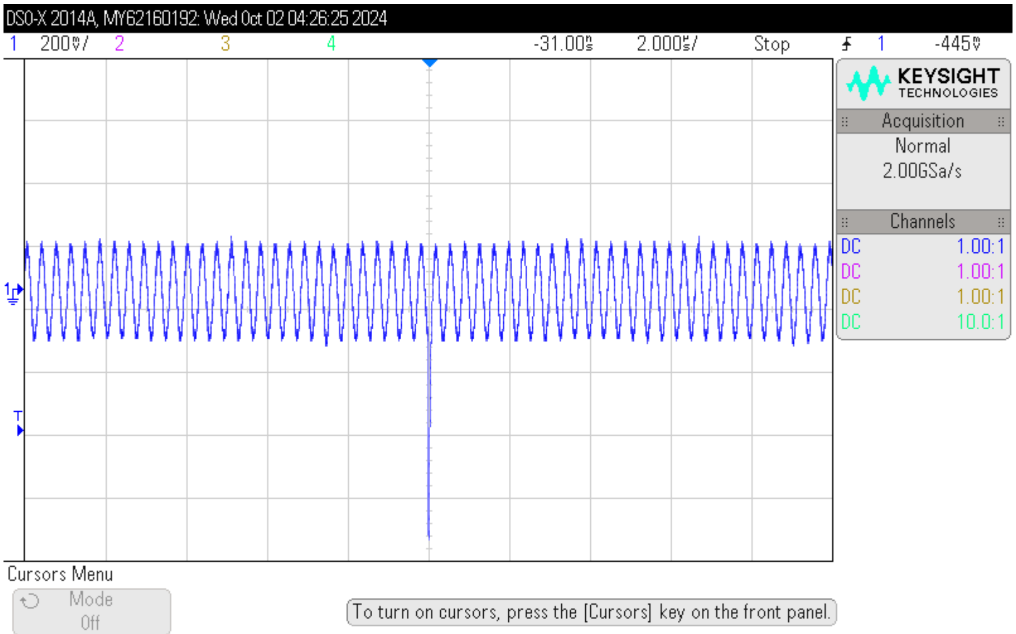
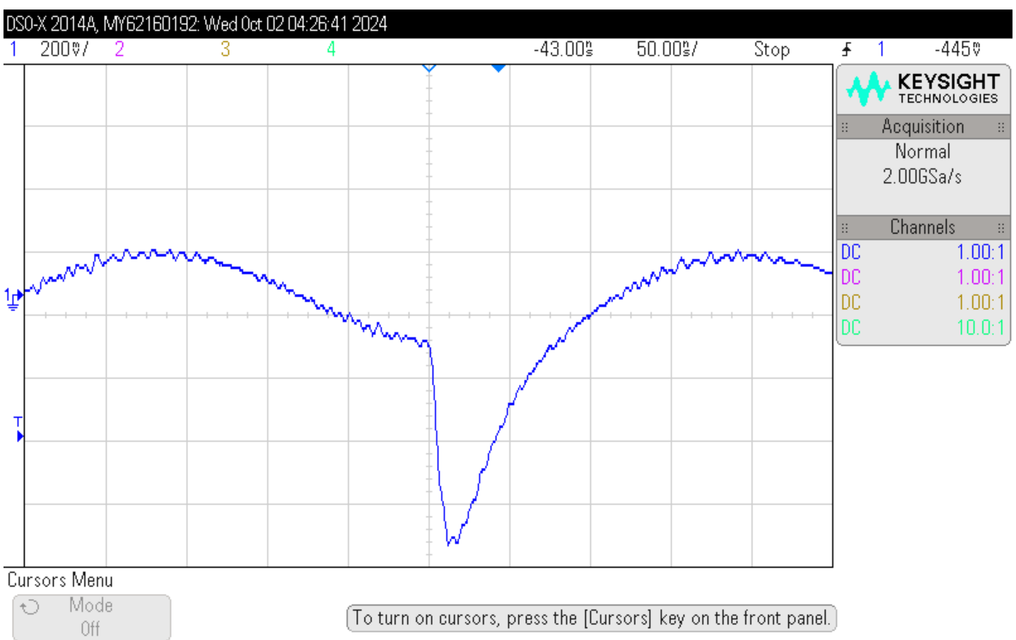


Figure 2: Example spectrum as viewed on oscilloscope.



