

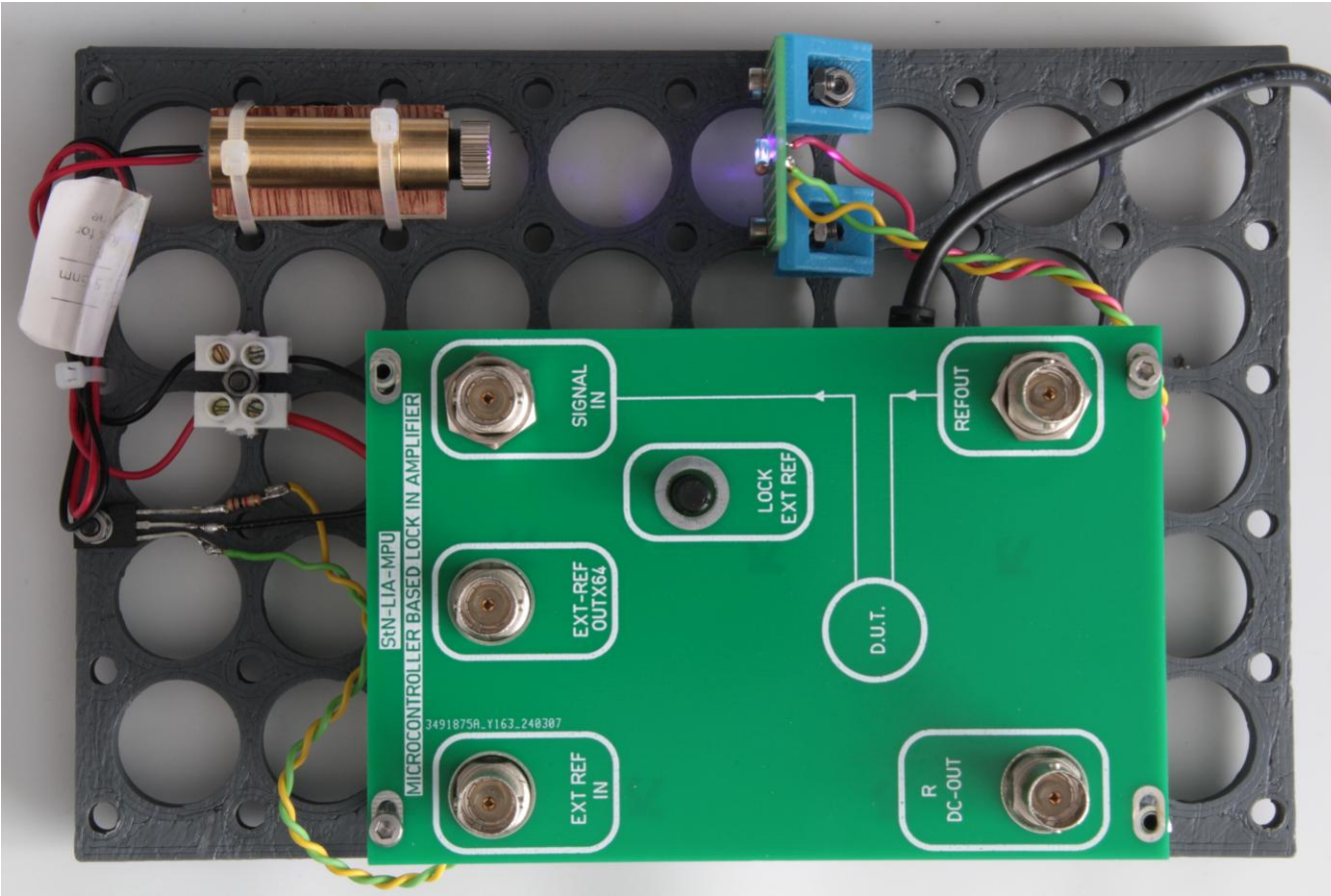
# STN-LIA-MPU

An OLIA spinout development

Development/Discussion LOG

Nikos Chalikias

# 405 nm setup with 1000mW (electric ) power

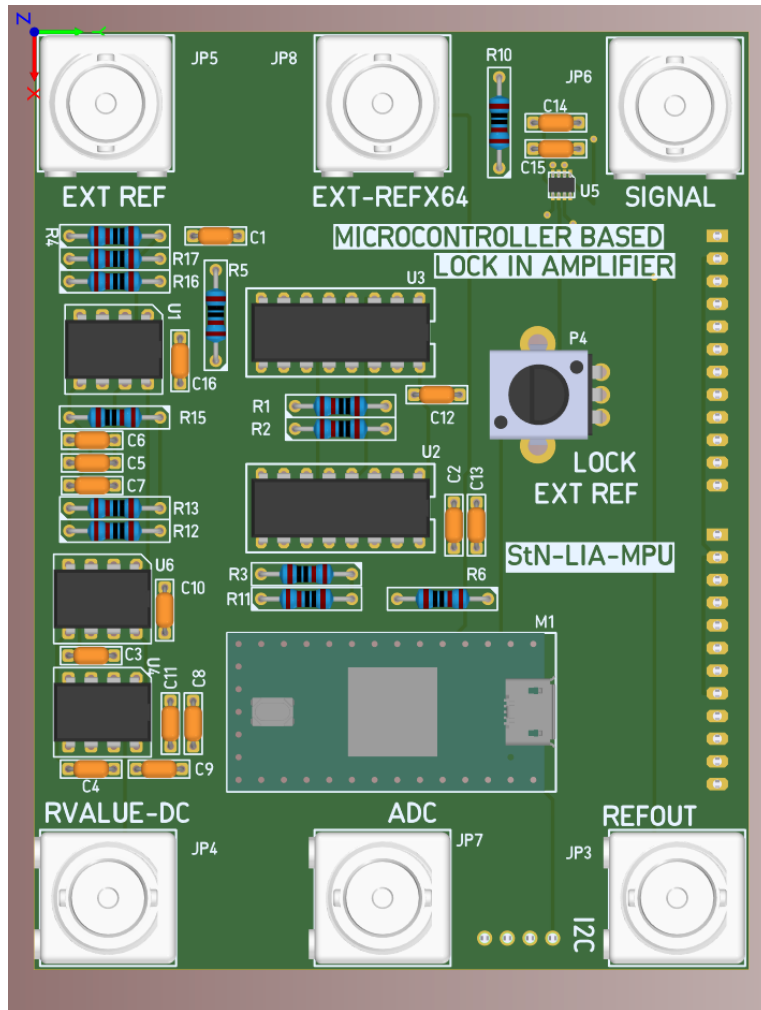


- StN-LIA-MCU with a NPN transistor to drive the 1W laser
- BPW34 general purpose Photodiode
- We used a 405nm Laser instead an infrared
- Output is high: 2000mV (direct laser beam to Photodiode)
- Can see consistently a 5mV variation when exhale
- Will work with similar size/power/lens Infrared Laser
- Need for a 2<sup>nd</sup> Photodiode for liquid tests
- It is easier to multiplex and use a 2<sup>nd</sup> laser, [...if this works with the liquid project]

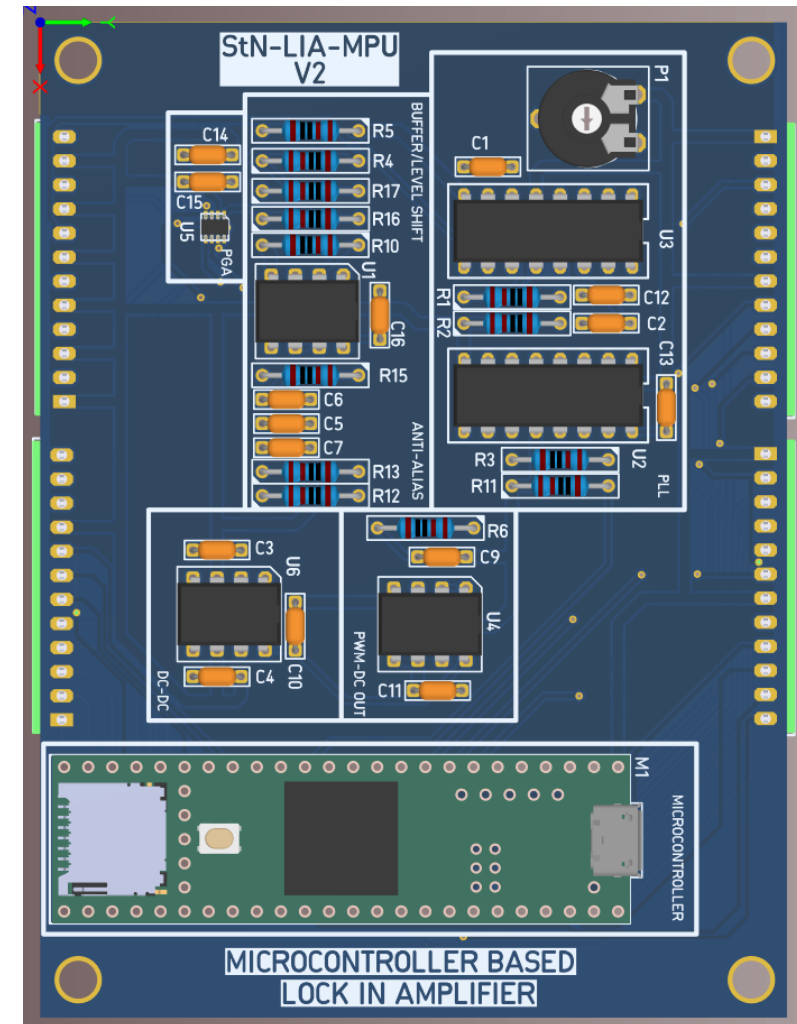
# 2000nm setup

- Proposed to setup a photodiode experiment only with PCBs
  - This is our goal, but many little details can block the operation for ...some time
- Chinna proposal: **to use existing instrumentation and only PCB LIA (StN-LIA-MCU)**, seems much better, as a 1<sup>st</sup> step
  - Then we can replace:
    - TEC with PCB (2<sup>nd</sup> step)
    - LDD with PCB (3d step)
    - Generator with PCB (4d step)
    - Add a microcontroller with LCD/buttons as experiment administrator (5<sup>th</sup> step)
    - **Add A PC or R-Pi as experiment administrator** (6<sup>th</sup> step)
    - Evaluate Preamplifier performance
    - Develop and evaluate, ultra low noise multi-output PSU
- This is scalable and sustainable, can start now
- 2000nm LED and photodiode to be delivered in a couple of days

# StN-LIA-MCU



- V1 ongoing testing, works as expected
- A 2<sup>nd</sup> PCB to be assembled
- Most probably the 3d PCB will be V2



- V2: Fixed PCB bugs, removed expensive connectors, Easier to use screw terminals, local SD-Card, lower cost
- 2 layers PCB faster to be delivered from manufacturer, clean

# Plan to assess LIA performance

- Started with evaluating Standard Deviation [ $\sigma$ ] of the R component DC output of commercial LIA
  - Already have results for 3 COTS LIA
- **Propose to expand our evaluation scope with a basic setup for a QTF characterization**
  - Real problem
  - Experience on the setup
  - No need for expensive laser or optics
  - Can work with 0.5 euro 32.768 RTC crystals
  - No need for Preamplifiers
  - Can compare with Bari electronics

