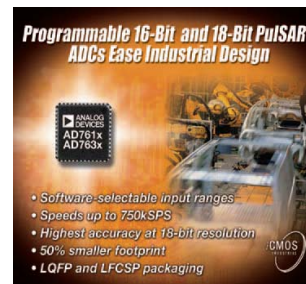
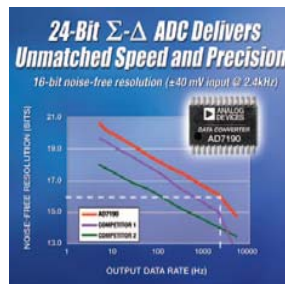
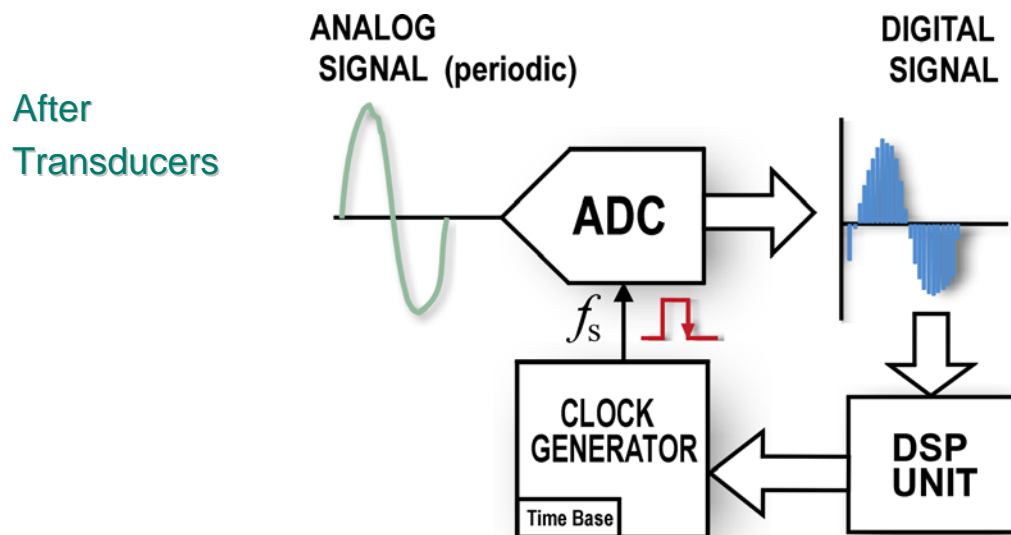


## PRECISION DIGITIZERS FOR POWER & ENERGY MEASUREMENTS

(W. G. Kürten Ihlenfeld – PTB)





## Metrology Grade Digitising Technology for Power Quality Measurements (PTB, NPL, MIKES, TRESICAL, VSL, METAS, LNE, INRIM)

- 1. Compact three phase voltage digitiser up to the 50th harmonic of the mains (PTB).**
  - a) ADC interface with USB to PC, b) self-cal., c) Self-Locking (pat. pending) & asynch, c) DSP is a PC, d) Ultra-Linear & unc. < 10 ppm, e) for lab. applic. (RMS, Phase, Ratio, & self-checking), f) Allow other ADCs to be used, e.g., A3458A, AD7763 (Sigma-Delta) & SAR AD7767.
- 2. Portable three phase digitiser for on-site measurement of the high voltage grid (NPL, MIKES).**
  - a) ADC 7767 interfaced to AD DSP (pre-processing data) & Wireless data transfer, b) asynch. Sampling, c) further DSP is a PC, d) Ultra-Linear & unc. < 50 ppm (close to above), e) for live lines.
- 3. & 4. Wide band digitisers for transient and impulse measurements (TRESICAL, VSL).**
- 5. Metrological characterisation of digitisers (METAS, LNE, INRIM, VSL).**