(a) Single pulse output from EM as captured on oscilloscope. Note the presence of the RF pickup as well (high frequency sinusoid).



(b) Zoom of Fig. 3a to highlight ∼50 ns pulse width.

Figure 3

impedance for 500 Ω.

4. Connect the Option 3 SMB-to-BNC cable to the preamplifier input. If using the SR445A, cascade the CH1 OUT into the CH2 IN to obtain 25x amplification at the CH2 OUT. If using the SR446, the gain can be configured directly for 25.1x (or 28 dB). (Note that once connected to the 500 Ω preamp input, the signal becomes much less detectable to the ECU and RGA software, so Analog Scanning is not recommended in this configuration).

5. Connect the preamplifier output to an oscilloscope to check the signals. At this stage, you should only see RF pickup, at a frequency of 2.76 MHz. The

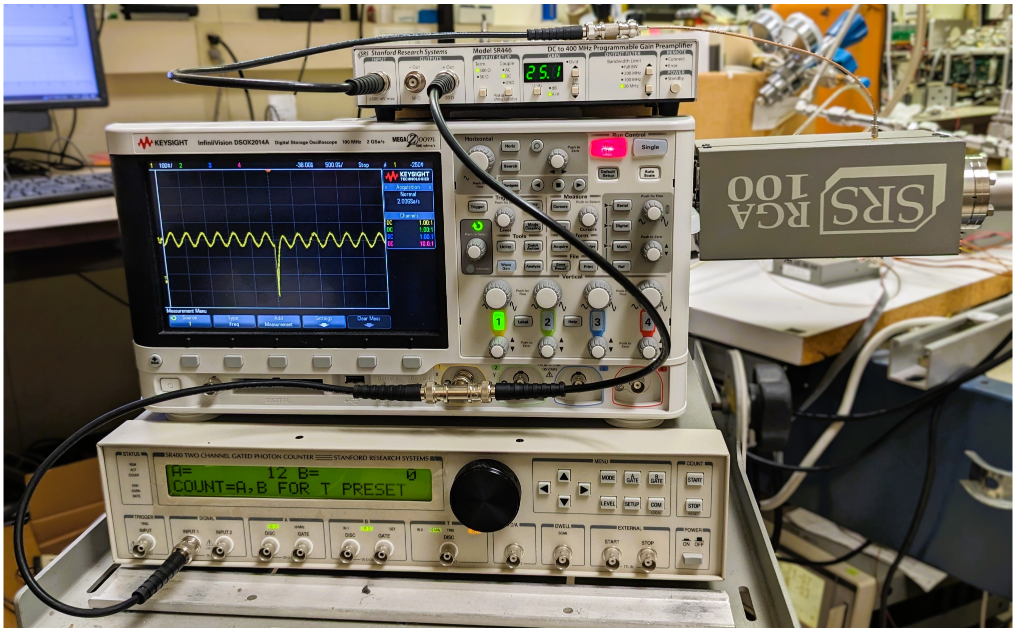


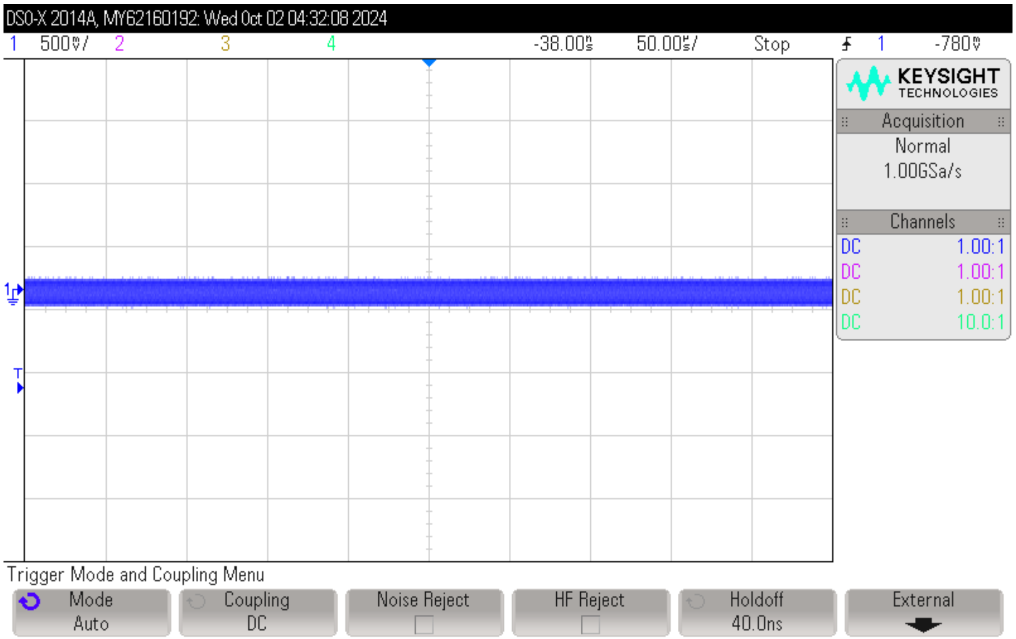
Figure 4: Pulse counting setup showing instrument connections. The SMB connector on the RGA100 ECU is connected via the included SMB-to-BNC to the INPUT of an SR446 RF preamplifier. The output of the preamplifier is routed