# KNOWN ISSUES

HW and FW is based on OLIA

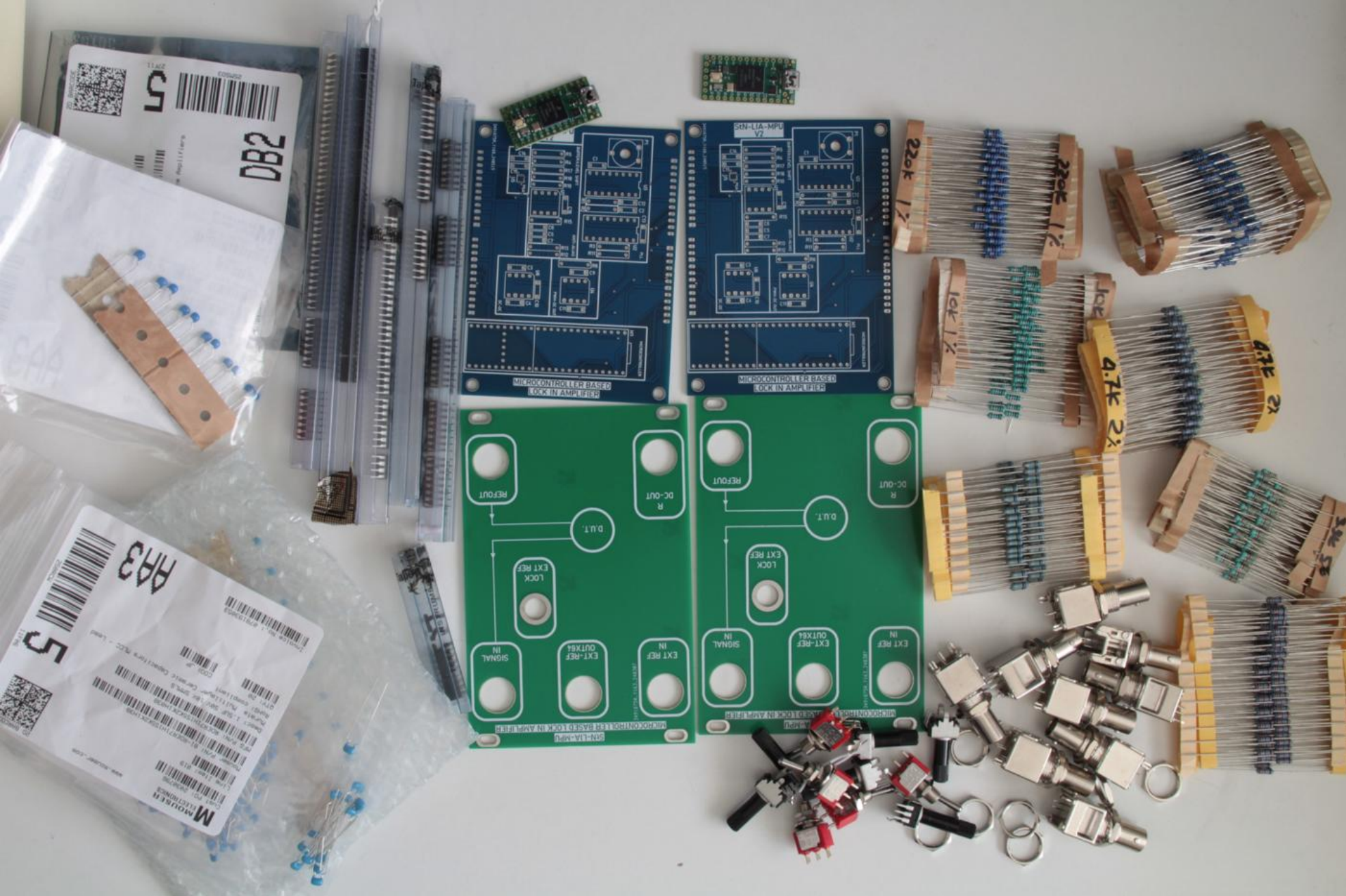
- Works good with internal REFERENCE signal generator but not for all Frequencies
- The external REFERENCE frequency is 64X the wanted Frequency, this is confusing for the user
- Works well with External REFERENCE at the order of 1KHz, but can't follow for order of 10KHz
- In our FW version we have updated the multiplier ratio to 32X: so it works for 12KHz range
- Not any frequency for REFERENCE is working: It has to be an integer fraction of the sampling frequency
- Sampling Frequency is 200KHz
- We should not have the Integer fraction issue with external REFERENCE, as the sampling rate is (..should) be controlled by the external REFERENCE!!! ....But this not resolved yet...

# N2O App4Farm GAS CELL

- RUN LIA 2 UNITS AT THE SAME TIME AND SAME REFERENCE
- TEST IF COMMON EXTERNAL REFERENCE CREATES 2 REF OUTPUTS AT CONSTANT PHASE DIFFERENCE
- BNC ARE NEEDED
- **IN 2 WEEKS?? YES IT IS POSSIBLE**
- DRIVE 5V 500mA LED, IS IMPORTANT
- USE EXTERNAL PSU FOR THE LED
- 3+ Boards needed
- STATUS
  - Tested Running 2 GUIs at the same time
  - 3D printing a plastic optics breadboard
  - To mount/integrate inside a Passepartout enclosure, bottle outside



# PCBS TO BE SOLDERED





# GUI

\*\*\*\* StN-LIA-MCU \*\*\*\* based on olia

Port: COM0 Connect No default port set  
Set default

---

f (Hz): Input gain: 1

☐ External reference Query freq. Time constant (s): 0.6

☐ Synchronous filter Analogue output scaling: 10

---

filename.csv ☐ Save to file Start

First higher harmonic: 2

---

R (mV)  $\phi$  (deg) Noise (mV) X (mV) Y (mV)

☐ Plot data: R and  $\phi$  Phase offset (deg): 0

Time range (s): 30 ☐ Wrap phase

---

R (mV)

t (s)

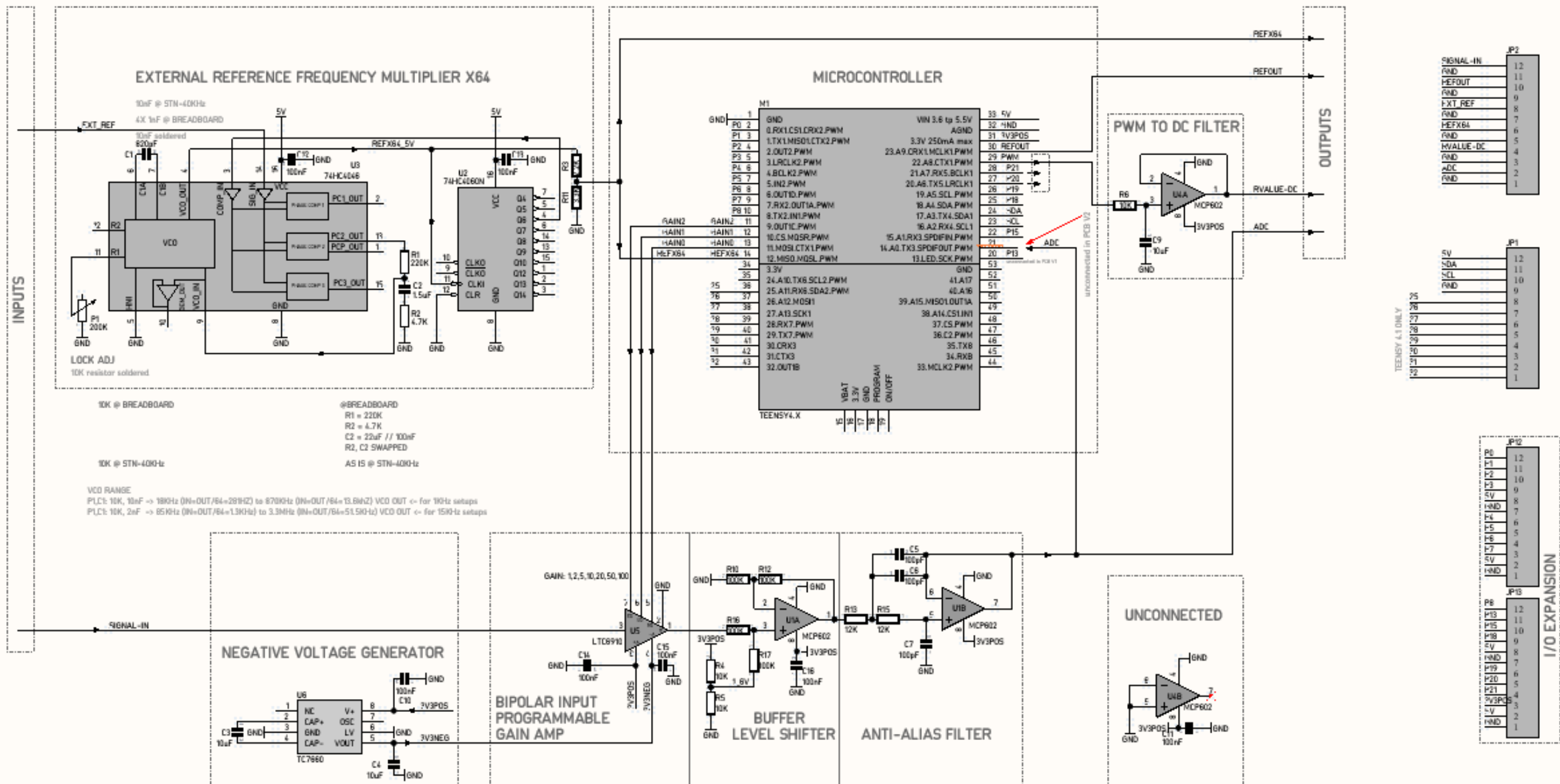
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$\phi$  (°)

t (s)

For our version of GUI: Only minor updates

# Schematic



# Function Calculate() runs every 5μs

Input is sampled 200 times for the 1ms REF period (1KHz)

```
397 | xSig = (double)adc->analogReadContinuous(A0); //sample current adc value
```