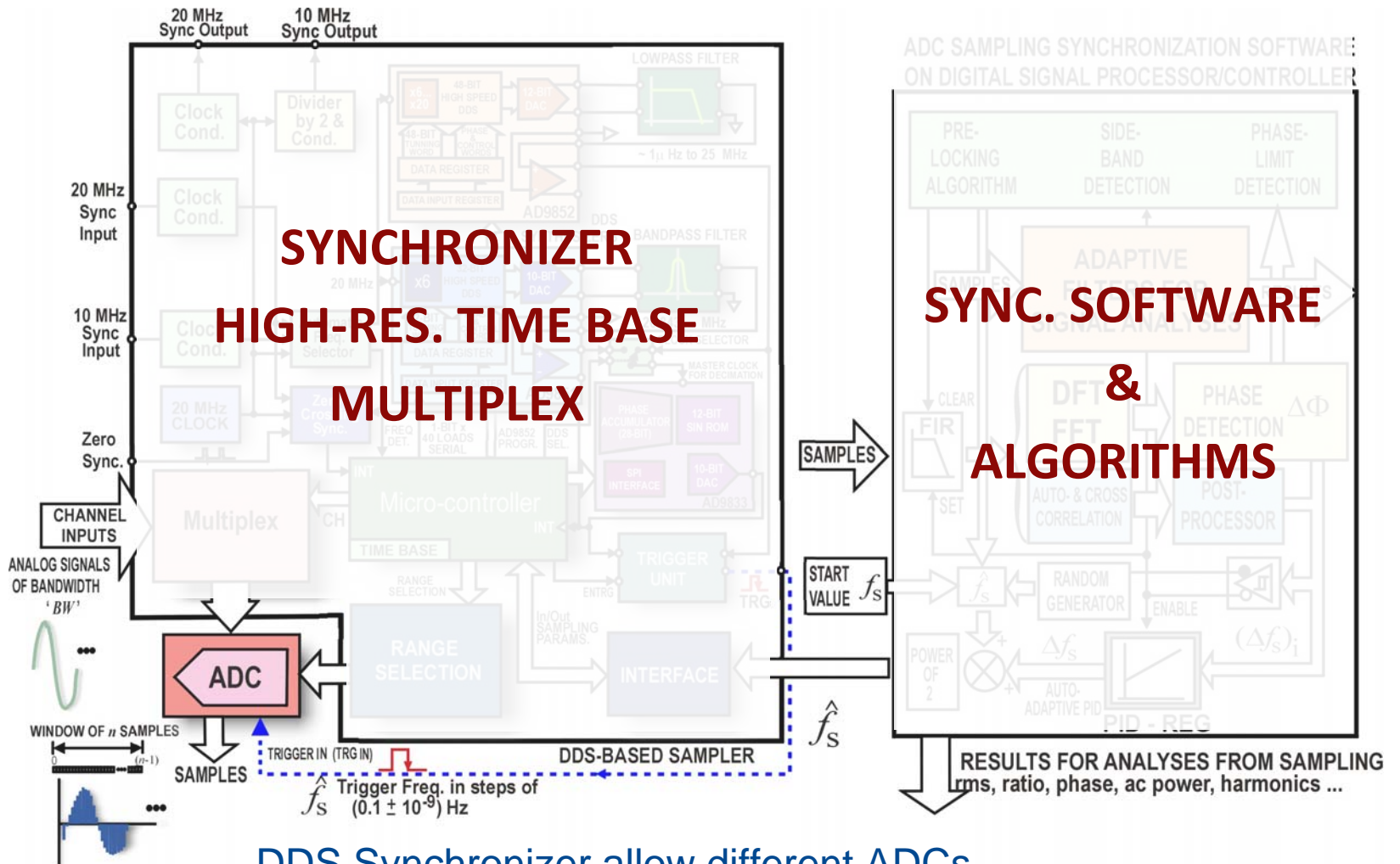


## Compact three phase voltage digitiser with a frequency range up to the 50th harmonic of the mains (PTB)

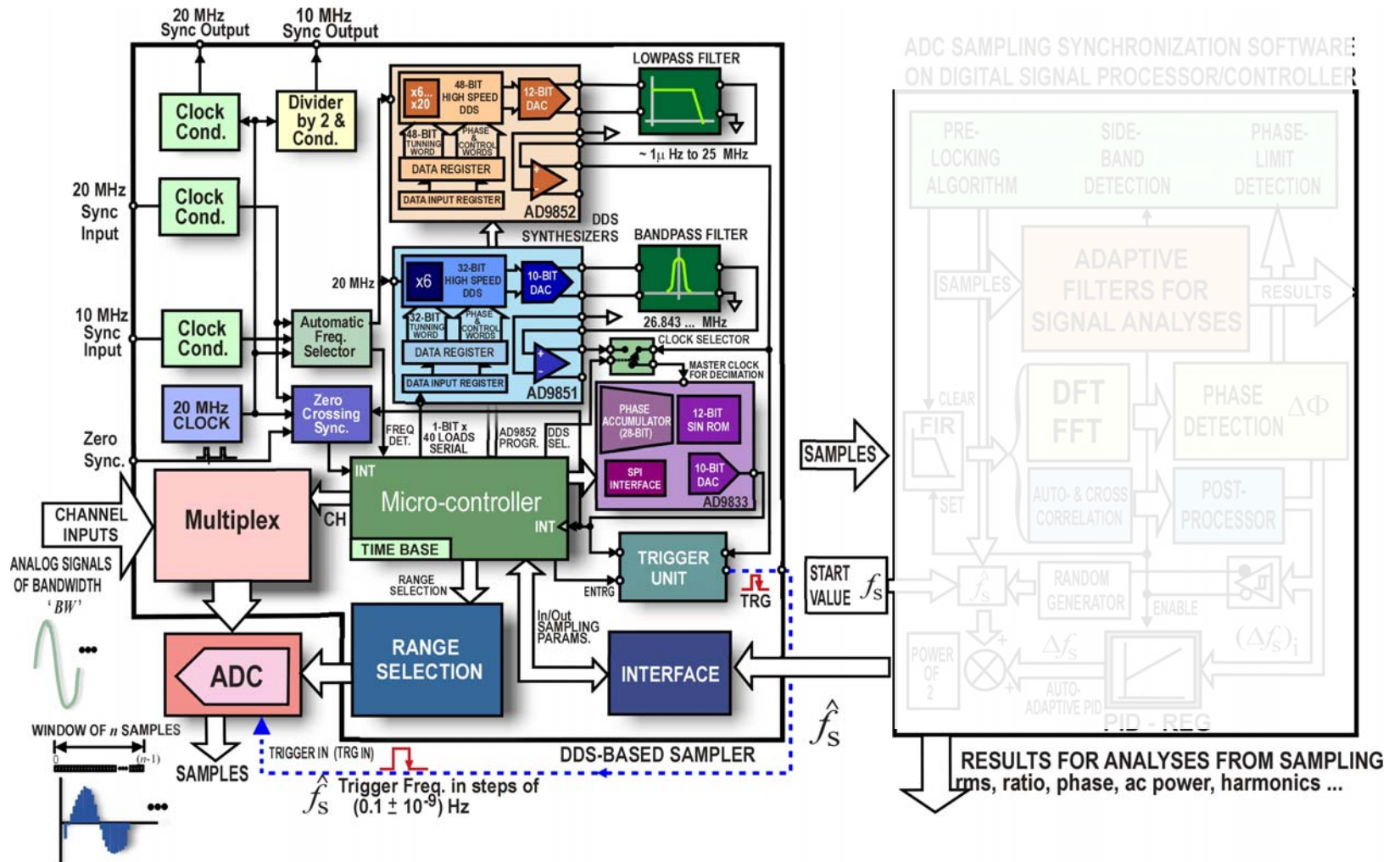
Design constraints:

- uncertainties  $< 10E-6$  V/V
- compact
- self-locking<sup>1</sup> (digitally)
- easy calibration (chopped DC & AC)
- ac metrology: phase, ratio, ac power...
- any ADC (IADC, SAR, S-D)
- intelligent (?, algorithms)

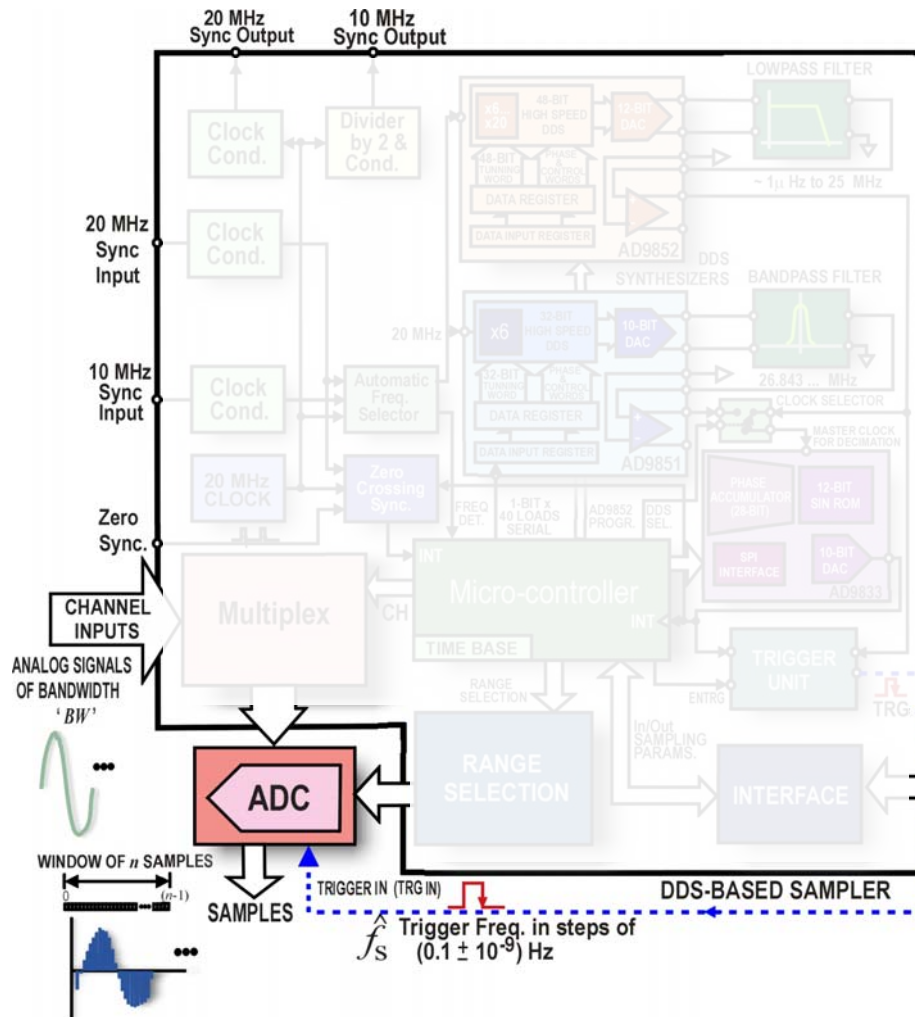
<sup>1</sup> German Patent Application DE 10 **2007** 043 927 A1



