INTRODUCTION

Outside an ionization source and a Faraday plate, a drift tube IMS system is fundamentally comprised of 5 primary components:

• Reaction/Drift Cell
• Ion Gate
• Gas Pulsing Electronics
• Current to Voltage Converter
• Data Acquisition System

Within the IMS research community hardware and DAQ solutions are often custom and rarely replicated exactly.

In an effort to address this knowledge and resource gap, we outline a range of solutions to the construction and operation of research grade ion mobility spectrometers.

AIMS

• Develop and disseminate a series of hardware, software, and DAQ solutions.
• Leverage off the shelf, compact DAQ solutions
• Demonstrate the feasibility of a wireless DAQ systems for IMS experiments.
• Evaluate performance of floating, wireless ion gate pulsing system.
• Encourage collaborative efforts to realize optimum hardware/software solutions for reproducible IMS research.

SOFTWARE AND HARDWARE TOOLS

• DipTrace/Eagle CAD (electronic design)

  • www.wipy.io
• Open source, wireless, microcontroller
• Python
• Cross platform GUI and signal processing
• Redis (results database)

METHODS

• Development of FET pulser was based upon initial designs by WSU employed over the past 25 years.

• Testing of the FET pulser and resulting mobility spectra was acquired using a custom stacked ring IMS system operated at 180 °C.

• Initial benchmarking of the pulser was conducted using a 1kHz square wave with a 50% duty cycle (Figure 2).

• Code revisions, design documentation, and updates are currently available through both github and www.clowersresearch.com.

FET Pulser System

• +/- 200 V 0-peak
• 12 Volt Input
• Wireless control of settings
• Fiber optic isolation
• TTL input logic
• Independent channel control

Data Acquisition System

• Wireless microcontroller
• Cortex M4 @ 80MHz with RTC
• RAM: 256 Kbytes
• Flash: 2 Mbytes
• 4 16-bit timers (16 and 32-bit)
• 3 12-bit ADCs (1.8V limit)
• WiFi: 802.11b/g
• Python control environment
• Standard python modules
• Excludes floating point numbers
• Hardware based DAQ
• TTL Trigger
• Redundant Storage/Transfer

Redis server

• Laboratory computer
• Direct streaming
• Onboard SD card

RESULTS

The normalized traces shown in Figure 2 highlighted the ability of the newly designed FET pulser to realized improved rise and fall times. Measured with an oscilloscope probe, the actual peak voltage was routinely lower than expected by approximately 2.1 volts, however, this offset was easily accommodated. The wireless-enabled Wipy platform demonstrated acquisition rates approaching 100 kHz which is more than sufficient for IMS measurements. Challenges to the system remain, specifically, with ADC input voltages limited to 1.8 V. A solution for ion current conversion and amplification highlights gains for 10° exists, however, input source matching remains critical. The cross-platform GUI is compatible to any redis server and may prove useful for a wide range of DAQ efforts.

FUTURE DIRECTIONS

• Improve data streaming and pulsing control across the wipy and pulsar platforms.
• Integrate thermoelastic trickle charger to harvest excess heat from the IMS cell.

ACKNOWLEDGEMENTS

Support for this work was supported in part by the NSF (CMI-1506672) and AR0 (W911NF-15-1-0619). The authors would also like to recognize the assistance of both Wenjie Liu and Eric Davis.

FUTURE DIRECTIONS

• Using git as a repository, a series of hardware and software solutions are presented and open for improvement.

• The solid-state, floating ion gate pulser marked an improvement over the performance of historical pulser.

• Continuous battery operation at high voltage is possible for ~2 hours.

• The DAQ platform is highly customizable, relatively inexpensive ($50 USD), and demonstrates data acquisition rates sufficiently high for IMS measurements.

• The use of the asynchronous redis server maintains a local copy of data but is compatible with real-time streaming from the wipy device and can also be used to push DAQ settings.

• Redundant data storage is accomplished with the wipy using an onboard SD card.

• A cross-platform data viewing and processing platform was developed that leverages a reds server which features direct data export and peak picking.

Figure 1. Circuit schematic for a common to voltage amplifier used for gains of 108 established through R1. Optimization of the amplifier circuit is required for higher gains. Opamps and saga files are located via github (https://github.com/gb2270).

Figure 2. Comparative performance of the newly designed FET pulser illustrates improved rise and fall times when tracking a TANOO input

FET pulser with a 20% duty cycle. The +/- voltage for both the traditional WSU pulser and the newer design was set to 50 V for each output. The performance of the custom, wire-less solution transistors, illustrated, improved the rise and fall times that approach a few hundred nanoseconds where the newer solid state design yielded pulse transitions in under 20 ns.

Figure 3. Using a 150 μA input pulse width as an input, the mobility spectrum to the right illustrates the ion peaks obtained using the new FET pulser. The newly design system was floated at 7500 V on the input and 200 V on the output. The performance of the traditional WSU pulser and the newer design was set to 50 V for each output. The normalized traces shown in Figure 2 highlights the ability of the newly designed FET pulser to realized improved rise and fall times. Measured with an oscilloscope probe, the actual peak voltage was routinely lower than expected by approximately 2.1 volts, however, this offset was easily accommodated. The wireless-enabled Wipy platform demonstrated acquisition rates approaching 100 kHz which is more than sufficient for IMS measurements. Challenges to the system remain, specifically, with ADC input voltages limited to 1.8 V. A solution for ion current conversion and amplification highlights gains for 10° exists, however, input source matching remains critical. The cross-platform GUI is compatible to any redis server and may prove useful for a wide range of DAQ efforts.

CONCLUSIONS

• Develop and disseminate a series of hardware, software, and DAQ solutions.
• Leverage off the shelf, compact DAQ solutions
• Demonstrate the feasibility of a wireless DAQ systems for IMS experiments.
• Evaluate performance of floating, wireless ion gate pulsing system.
• Encourage collaborative efforts to realize optimum hardware/software solutions for reproducible IMS research.

Figure 4. Wipy system mounted to an expansion board providing direct access to the FID pipe and an onboard micro SD card.

Figure 5. Cross platform GUI providing an interface to the local redis database. Additional features include data export, DAQ parameter uploading, and peak picking.

Figure 6. Comparative performance of the newly designed FET pulser illustrates improved rise and fall times when tracking a TANOO input

FET pulser with a 20% duty cycle. The +/- voltage for both the traditional WSU pulser and the newer design was set to 50 V for each output. The performance of the custom, wire-less solution transistors, illustrated, improved the rise and fall times that approach a few hundred nanoseconds where the newer solid state design yielded pulse transitions in under 20 ns.

Figure 7. Prototype desolvation region with built-in gas heating. Electrodie surfaces are made from Figures 4505 PCB material and 0.145 diameter stainless stainless. The dimensions are compatible with grounded insulator to minimize high voltage exposure.