Sin (0 to  $2\pi$ )  
in 200 steps

0 to 199

For 1KHz: 200 samples per REF period

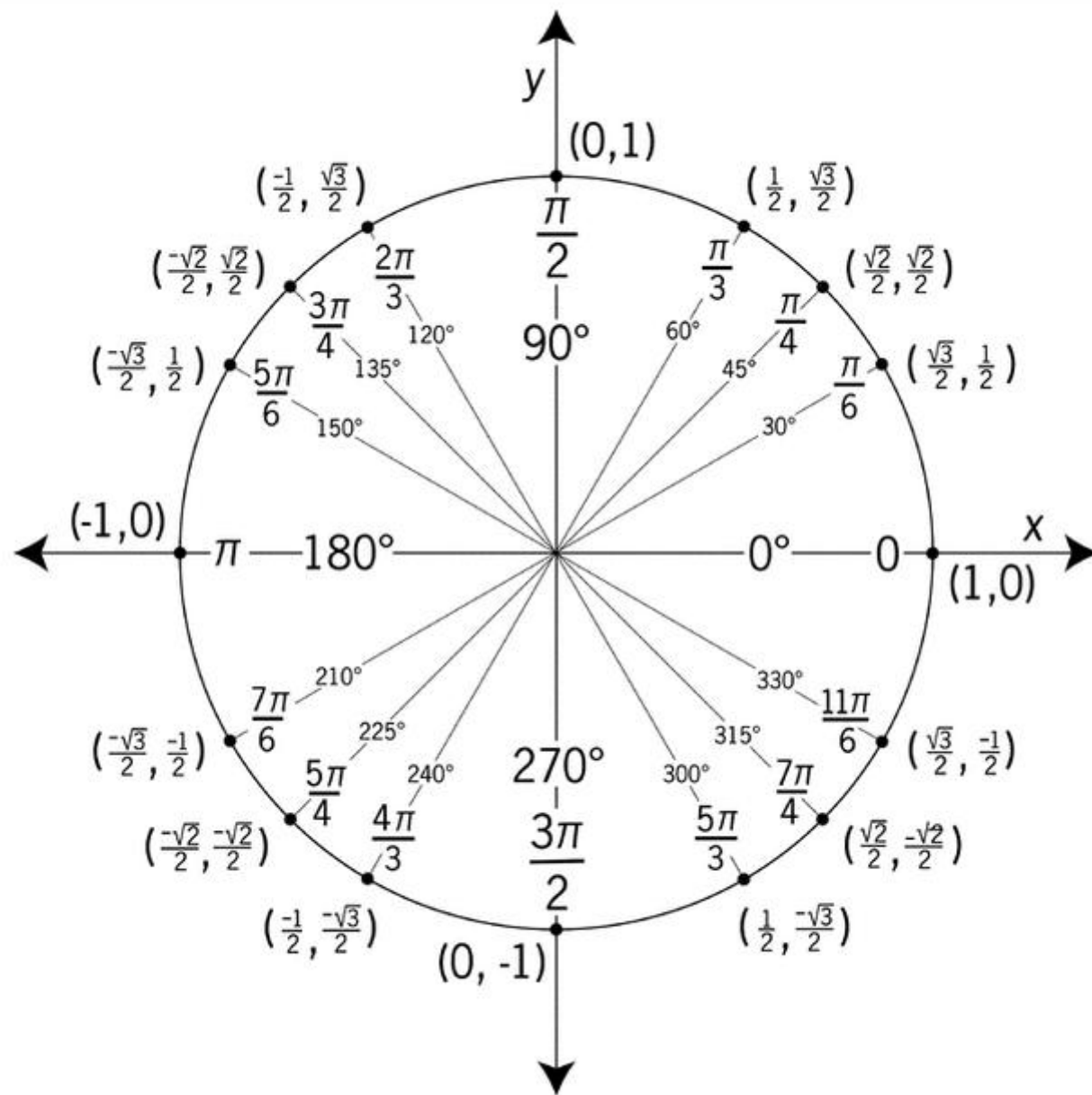
```
432 | // Nikos: Below 2 lines are the core of the Lock In Amplifier
433 | //calculate reference value and multiply (-1* because preamp is inverting) // Nikos: Sinusoidal Reference signal is created here, Is like sampling a 1000Hz sinus
434 | phasSig = -1*sin(((2.0 * (j + 1) * pi * sampleIndex) / samplesPerPeriod) - ((j + 1) * phaseDiff));
435 | xi0 = (xSig*phasSig); //-1 because preamp is inverting // Nikos: Input sample is multiplied with Reference 'sample' here
436 |
```

Review of code for 1<sup>st</sup> harmonic lock-in

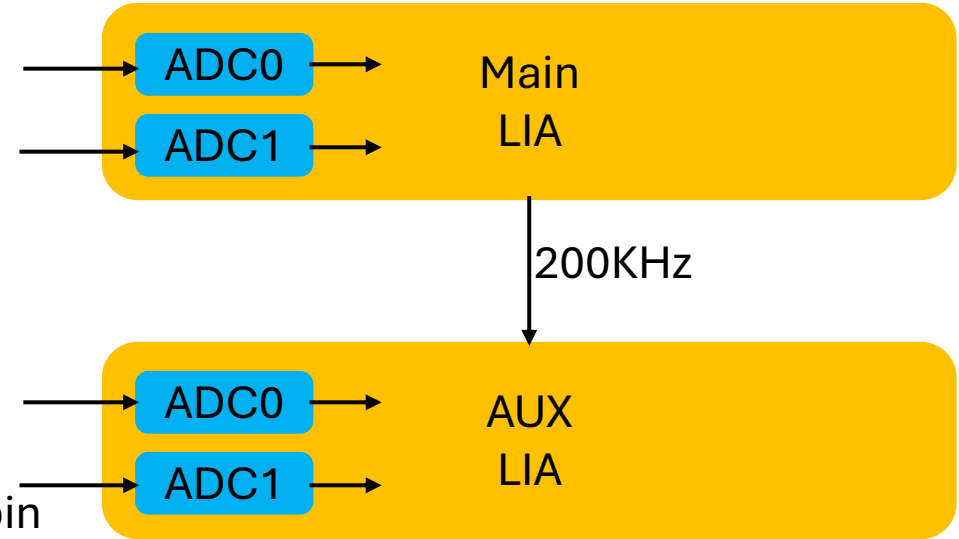
OLIA firmware Function **calculate()** is called periodically every 5μs (200KHz), to

- Sample input (ADC)
- Calculate the Reference **sinusoidal** 'virtual-sample' (200 samples)
  - The Reference frequency is:  $F_{\text{sample}}/A$ , where A is integer and  $F_{\text{sample}}$  is 200KHz
- Multiply the input sample with the Reference 'sample' and filter
- **Generate the Rectangular Reference frequency** for the D.U.T.
  - This is in phase with the Internally used sinusoidal Reference

# Sinus calculation



# Possible upgrades



## Sync the sampling

- Use main/aux SNT-LIA-MPU boards with updated firmware
- Aux LIA board sampling interrupt is driven from the main
  - Main outputs the sampling frequency on a new output pin
  - Aux receives the sampling frequency in a new input pin
- Aux sampling interrupt(200KHz) is generated from the input pin, not from internal timer

## Sample an external sinusoidal reference

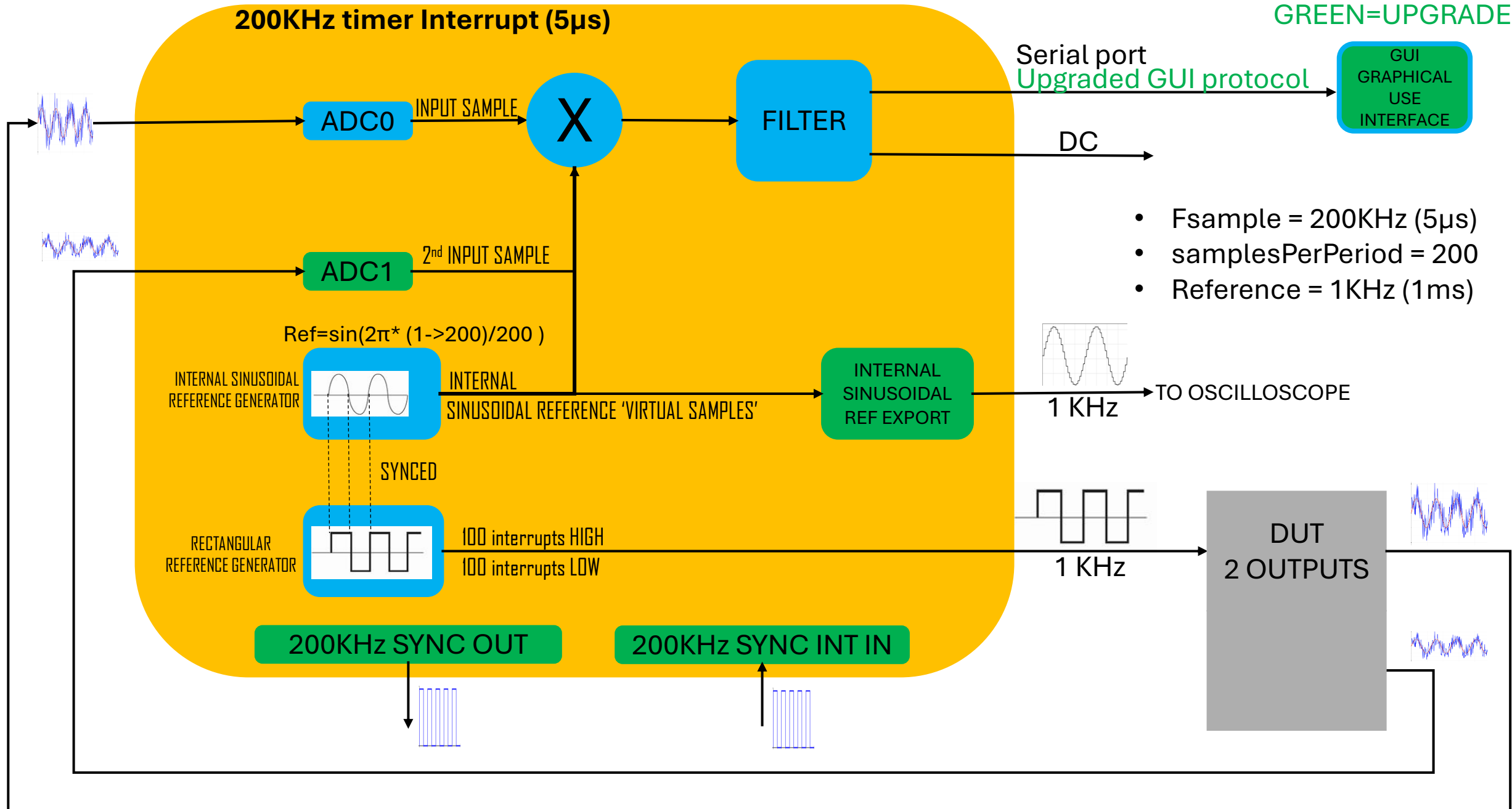
- Use a 2<sup>nd</sup> ADC analogue input pin
- Apply external sinusoidal external Reference to the new ADC analogue input
- Update the Firmware
  - Use the external ADC sampled sinusoidal Reference, instead the internally generated

## Monitor the internally generated sinusoidal Reference

- Add a new DAC chip and connect external oscilloscope for monitoring
  - Alternatively, export the sinusoidal Reference to a PWM output, without using a new DAC
- Update the firmware to export the sinusoidal Reference to DAC, or the PWM output