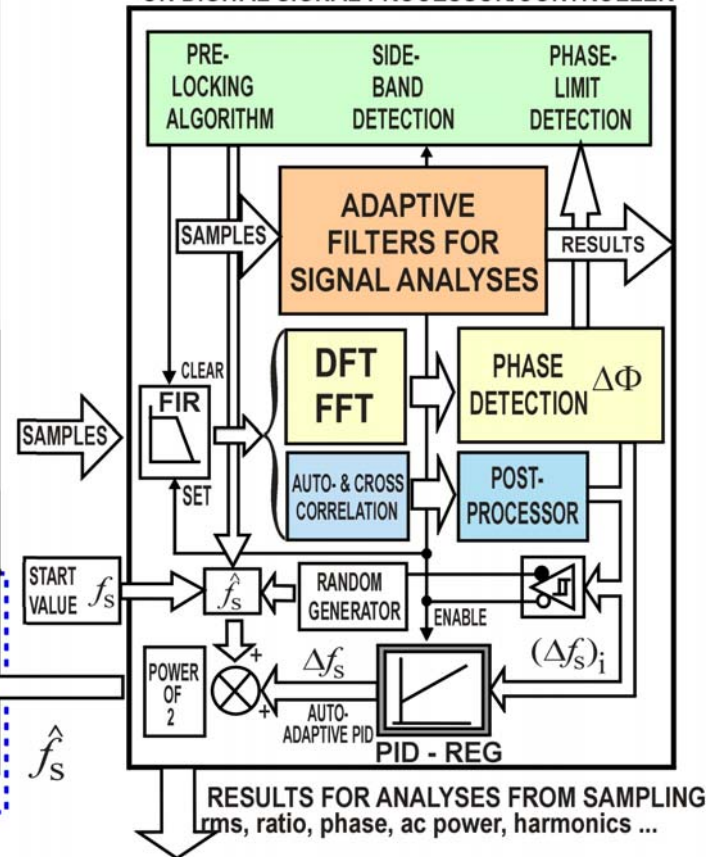
DDS Synchronizer allow different ADCs to be synchronized: Sigma-Delta, SAR, Dual-Slope

