

# **HDice NMR Synchronization Status**

Detector Support Group

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# Synchronization Topics

- Goals of synchronization.
- Functionality of existing NMR.
- Planned features of synchronized NMR.
- Limitations of Lock-in Amplifier.
- Synchronization test programs.
- Project schedule.
- Status summary.

# Goals of NMR Synchronization

- Provide an independent and accurate magnet current measurement.
- Current measurements to be synchronized with the lock-in amplifier measurements.
- Maximize the number of acquisition points for variable NRM sweep lengths (20-600 sec.)
- Store measurements in NMR data files.

# Existing NMR Program

- Uses internal lock-in amplifier triggering.
- Current/field is read back from power supply.
- Asynchronous lock-in amplifier and current measurements.
- Different acquisition rates for current/field measurements and stored lock-in amplifier data.
- Current measurements are not stored in NMR data files.

# NMR Synchronization Features

- Use external lock-in amplifier triggering.
- Current measured by shunt instrumentation.
- Current and lock-in amplifier measurements synchronized.
- Variable acquisition rates to maximize number of data points.
- Synchronized current & lock-in amplifier measurements stored in NMR data files.

# Comparison of Features

| Feature                             | Existing NMR  | Synchronized NMR   |
|-------------------------------------|---|--|
| Triggering                          | Asynchronous lock-in trigger.                                       | Synchronized by external lock-in trigger.                                    |
| Current Measurement Instrumentation | Oxford Power Supply.  | CT-Box current shunt.  |
| Data Stream                         | Asynchronous lock-in amplifier and current measurements.            | Synchronized lock-in amplifier and current measurements                      |
| Data Acquisition Rates              | Different DAq rates for lock-in buffer data & current measurements. | Same DAq rate for instrumentation.<br>Variable rate to maximize data points. |
| Data Files                          | Current measurements not stored in NMR data files.                  | Current and lock-in amplifier measurements are stored in NMR data files.     |

# CAENels CT-Box Current Shunt

## Synchronization based on a new product by CAENels:

- Summary of Specifications:

- +/- 150 Amp range
- 24 bit ADC current resolution
- < 0.005% current accuracy
- 1Hz – 100 KHz sampling frequency in 10 $\mu$ s steps (Oscilloscope mode)
- Output TTL triggering
- Local current monitoring and status



- New product Issues:

- Firmware errors requiring updates.
- Hardware issues.
- Lack of documentation on software protocols, etc.
- Not shipped with software we could use.
- Required extensive development of a library of LabVIEW instrument device drivers.
- Developed LabVIEW DAq code using DSG device driver library to test the CT-box.
- **All Issues resolved.**

# Lock-in Amplifier

- Stanford SR844 Lock-in Amplifier Limitations:
  - Internal buffer depth only 16.3K:
    - Limits number of data points on NMR sweeps.
    - Must lower acquisition frequency on longer sweeps.
  - No output trigger available.
  - Slow acquisition rate – 512Hz maximum (internal trigger)
  - Slow buffer data readout speed (~70 Sec. for 16K)
  - Input (external) triggering issues:
    - Specifications: *Up to 512 Hz external triggering.*
    - DSG testing shows at acquisition frequency  $\sim > 300\text{Hz}$ , trigger efficiency is less than 100%
    - Trigger efficiency needs to be 100% for synchronization.