# LIA Sampling interrupt: Upgrade for 2<sup>nd</sup> Input

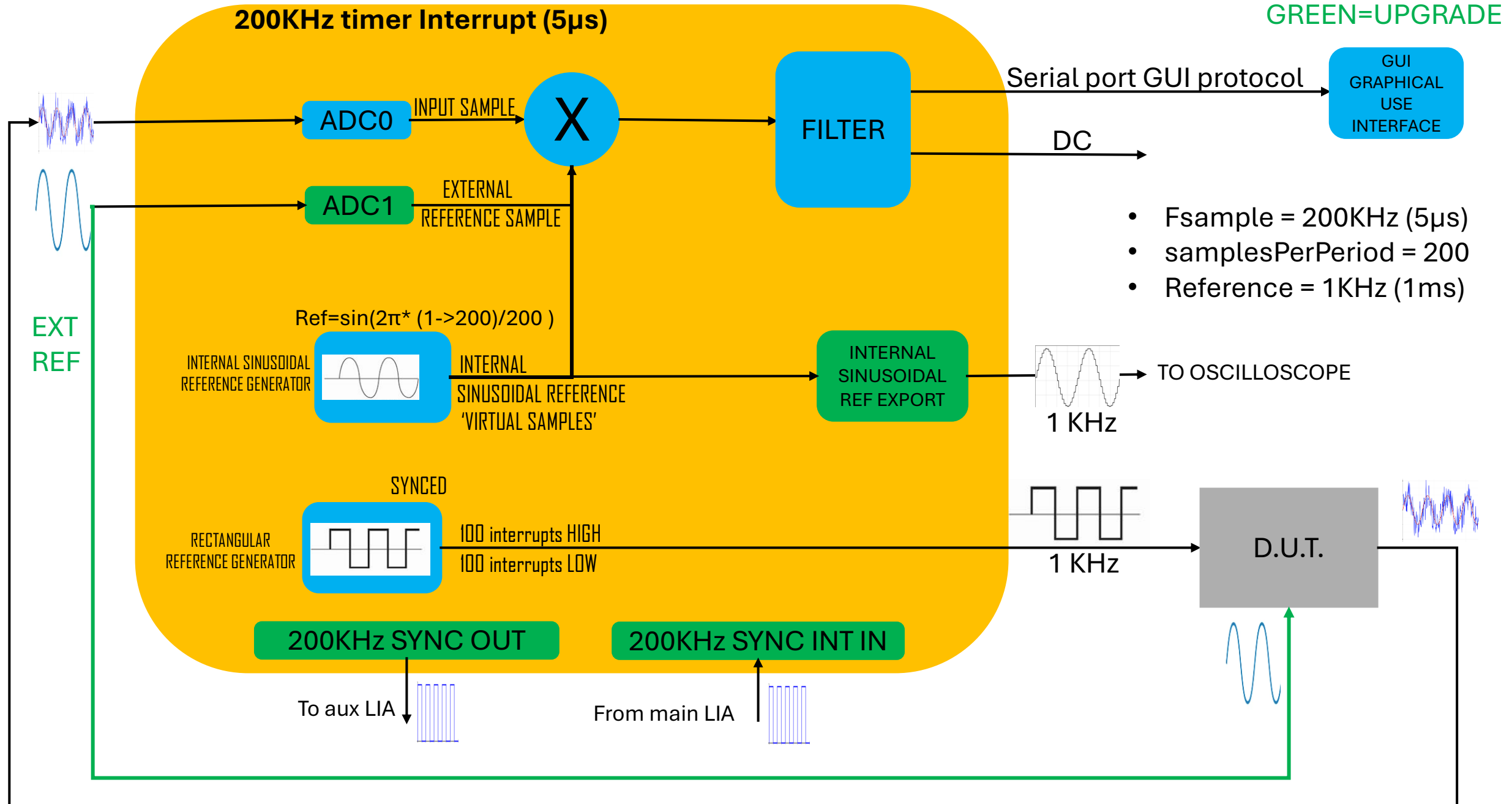
BLUE=CURRENT  
GREEN=UPGRADE



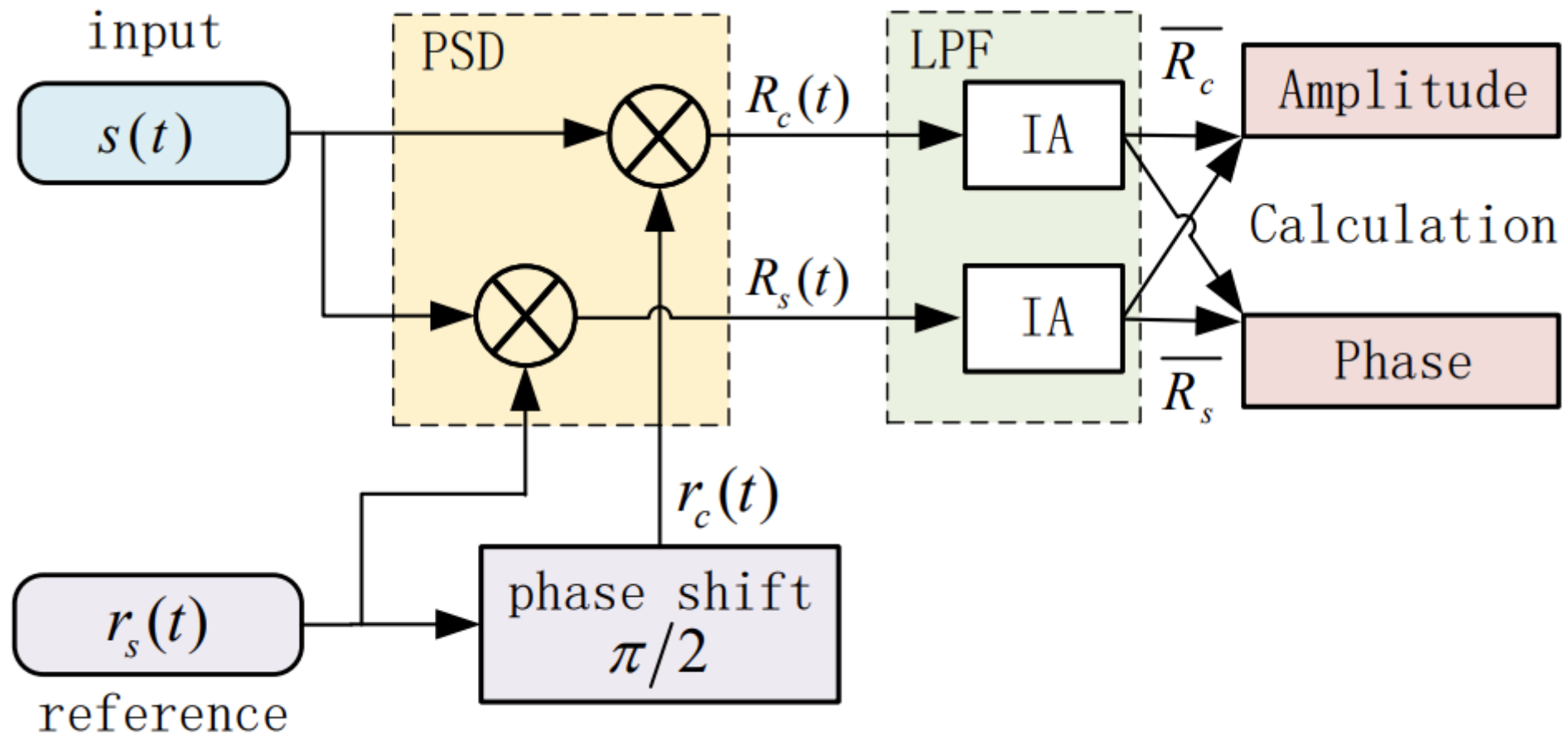


# LIA Sampling interrupt: Upgrade for external Reference

BLUE=CURRENT  
GREEN=UPGRADE



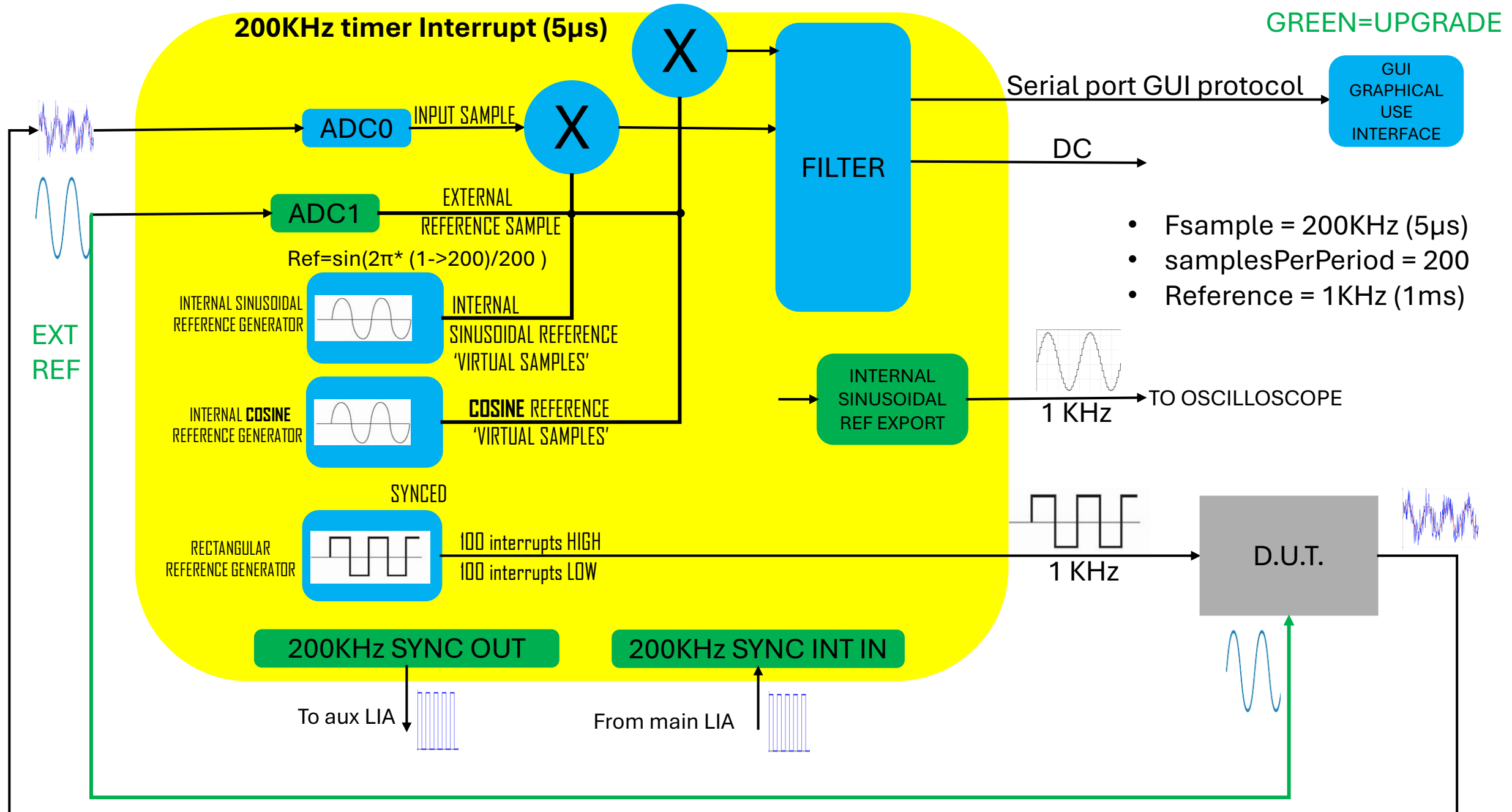
# Higher Level Diagram for Orthogonal LIA



**Figure 1.** Structure of the orthogonal lock-in amplifier.

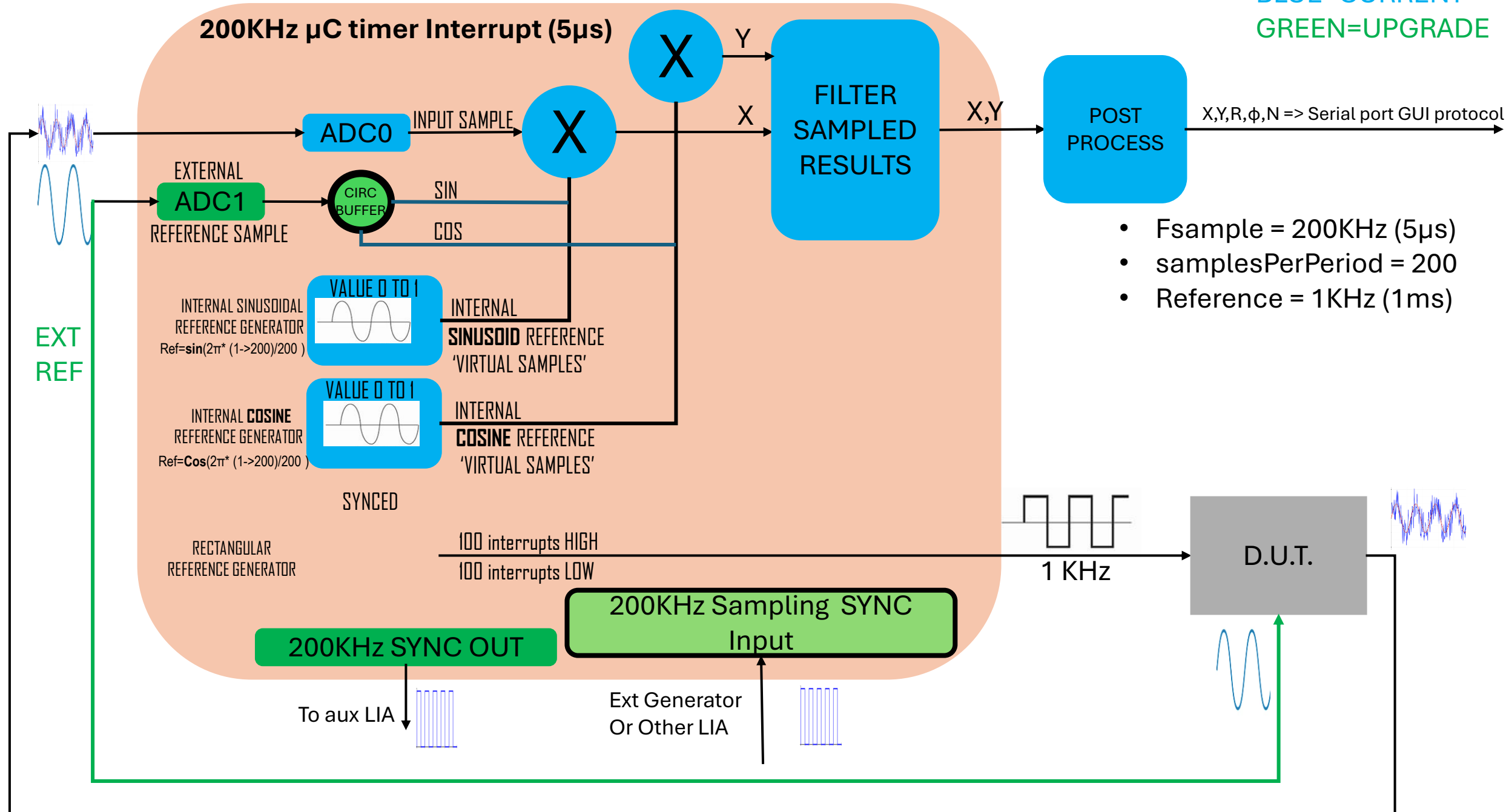
# LIA Sampling interrupt, Includes COS : Upgrade for external Reference