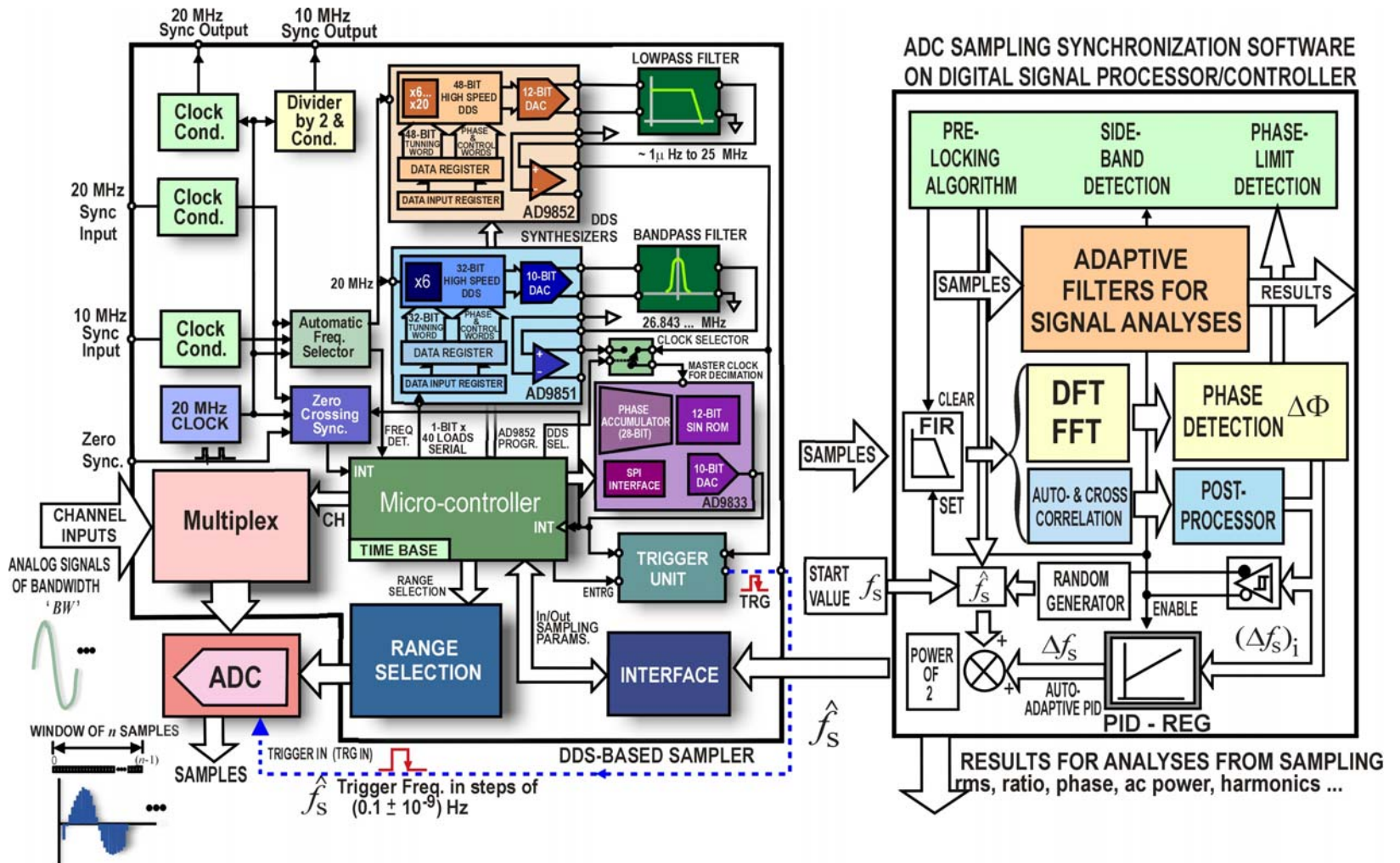


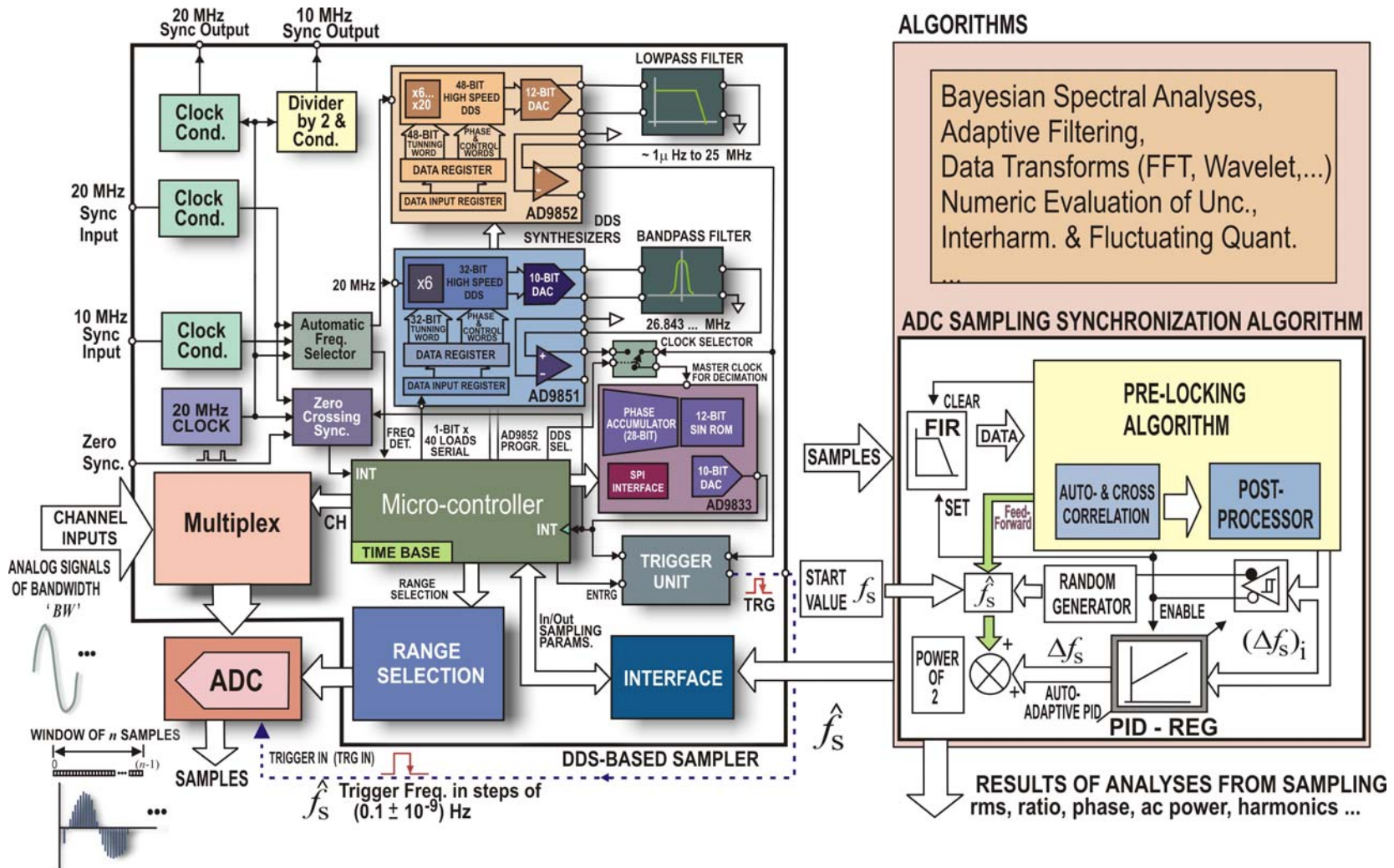




## ADC SAMPLING SYNCHRONIZATION SOFTWARE ON DIGITAL SIGNAL PROCESSOR/CONTROLLER











# Compact three phase voltage digitiser Software (on PC)



**Frequency Synchronization**

Communication System parameters Measurements Setup Service Help

Channel | Ratio

Channel1 | Channel2

Sub - Harmonic: 8 Harmonic: 1

Magnitude:  $4.2816484E-1$  V u Magnitude:  $2.8E-4$  V/V

Standard deviation:  $1.55E-6$  V/V

Angle:  $6.490769E-6$  rad u Angle:  $7.92E-5$  rad

**Magnitude / Spectrum in dB**

**Ch 1 Spectrum in dB**

**Ch 2 Spectrum in dB**

**Legend:**

- phase - locking
- measurement ready
- power-of-two per period
- log synchronization

No. locking - trails: 17151

Sampling Freq.(Fs): 127998.0538 Hz Bandwidth: 50000 Hz

Aperture Time [s]: 0

No. Samples (n): 16384

Samples/Per (N): 2048 Periods (M): 8

d Fs [Hz]:  $-6.84E-3$  d Phase [rad]:  $-5.35E-8$

$-2.71E-2$   $-2.11E-7$

$6.27E-2$   $4.9E-7$

Freq. F1 [Hz]: 62.49905440 Phase F1 [°]: 8.981209E1

Red Lobe (A-) [V]:  $2.8874935E-6$  Blue Lobe (A+) [V]:  $6.639299E-7$

Magnitude (Ai):  $4.2816466E-1$  V  
RMS (Ai):  $3.0275814E-1$  V

Soft Sync off  
 Simulate

Start Measuring Cancel / Stop

Sampling the signal - reading ADC7767



# Compact three phase voltage digitiser Software (on PC)



**Communication Device - Parameter**

Serial Communication: Serial Port: COM1, Baud Rate: 115200, Number of Bits: 8,  Serial activate

NoChannels:  1 Channel,  2 Channels,  3 Channels,  4 Channels,  5 Channels,  6 Channels,  7 Channels,  8 Channels

Sigma-Delta ADC: Reference Clock MHz: 20, Clock Correction: 1, DDS ID: AD9852, DDS Multiplier: 6, Device Address: 0

DVM\_3458A: Device Address No.: 4, Aperture Time (us): 100, Ti-Margin (us): 25, Range:  1000 V,  100 V,  10 V,  1 V,  0.1 V

ADC7767:  activate, Reference Voltage: 4.078

Sync-Board DDS:  DDS B and C, Multiplier: 6, Decimation: 8

Source Trig.Freq:  Source GPIB, GPIB Address: 11,  Sync-Board, Wait No. of Periods: 10, Communication:  Serial,  USB, Clock:  20MHz,  10MHz, Clock Correction: 1, No. of Periods: 16, No. of Samples: 16