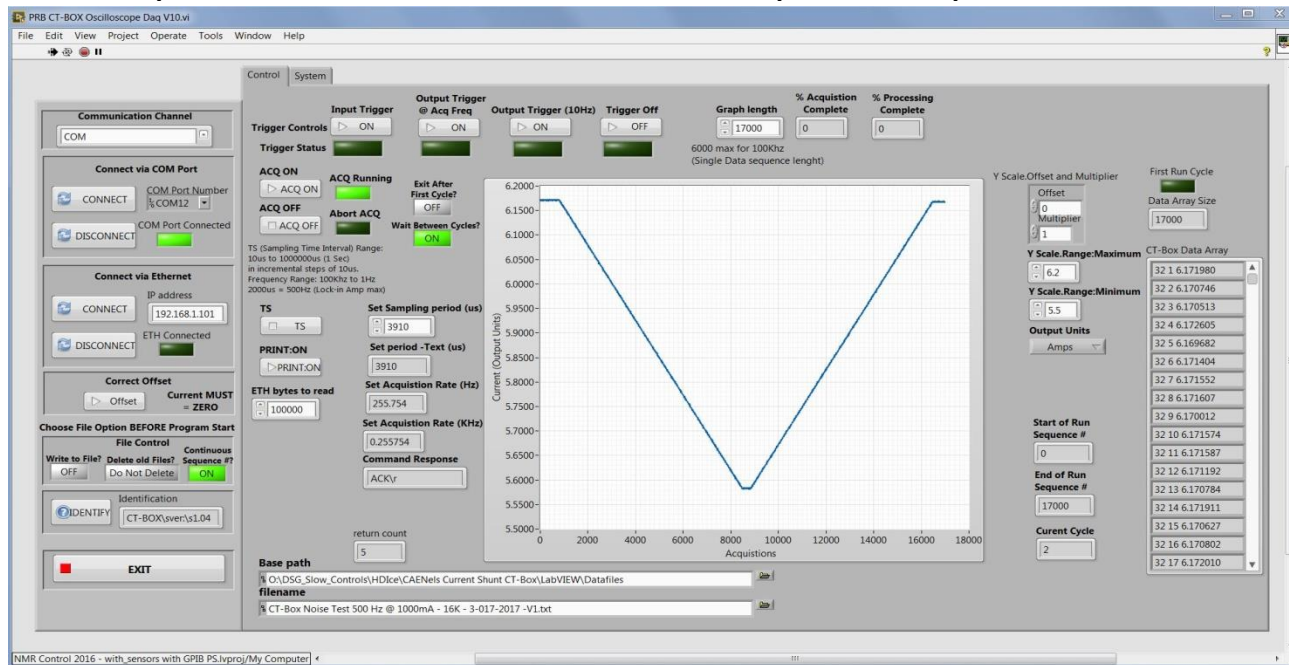


# Synchronization Test Programs

- CT-Box data acquisition program.
- Lock-in amplifier test program.
- Triggering efficiency program.
- NMR development test program.

# Synchronization Test Programs

- CT-Box data acquisition program.
  - Tests CT-Box data acquisition and triggering.
  - Uses queued data (FIFO)
    - Acquisition & data decode are independent processes.

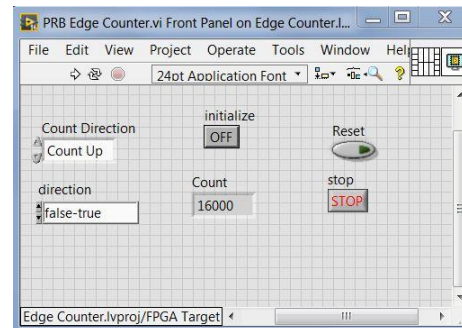
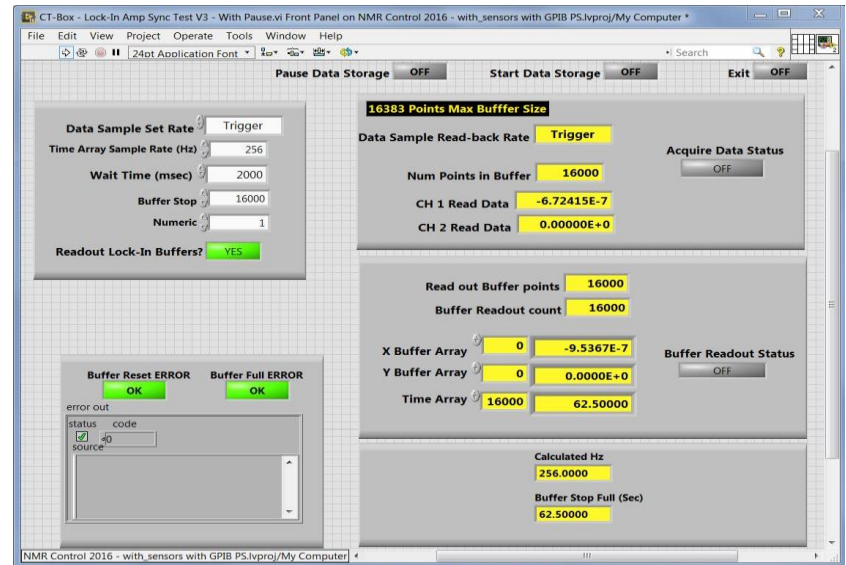


# Synchronization Test Programs

- Lock-in amplifier test program.
- Triggering efficiency program.

## Programs used together to test:

- Lock-in amplifier data acquisition.
- Data buffer storage and read out.
- Lock-in amplifier dual data stream.
- Lock-in amplifier external triggering capabilities and limitations.