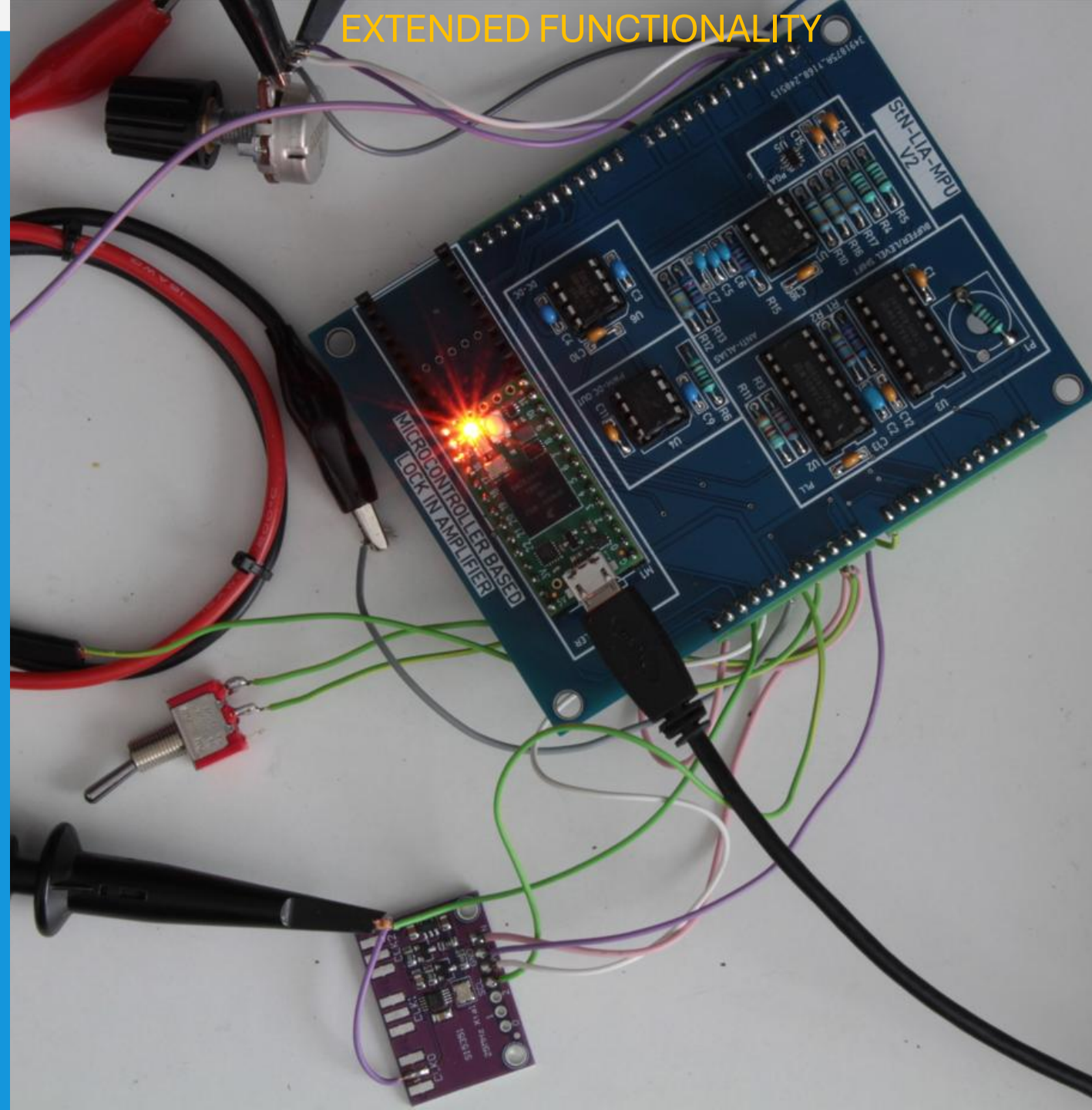
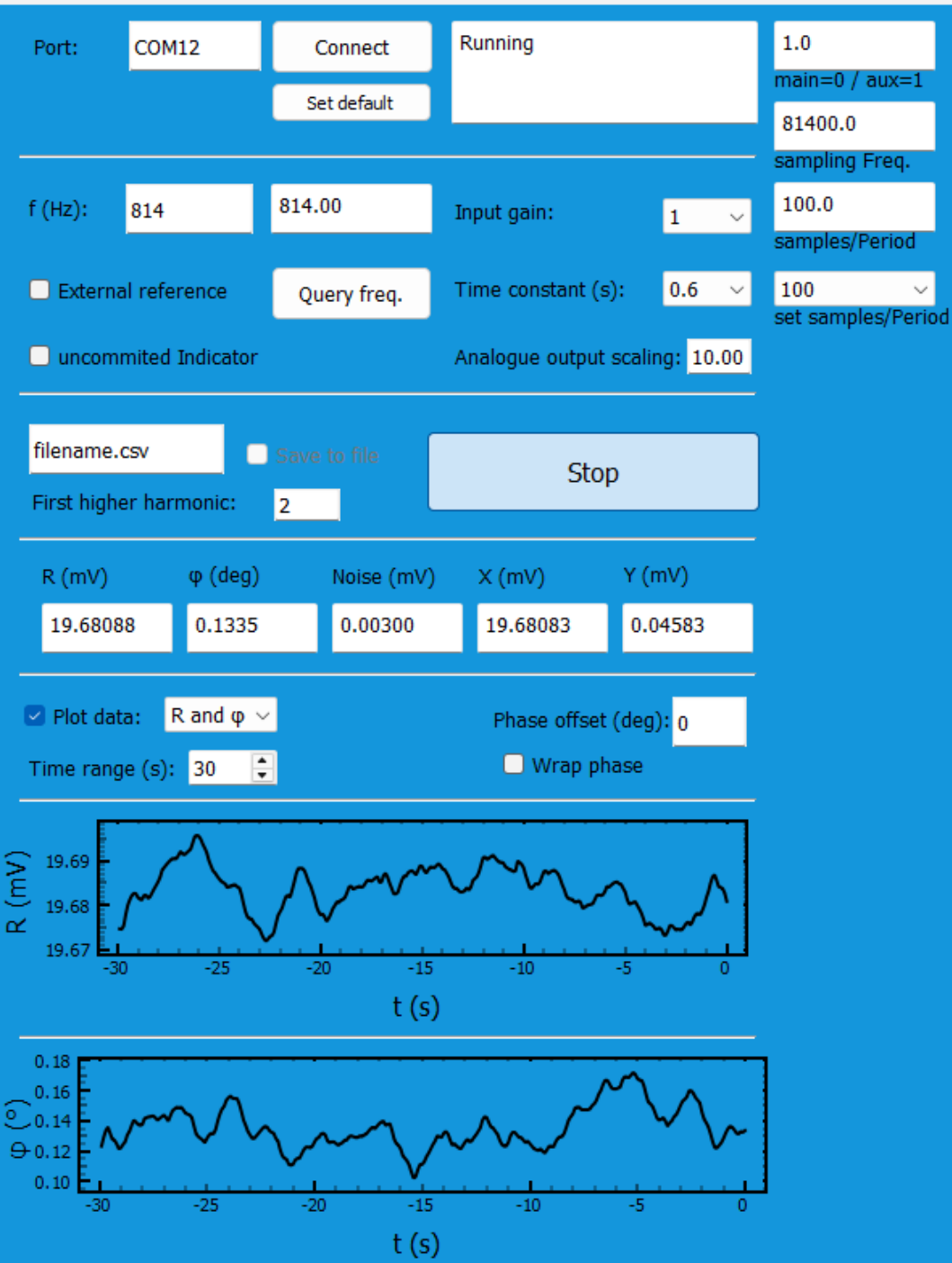
BLUE=CURRENT  
GREEN=UPGRADE



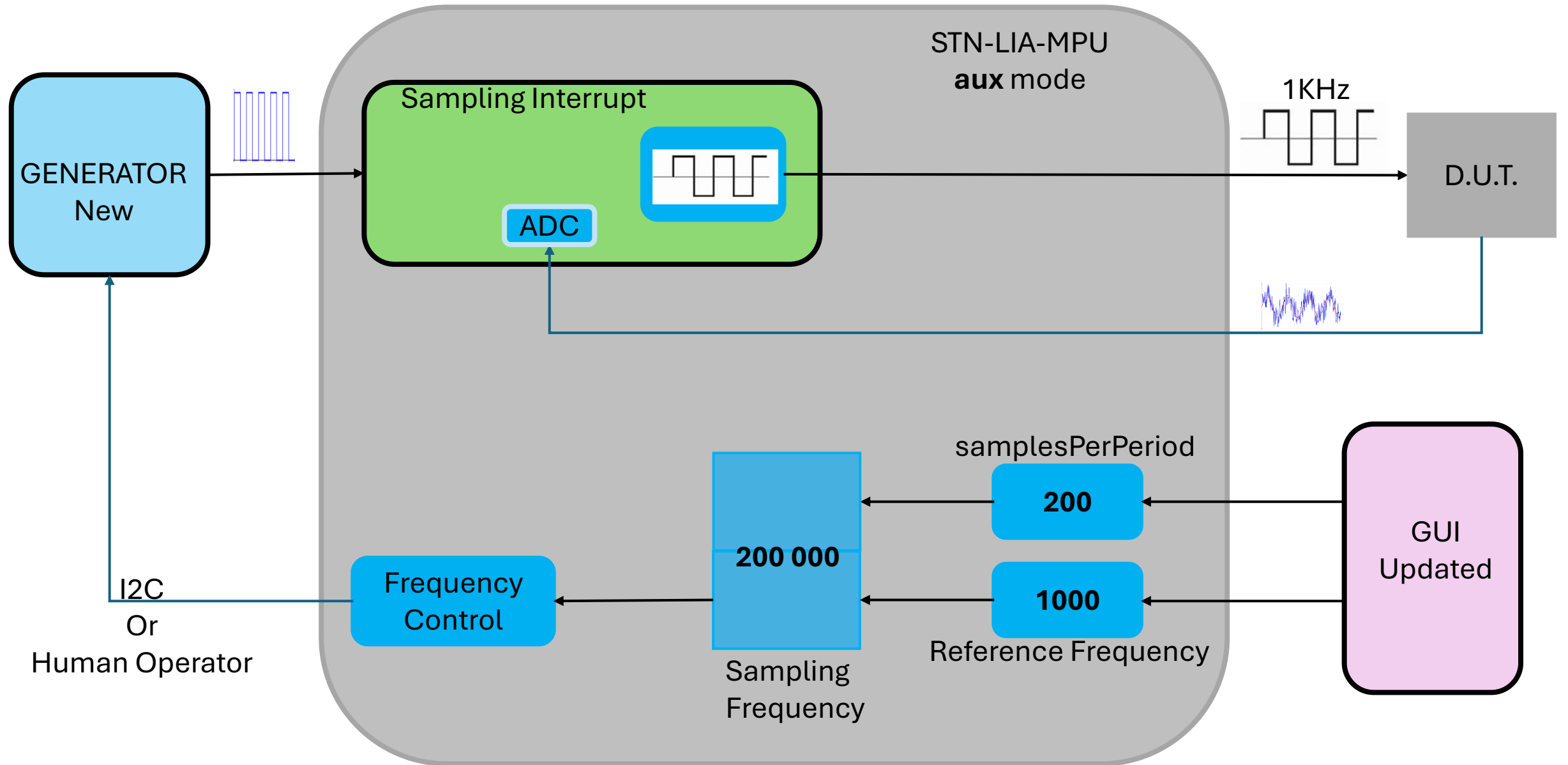
# LIA Sampling interrupt, with cos and circular buffer: Upgrade for external Reference