Transfer Format:  ASCII,  DINT,  SREAL,  ASCII single Value,  DINT single Value,  SREAL single Value

DSDC activate

Update from Setup, OK

**System - Parameter**

Regulation / Regler: Time Component: 0,3, Proportional Component: 0,3, Derivative Component: 0, Threshold Hardness:  1000e-6

Synchronisation:  Target Periods Active, Target Periods: 16,  Const. Samples, Synchronization Channel: 1, Synchronization Alg.:  FFT,  Autocorr. + FFT

Power-Line Frequency:  50 Hz,  60 Hz

Power of Two:  Active, Searching:  Once,  Smallest, Threshold [V/V]: 1e-4, No. of Phase-Locking: 5

Compute Uncertainty:  dPhase < Threshold, Threshold: 1e-9,  Automatic

Clamping:  Activate, Clamping Voltage: 1

Signal Correction:  by Phase, Per. Factor: 1e-6, Noise Limit: 1e-6

Update from Setup, OK

**Windowing**

Window Function:  Rectangle,  Bartlet,  Hamming,  Blackmann,  Blackmann - Harris 3 Term (-67dB),  Blackmann - Harris 3 Term (-61dB),  Blackmann - Harris 4 Term (-92dB),  Blackmann - Harris 4 Term (-74dB)

Update from Setup, OK

**Applied Instruments**

Current Transducer CT 2 Channel, Voltage Transducer VT 1 Channel

Range: 0.1A, 0.2A, 0.5A, 1A, 2A, 5A, 10A, 20A, 50A, 100A, 200A, 500A, 1000A

File: Load, Save

VT Over-range Settings: 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000

Threshold Analysis List: No. of Periods, No. of Samples, No. of Cycles

Refresh, Exit

**Parameter: Measurements & Logging**

Compute Measurement Uncertainties, No. Phases Active: 1

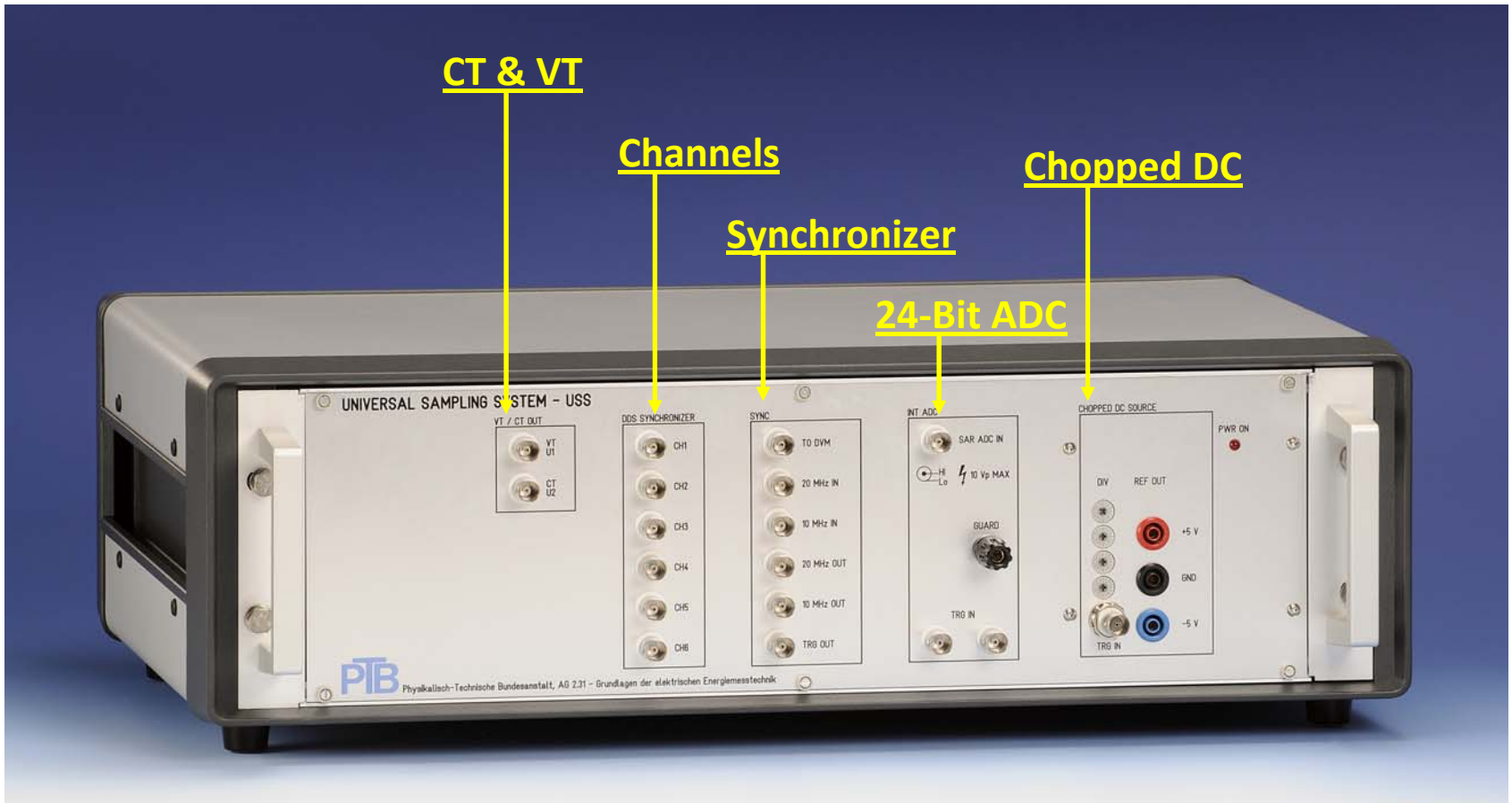
Computation:  Moving Average of 10,  Ratio,  Power,  Normalized Power,  Energie Kwh: 0,0,  IEEE,  Flicker,  Capacitance

Protocol:  Channels,  Ratio,  Power,  Normalized Power,  IEEE,  Flicker,  Capacitance