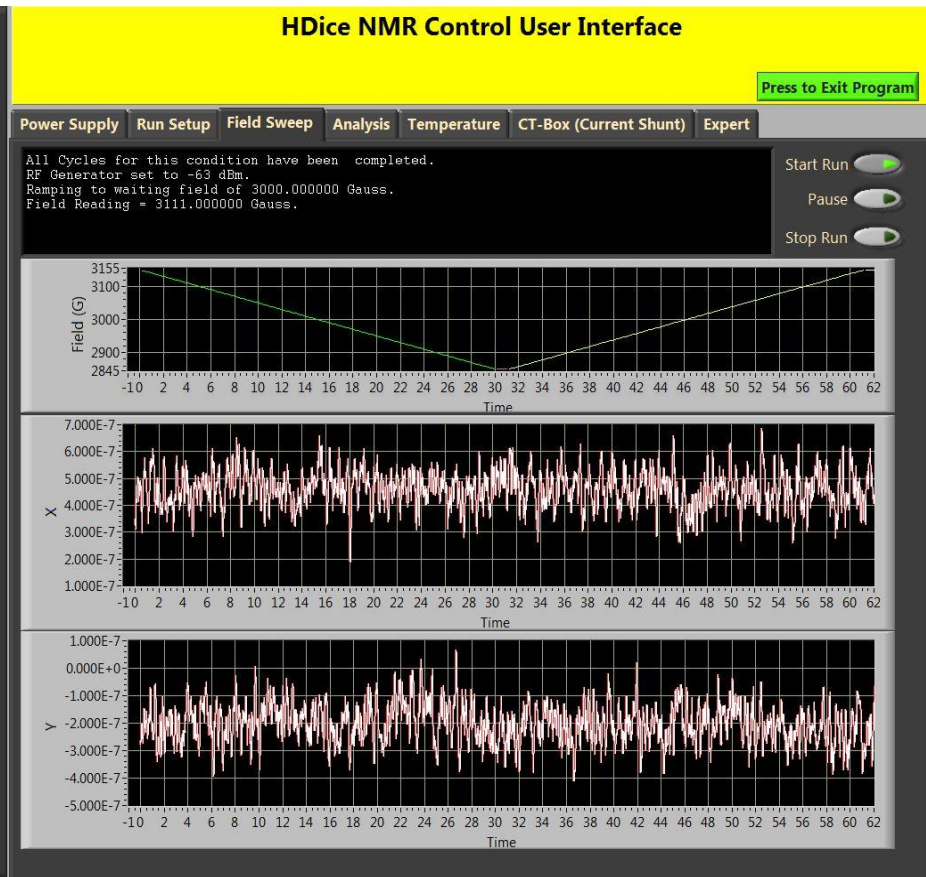
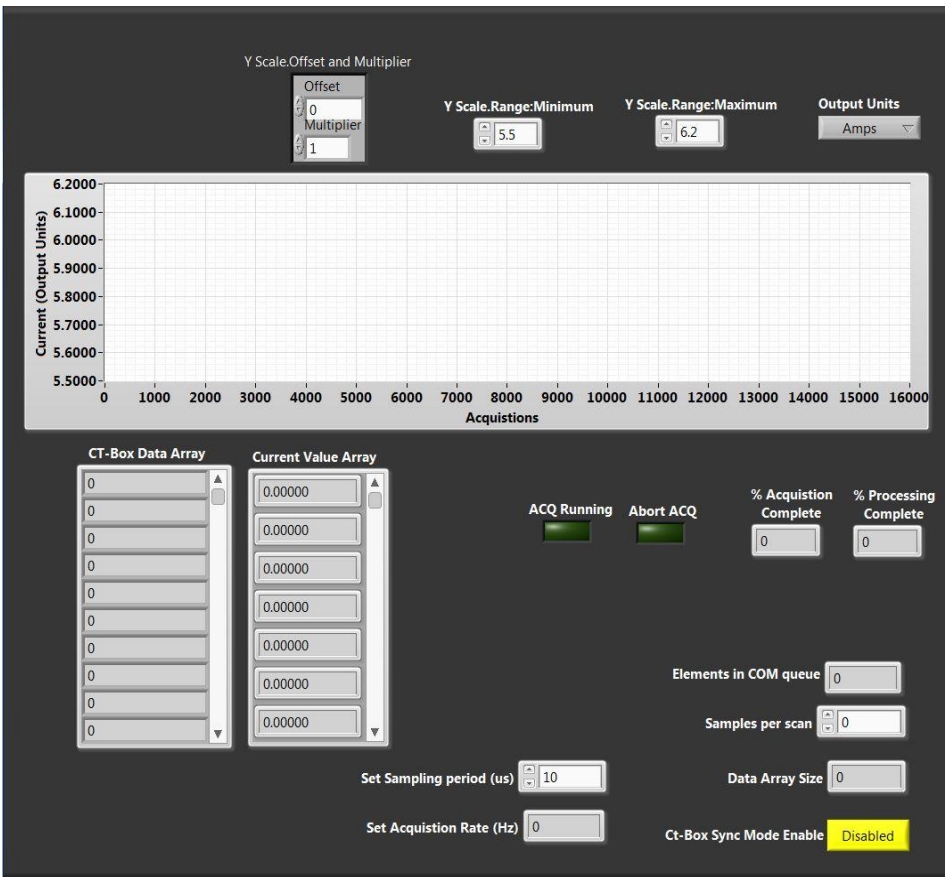
# NMR Development Test Program