BLUE=CURRENT  
GREEN=UPGRADE



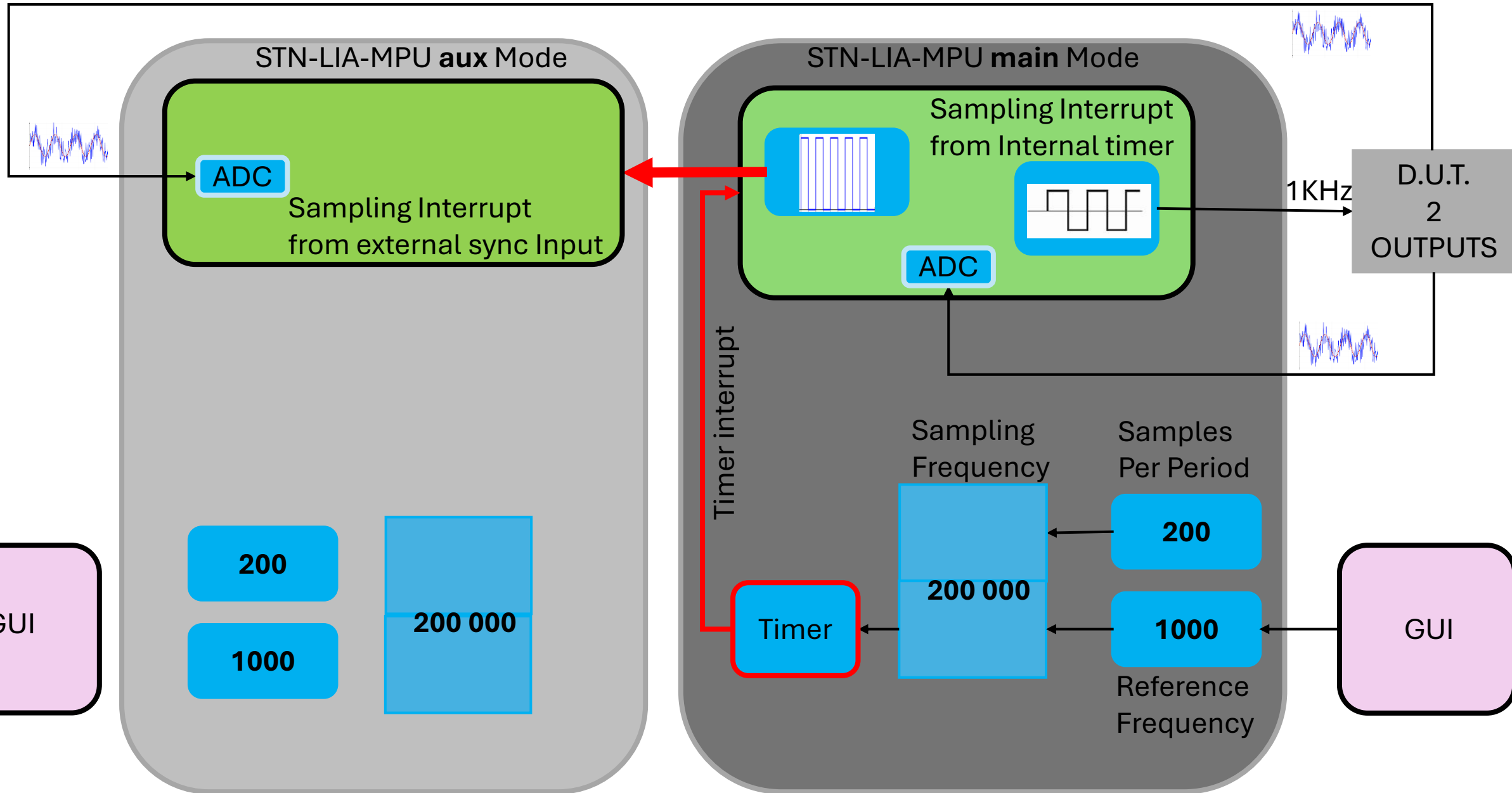


# StN-LIA-E: Extended Functionality





# StN-LIA-E: Two Synchronized Lock In Amplifiers



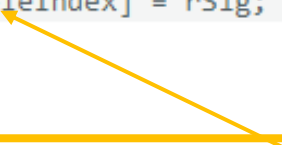
## LIA Sampling interrupt, Control with external Precise generator

- Any Frequency, including QEPAS resolution
- Precise [0.0001Hz] Frequency Resolution (0.01Hz / 100)
- Can be used as External Generator for a Bench Lock In Amplifier
- Synchronized operation of multiple STN-LIAs [solves UCC setup]
- With a small addition the PCB setup can produce sinusoid output in the audio Freq Range

# Synced Input ADC channels and Circular Buffer

## Synchronized reading of 2 ADC channels and circular buffer for the Reference

```
411 result = adc->readSynchronizedContinuous();  
412 result.result_adc0 = (double)result.result_adc0;  
413 result.result_adc1 = (double)result.result_adc1;  
414 xSig = result.result_adc0;  
415 rSig = result.result_adc1;  
416 adcBuffer[sampleIndex] = rSig; // Nikos: Experimental Circular buffer, collects sampleIndex samples of the sinusoid Reference Input,  
417
```



[0 to 199] for 1KHz and Sampling rate 200 KHz

The circular buffer for the sinusoid Reference signal Input, is used to create the **Cosine** of the Reference

# Sin and Cos implementation in C++

```

454 // Nikos: Below 2 lines are the core of the Lock In Amplifier
455 //calculate reference value and multiply (-1* because preamp is inverting) // Nikos: Sinusoidal Reference signal is created here, Is like sampling a 1000Hz sinu
456 phasSig = -1*sin(((2.0 * (j + 1) * pi * sampleIndex) / samplesPerPeriod) - ((j + 1) * phaseDiff));
457 //xi0 = (xSig*phasSig); //-1 because preamp is inverting // Nikos: Input sample is multiplied with Reference 'sample' here
458 xi0 = ( xSig * adcBuffer[sampleIndex]); // Nikos: Experimentall Multilpy the 2 ADC inputs: Signal Input / Sinusoidal Signal Input
459 | | | | | | | | | | | | | | | | | | // Nikos: Experimental Circular Buffer for the sinusoid external Reference, get the sin
460
461 //first smoothing
462 delta = xi0 - xiFilt1[j];
463 incr = alpha*delta;
464 xiFilt1[j] = xiFilt1[j] + incr;
465
466 //second smoothing
467 delta = xiFilt1[j] - xiFilt2[j];
468 incr = alpha*delta;
469 xiFilt2[j] = xiFilt2[j] + incr;
470
471 if (j == 0){ //skip to first higher harmonic
472 | j = firstHigherHarmonic - 2;
473 }
474 }
475 //same for quadrature harmonics
476 for (j = 0; j < lastHigherHarmonic; ++j){
477
478 //calculate reference value and multiply
479 quadSig = -1*cos(((2.0 * (j + 1) * pi * sampleIndex) / samplesPerPeriod) - ((j + 1) * phaseDiff));
480 //xq0 = (xSig*quadSig);
481 xq0 = ( xSig * adcBuffer[sampleIndex+49]); // Nikos: Experimental Circular Buffer for the sinusoid external Reference, get the cosine after samplesPerIndex/4
482

```

Cosine is  $1\pi$  (200/4 for 1KHz) later in the Circular Buffer

# Requirements discussion

We're looking for two signal channels driven by a single modulation source, ideally produced by the LIA, to modulate a single LED.

From the LED, we get two signals by splitting the light into two separate channels that are individually detected after the light passes through the sample. These need to be separately lockin amplified.

We would ideally want to get a sensitive measurement of the channels individually, or maybe just the ratio of the channels if that was more sensitive and could be determined directly.

I think this means:

one modulation source (in the LIA)

two input channels

lockin signal processing for two channels . It might be possible to do the two channels from the same op amp etc., but maybe not.

## **After 31/12/2024 call**

- Must measure 2 outputs from the D.U.T. in parallel
  - Implementation with 2 LIA boards that use external reference
  - Implementation with 2 signal inputs on the same LIA board, with internal reference
- Lower priority: Calibrate by measuring the PHASE  $\Phi$ , at different frequencies 1KHz to 10KHz