Phases	Channel1	Channel2
1.Phase	1	2
2.Phase	3	4
3.Phase	5	6
4.Phase	7	8

Update from Setup, Signal Logfile, OK

Calibration,  Log Harmonic: 1,  Log Synchronization,  Log Sub-Harmonic: 1



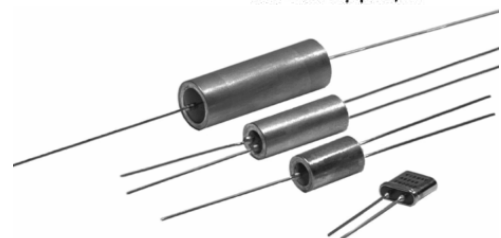
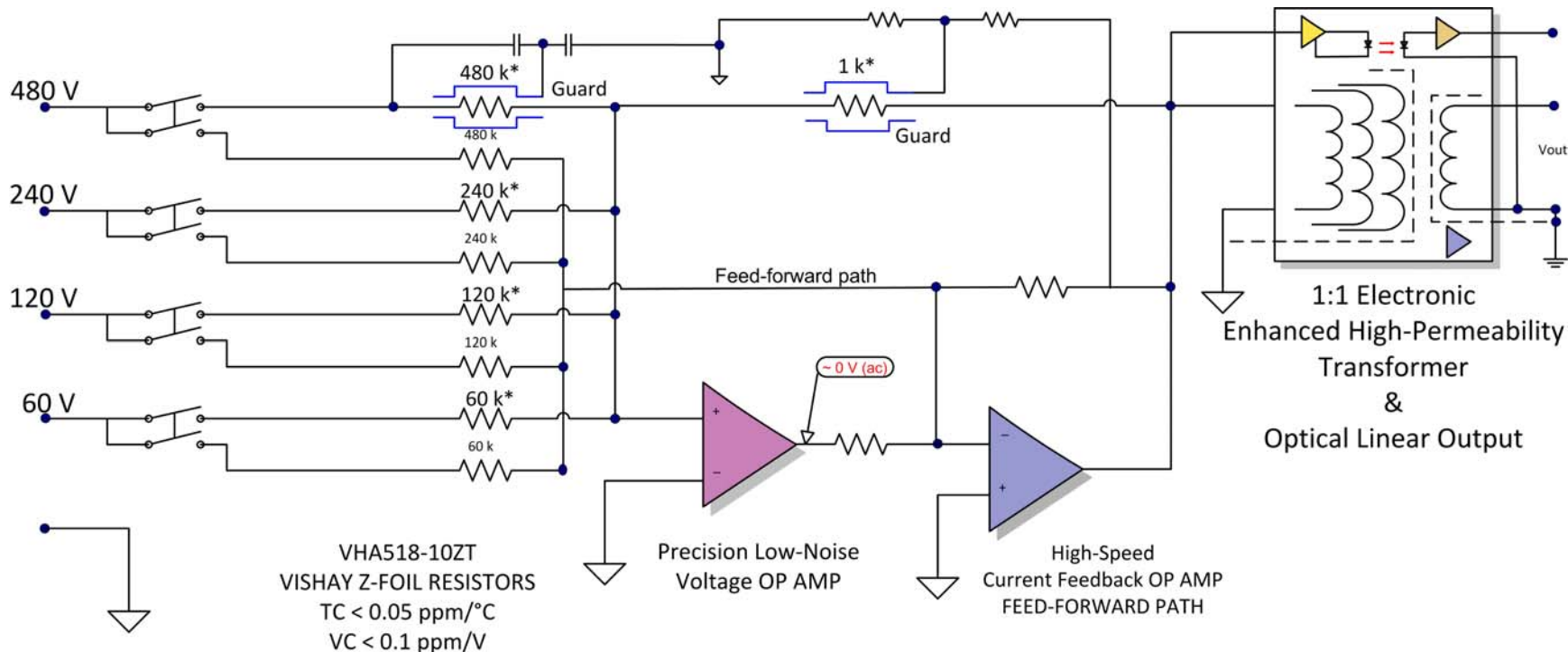
**Internal SAR ADC 24 Bit, max. 128 kHz, Nonlinearity < 10 ppm!**



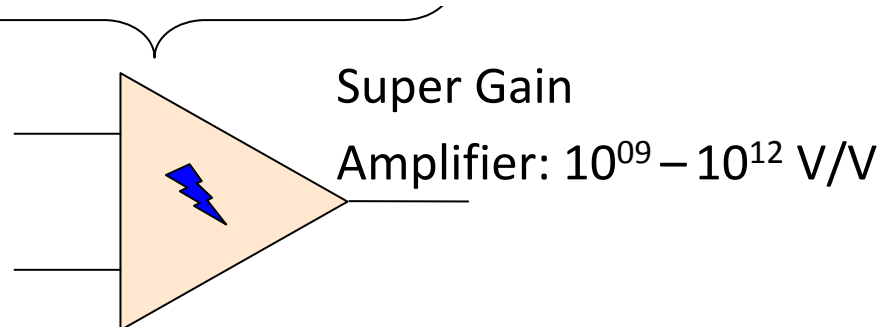




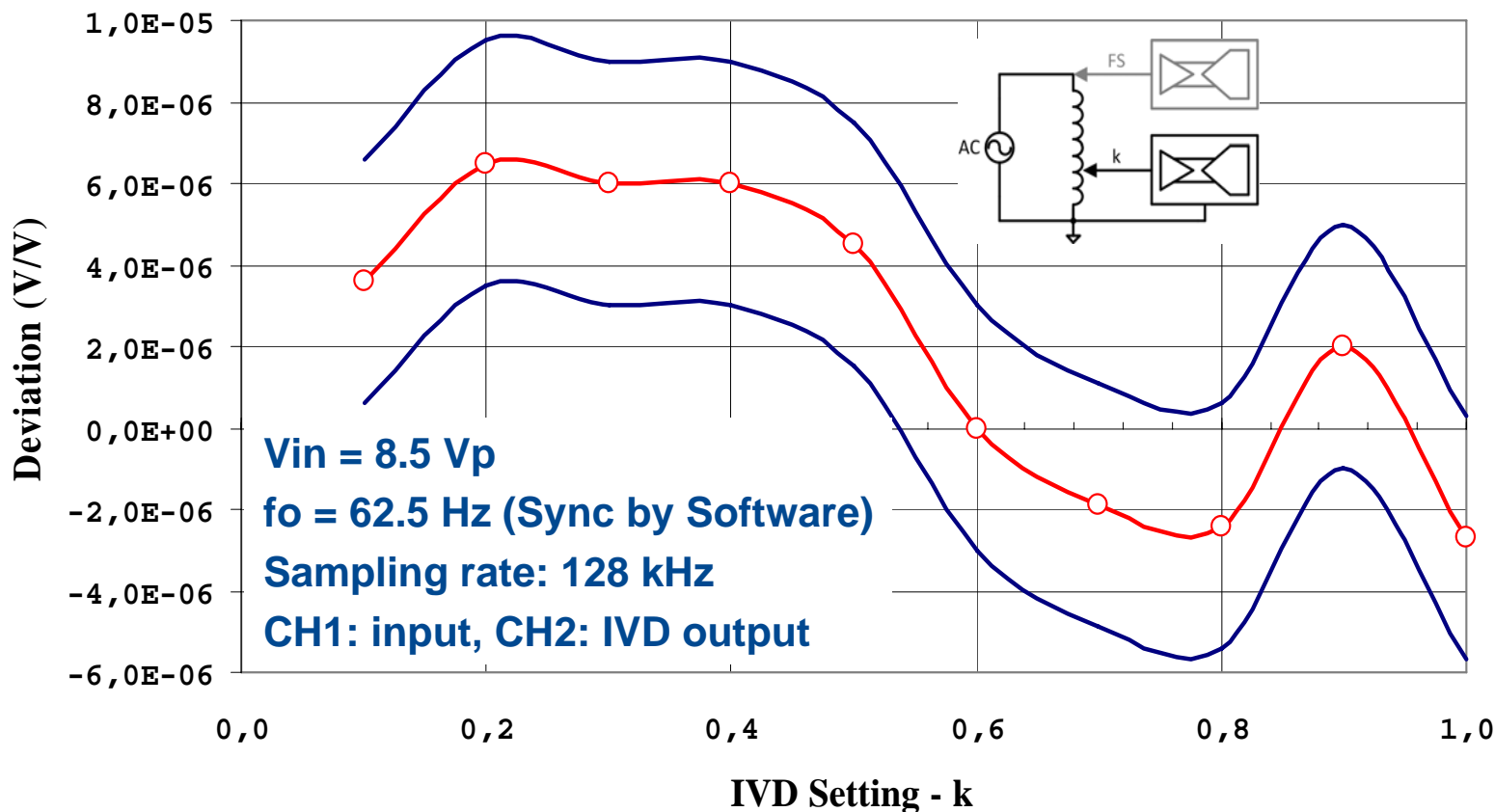
# Compact three phase voltage digitiser Voltage Transformer