to the oscilloscope and INPUT 1 of an SR400 Photon Counter. The trigger level on the oscilloscope, and the A discriminator level of the SR400 are set to −250 mV. A single ion pulse is visible on the oscilloscope screen. The SR400 shows that 12 such events were detected in the previous 1 s window.

magnitude of the RF (and its pickup) is proportional to the mass lock setting.

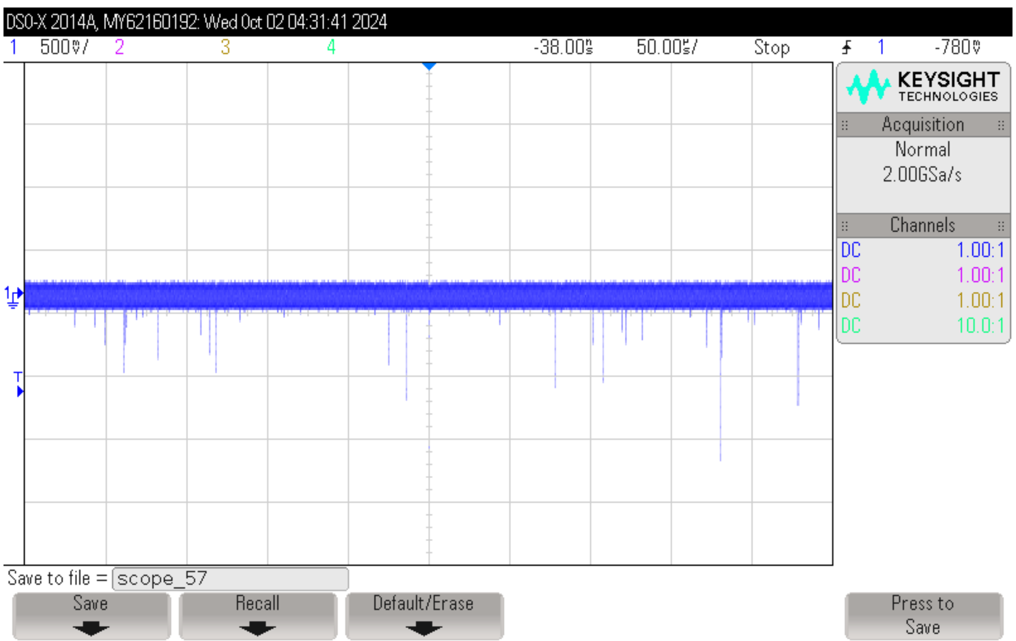
6. Turn on the filament by sending `FL1`.
7. If gas at the selected mass is present, you should begin to see brief pulses extending below the RF pickup envelope. Compare Fig. 5a and Fig. 5b for signal without and with ion pulses present. Note the magnitude of the pulses in comparison to the noise. The signal level will help inform the discriminator level setting of the SR400. The signal level is highly dependent on the gain (and age) of your CEM. Note that the SR400 discriminator threshold is limited to −300 mV. Adjust the High Voltage of the CEM and the gain of the preamplifier so that the pulses have an appropriate magnitude for easy discrimination from the background RF level.