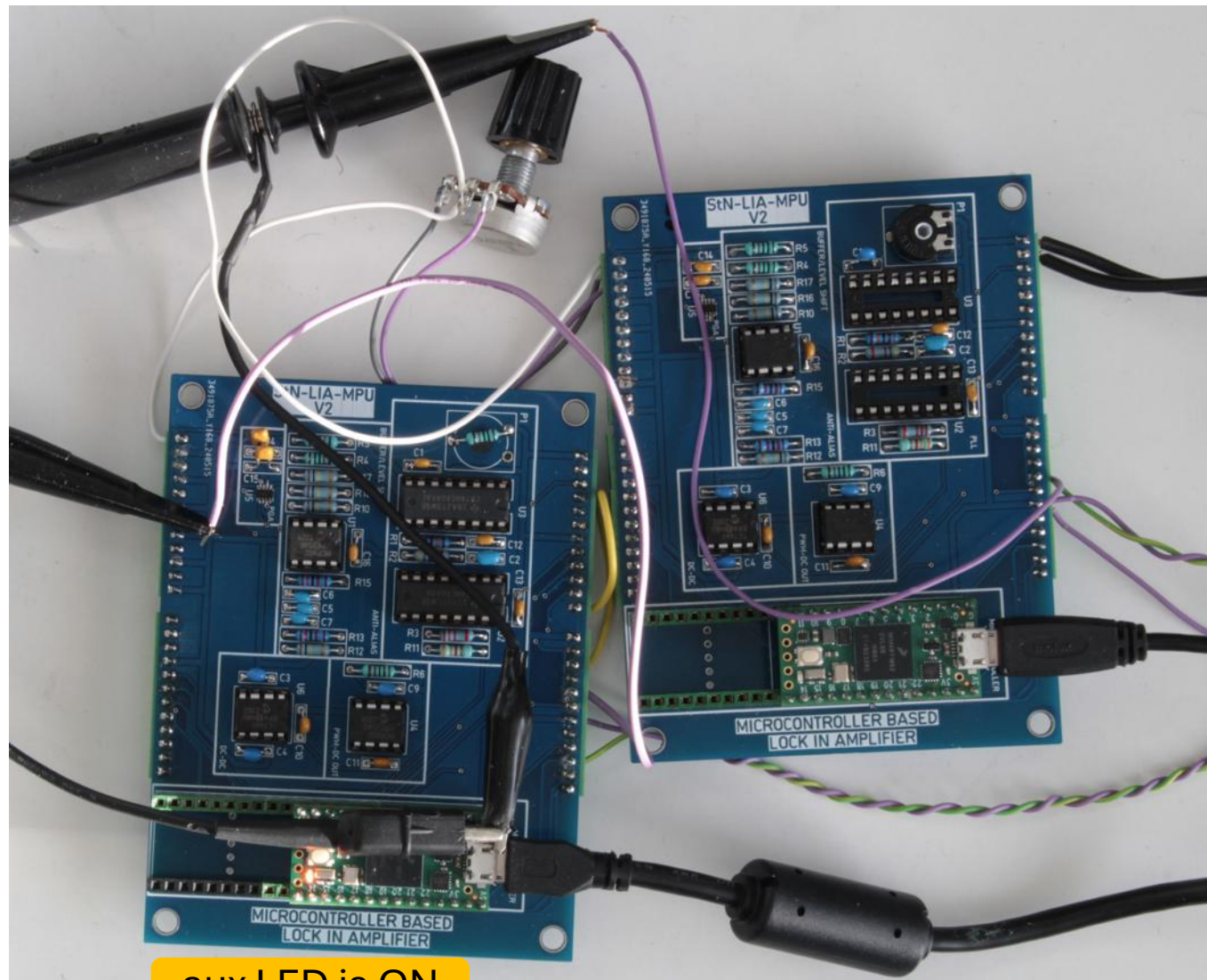
# UCC Requirements discussion: 31/12/2024 call

## **After 31/12/2024 call**

- Must measure in parallel, 2 outputs from the D.U.T.
  - Implementation with 2 LIA boards that use external reference
    - This option does not need extensive GUI updates
  - Implementation with 2 signal inputs on the same LIA board, uses only internal reference
    - Need major rework for the GUI
- Lower priority: Calibrate by measuring the PHASE  $\phi$ , at different frequencies 1KHz to 10KHz

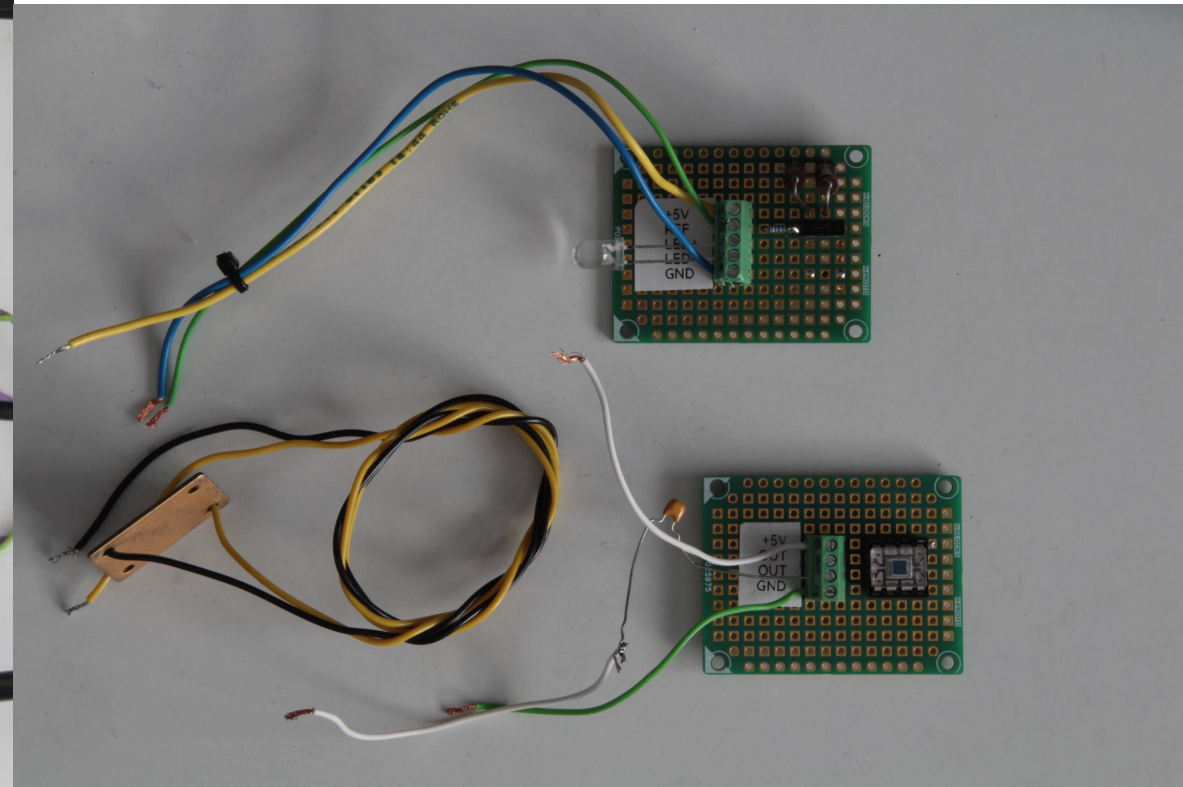


# Two PCBs tested in synchronization

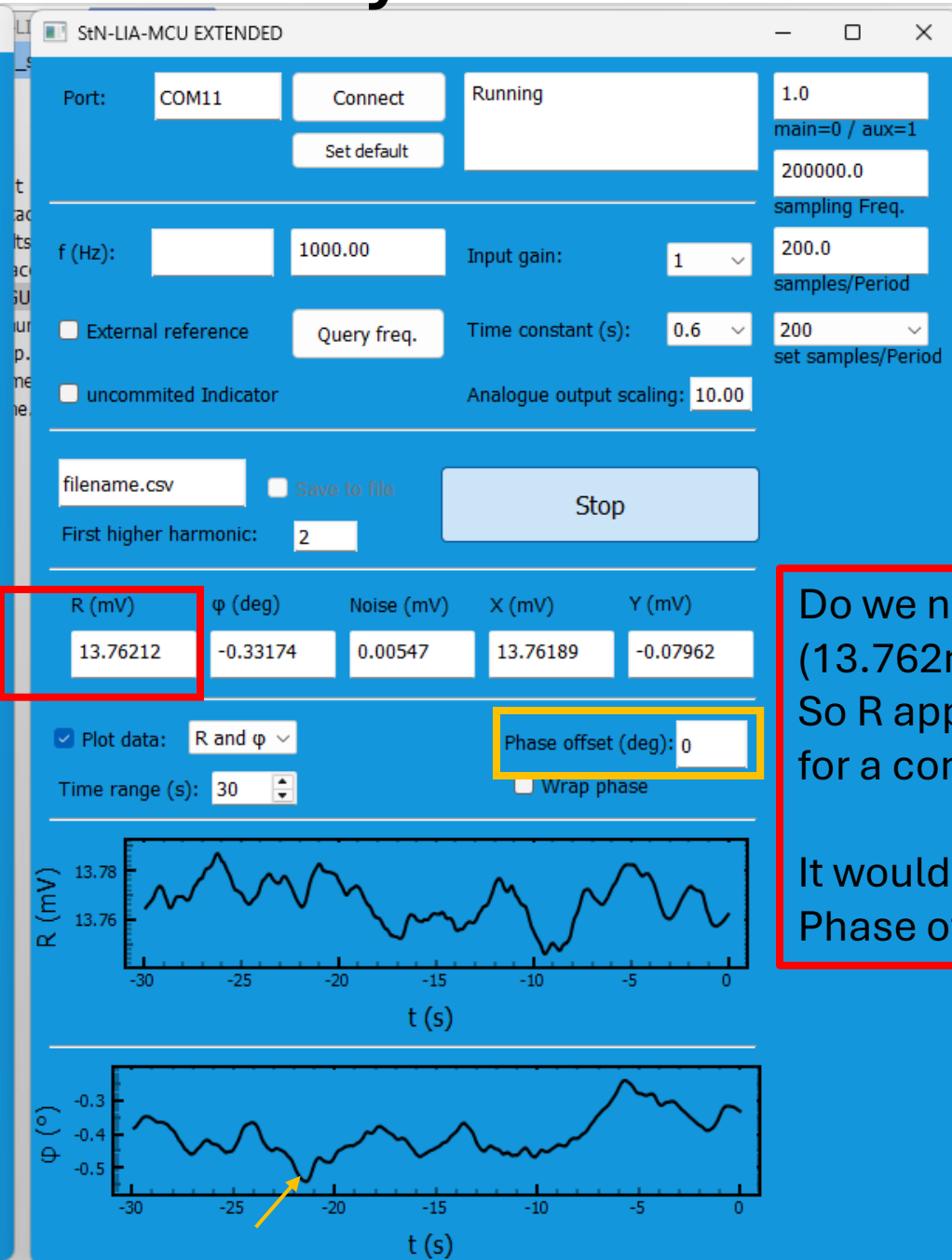


aux LED is ON

- Both PCBs have the same signal input (Potentiometer adjusted to 16mV)
- The Reference signal is created from the main PCB and drives to Potentiometer