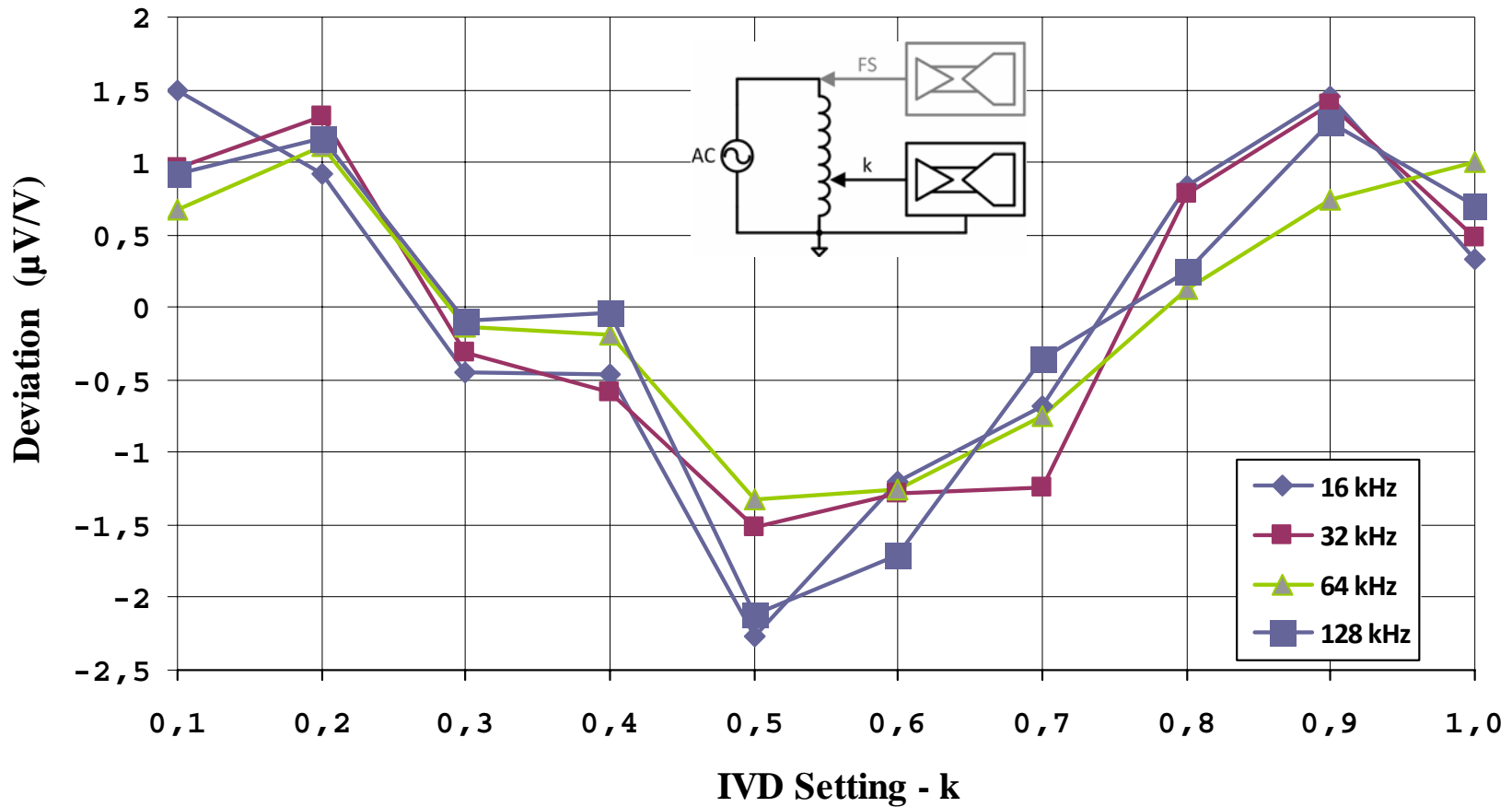
H-Series (Z-Foil) hermetically sealed  
Time-constant < 1ns