Pulse Counting with the SR400

1. Connect the preamplifier output to the SR400 INPUT 1.
2. Restore the factory default settings of the SR400 by holding the [STOP (Reset)] key during power-up. This configures the instrument to count events at the A and B discriminators for 1 s. The front panel display will show: COUNT=A,B FOR T PRESET with T=10 MHz and T SET=1E0 s. (Use the [UP] and [DOWN] arrows to view the different settings).
3. Press [START] to commence counting. By default, only a single measurement is performed, counting is stopped, and the result is displayed. To start a second measurement, you must first press [STOP], followed by [START].
4. To switch to repeated 1 s measurements, change the AT N=STOP to AT N=START. This changes the “scan end mode” behavior to START (i.e. at the end of a scan, start another one). This can be set remotely via the command `NE 1`.
5. Press the [START] button to commence counting.
6. We first need to establish the discriminator level to avoid any dark counts. Turn off the RGA filament (by sending `FL0` command).
7. As seen above, pulses generated by the EM have negative polarity. While watching the A reading (reported in counts per 1 s window), adjust the SR400 A DISC LVL by turning the black knob. The default value is −10.0 mV. Adjust



(a) Background signal: Only the RF pickup is visible (no ion pulses), with a peak-to-peak magnitude of ∼250 mV at ML=50, HV=2000, FL=0.



(b) Same as Fig. 5a but with filament ON. Note the presence of about two dozen sharp, negative pulses of varying magnitude. These are individual ion detection events produced by the EM.

Figure 5

the discriminator threshold towards increasingly negative levels until the dark count rate goes to zero (since we wish to avoid any false positive detection events).

8. Turn on the filament (`FL1` command).

The above settings are summarized in Table 1.

At this point, pulses exceeding the threshold should be real ion detection events, and the A count rate should become non-zero. In the example of Fig. 5b, there are about two dozen ion pulses. Their magnitudes can vary owing to the complexity of secondary electron emission in the EM. However, the distribution of peak magnitudes is not dependent on gas concentration, and so while the discriminator level will affect the absolute number of detected events, it does not affect the proportionality between count rate and gas concentration (so long as the discriminator level is set below the RF pickup envelope).

Table 1: Example SR400 Settings. The discriminator level you use will depend on the mass you choose to monitor (which affects the RF pickup amplitude), the EM age (and therefore gain), the EM High Voltage, and the preamplifier gain.

Setting	Value	Remote Command
A input	INPUT1	`CI 0, 0`
A discriminator slope	FALL	`DS 0, 1`
A discriminator level	-250.0 mV	`DL 0, -0.250`
A discriminator mode	FIXED	`DM 0, 0`
A gate width	CW	`GM 0, 0`
Scan End Mode (AT N=)	START	`NE 1`