- **Instrumentation used in NMR**
  - RF Signal Generator.
  - RF Switching/Attenuator Box.
  - Magnet Power Supply
  - Helium temperature & level.
  - **Lock-in Amplifier.**
  - **Current Shunt**

# NMR Development Test Program

- Tests the communication and timing between NMR Instrumentation.
  - CT-Box does not have an internal buffer memory.
  - Computer must accept CT-Box serial communication stream at data acquisition rate.
  - Program must communicate with all instrumentation used in NMR without dropping CT-Box events.

# NMR Development Test Program



## Asynchronous Test Sweep

# NMR Development Test Program



Synchronous Test Sweep

Synced CT-Box & Lock-in Data

Async Power Supply Data

# Synchronization Schedule

| DSG HDIc Schedule<br>2/22/2018   |   | Feb |    | March |    |    | April |   |   |    | May |    |   |    | June |    |   | July |    |    | August |   |    | September |    |   | October |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
|--|---|-----|----|-------|----|----|-------|---|---|----|-----|----|---|----|------|----|---|------|----|----|--------|---|----|-----------|----|---|---------|----|----|---|----|----|----|---|---|----|----|----|--|--|--|
|  |   | 19  | 26 | 5     | 12 | 19 | 26    | 2 | 9 | 16 | 23  | 30 | 7 | 14 | 21   | 28 | 4 | 11   | 18 | 25 | 2      | 9 | 16 | 23        | 30 | 6 | 13      | 20 | 27 | 3 | 10 | 17 | 24 | 1 | 8 | 15 | 22 | 29 |  |  |  |
| Upgrade of RF Rack #1  | Upgrade of RF Box # 1 and # 2:  |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
|  | Upgrade electronics for readback of terminator and cable types & interlock status           |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
|  | Debug and test  |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
|  | Isolate rack mounting on RF generator, RF amplifier, RF box, signal generator               |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
|  | Configure new PC and instrumentation interface hardware for NMR rack 1 upgrade              |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
|  | Debug and test NMR, RTP, and FRS programs with upgraded instrumentation                     |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
|  | Rack 1 instrumentation used to develop synchronization hardware and software                |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
| Install & debug instrumentation, computer, power supply, and hardware interfaces in HDIc lab           |   |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
| Synchronization for Lock-in Amplifier Data   | Develop, debug, and test hardware trigger interface for CT-box to lock-in amp               |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
|  | Develop code interface between lock-in amp triggers with current measurement device drivers |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
|  | Develop test program to test triggering rate efficiency and timing                          |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
|  | Develop, debug, and test synchronization library sub-routines into lock-in amp DAQ code     |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
|  | Modify, debug, and test NMR subroutines to write synchronized measurements to data file     |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
| Integrate, debug, and test synchronization code package into main NMR program                          |   |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
| Debug Gauss offset issue in NMR scans  |   |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
| Modify, debug, and test NMR code to write gauss/current measurements to data file                      |   |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
| Revise RF Splitter/Attenuation boxes to add local instrumentation status readback capabilities         |   |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
| Consolidate RF Splitter/Attenuation box communication interfaces into a single communication interface |   |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
| Debug VISA device base drivers for Oxford Mercury iPS power supplies                                   |   |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
| Revise, debug, and test RTP and NMR programs for Oxford Mercury iPS power supplies                     |   |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
| Update all NMR LabVIEW instrumentation drivers to VISA.  |   |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |
| Rewrite, reorganize, and document NMR main program and subroutine libraries                            |   |     |    |       |    |    |       |   |   |    |     |    |   |    |      |    |   |      |    |    |        |   |    |           |    |   |         |    |    |   |    |    |    |   |   |    |    |    |  |  |  |



# Status Summary

The present work being done has to address the following questions:

1. Is the CT-Box current shunt going to work in synchronization?
2. What instrumentation will be the trigger for synchronization and will the instrumentation work?
3. What are the limitations to the synchronization plan?
4. Will the two independent (but triggered by the CT box) data streams from the lock-in amplifier & CT-Box align and have 100% trigger efficiency?
5. Can all of the instrumentation used in the NMR program communicate at the same time without losing CT-Box events?

Code development is underway and more testing is definitely needed, but so far all the answers look encouraging:

1. Yes.
2. CT-Box will trigger the lock-in amplifier and it will work.
3. The lock-in amplifier is the limiting factor in the system.
4. Yes, the two data streams will align and have 100% trigger efficiency.
5. Yes, all instruments can work together at speed without losing CT-Box events.