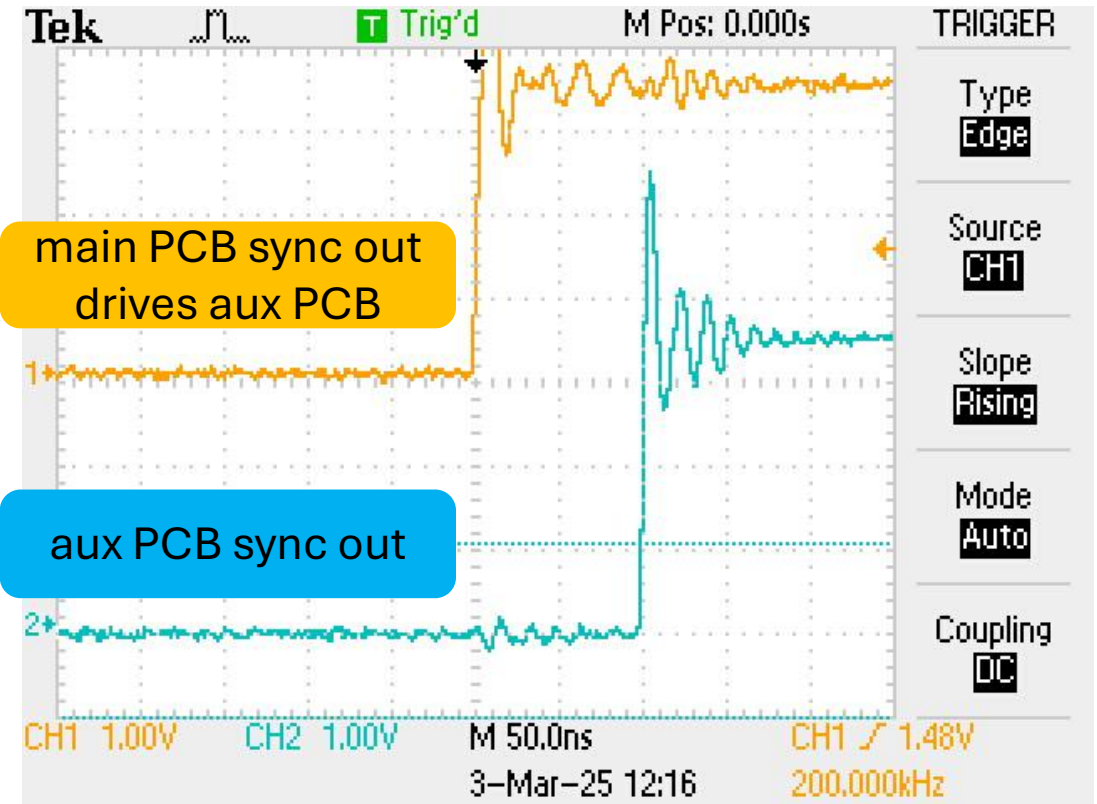
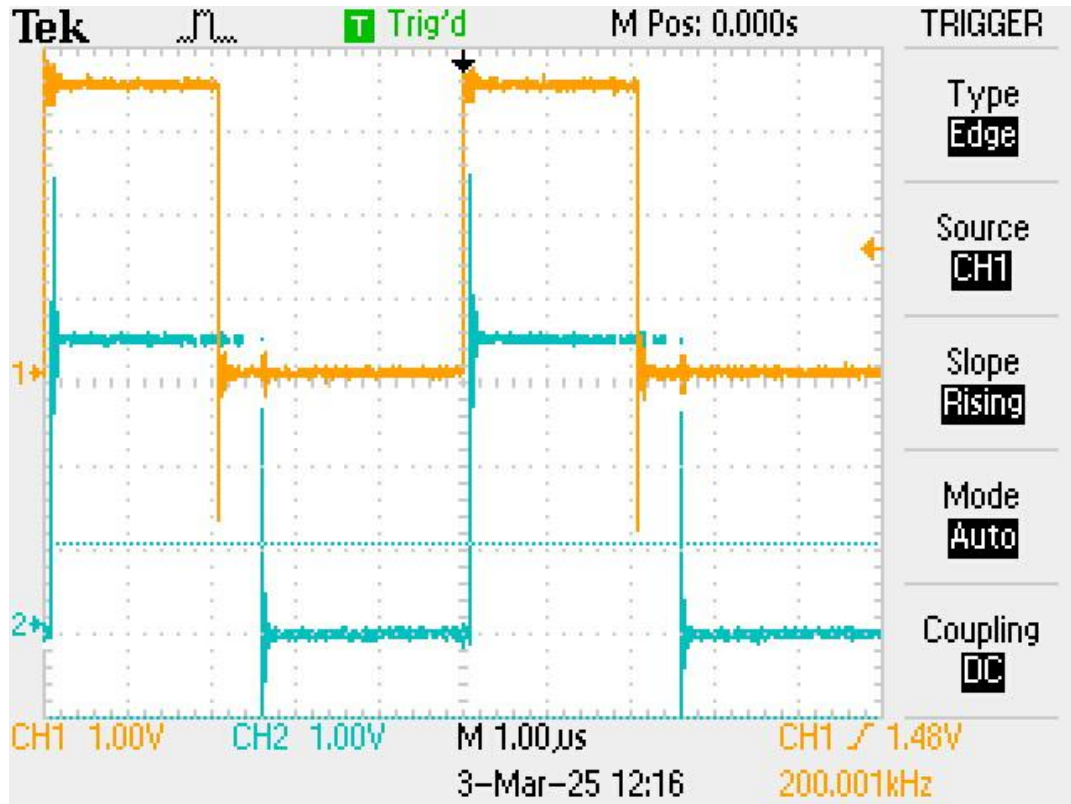
# Two PCBs tested in synchronization



Do we need R calibration Offset (13.762mV -13.52046mV here), So R appears exactly the same for a common input?

It would appear similar to the Phase offset **BOX**

# Two PCBs tested in synchronization

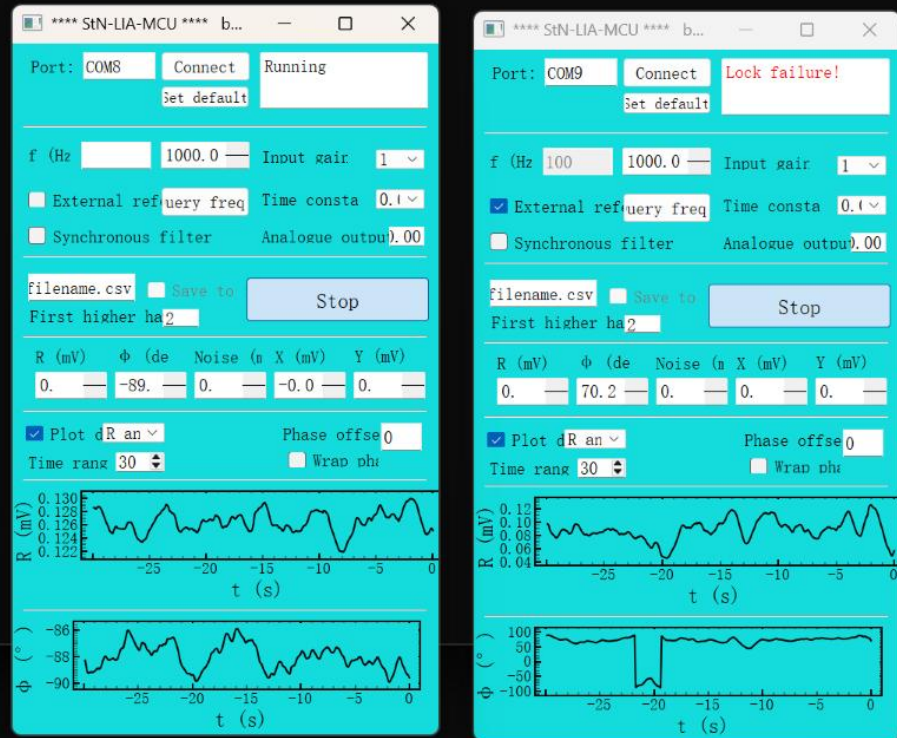


- The 2 PCBs are synchronized
- The aux PCB interrupt (sampling) has 100ns delay
- **The phase difference between the main and aux sampling is stable (100ns)**



# WRONG SETUP

main board → aux board



SETUP as reported at 29 April 2025:

- main (left) Board runs new firmware
- aux board (right, aka upper) runs old Firmware
- Running 2 instances of the OLD GUI

The visible results

- “Lock Failure” message
- R, Theta on right board seems inconsistent with very low values

Nikos notes:

- The setup is obviously wrong!
- Slide 20 (StN-LIA-E: Two Synchronized Lock In Amplifiers) thick RED ARROW is not implemented with old firmware
  - The [right, upper] aux board is not synchronized, as per slides 20,21,27,28,29

# new GUI (unconnected to boards)

StN-LIA-MCU EXTENDED

Port: COM12  Connect to a port to start measuring  main=0 / aux=1

f (Hz):  Input gain: 1  sampling Freq.   
samples/Period

☐ External reference  Time constant (s): 0.6  200   
set samples/Period

☐ uncommitted Indicator Analogue output scaling: 10

filename.csv ☐ Save to file

First higher harmonic: 2

R (mV)  $\phi$  (deg) Noise (mV) X (mV) Y (mV)

☐ Plot data: R and  $\phi$   Phase offset (deg): 0

Time range (s): 30  ☐ Wrap phase

R (mV)

$\phi$  (°)

main board → aux board

StN-LIA-MCU EXTENDED

Port: COM12  Connect to a port to start measuring  main=0 / aux=1

f (Hz):  Input gain: 1  sampling Freq.   
samples/Period

☐ External reference  Time constant (s): 0.6  200   
set samples/Period

☐ uncommitted Indicator Analogue output scaling: 10

filename.csv ☐ Save to file

First higher harmonic: 2

R (mV)  $\phi$  (deg) Noise (mV) X (mV) Y (mV)

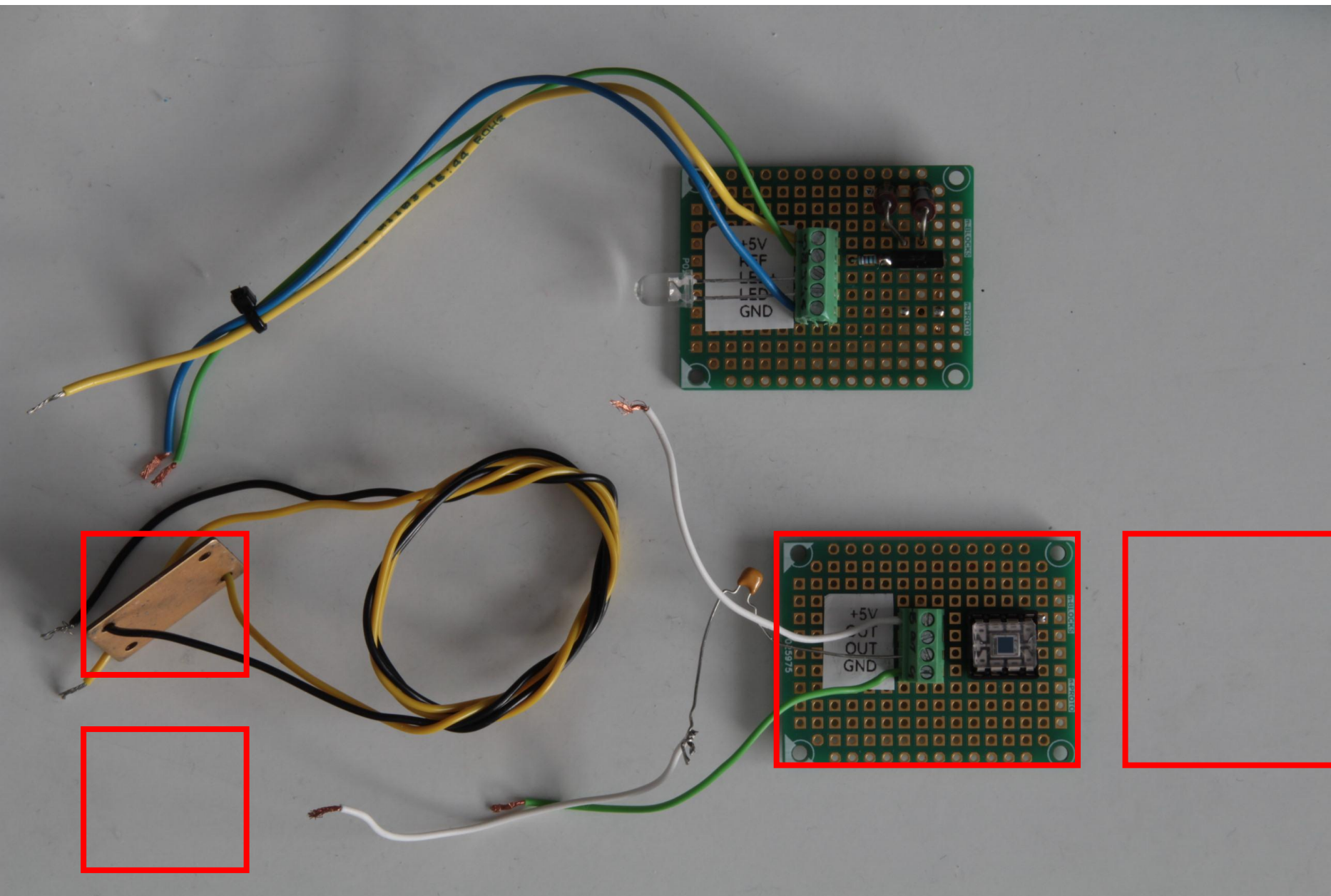
☒ Plot data: R and  $\phi$   Phase offset (deg): 0

Time range (s): 30  ☐ Wrap phase

R (mV)

$\phi$  (°)

# OPT101 SETUP



Expand with

- 2<sup>nd</sup> OPT101 PCB
- 2<sup>nd</sup> LED ???



# QUESTIONS