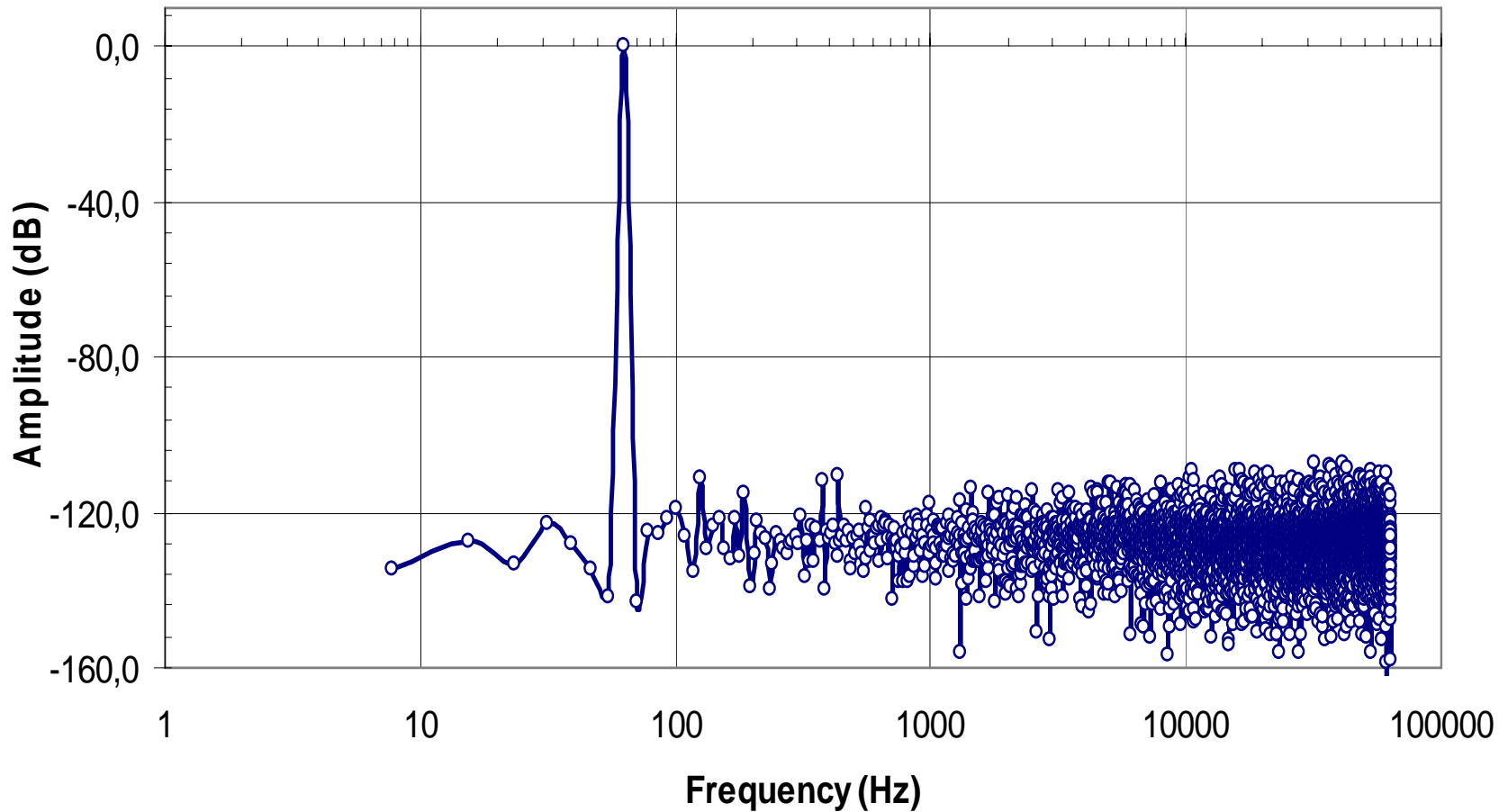
### Nonlinearity ADC of USS from Ratio Measurements



### Nonlinearity ADC of USS from RMS Meas



### Spectrum AD7767





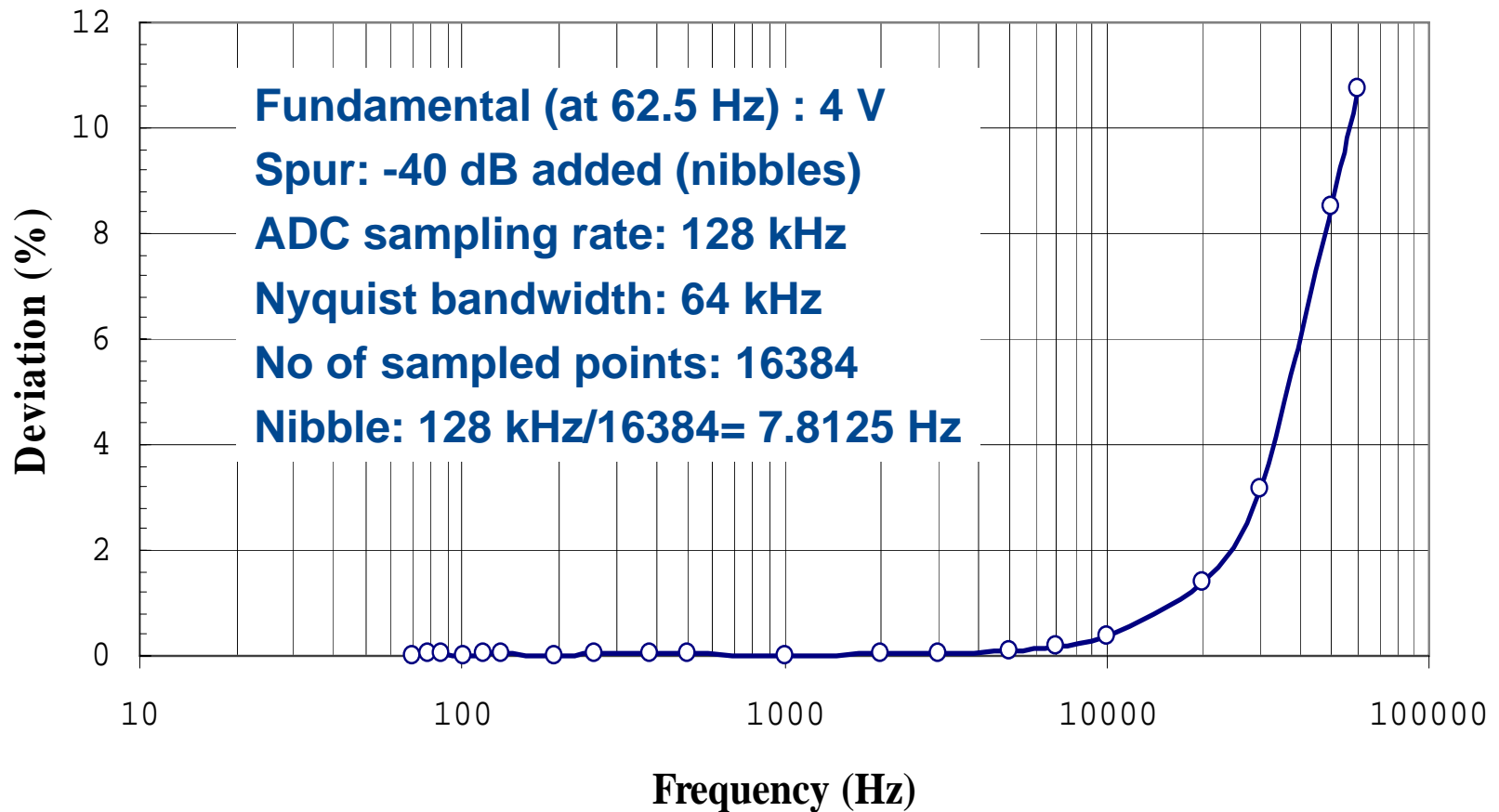


# Compact three phase voltage digitiser

## Some figures



ADC Error in respect to HP3458A in AC SYNC





- 24 bit delta sigma ADC, 24 bit SAR.
- Uses a DDS Synthesizers to generate variable sampling frequencies for digital PLL: Soft-Sync., asynchronous meas. also possible.
- Allow tight synchronous meas., quasi-sync and asynchronous too.
- Allow Agilent 3458A to be used if desired (not a must!)

The same unc. figures as the PTB primary standard.

Internal SAR with comparable performance as the Agilent 3458A, allowing but higher sampling rates.

- Ultra-pure sinewave gen. (Spurs  $< -180$  dB) locked to a quartz time base was developed to investigate ADCs.

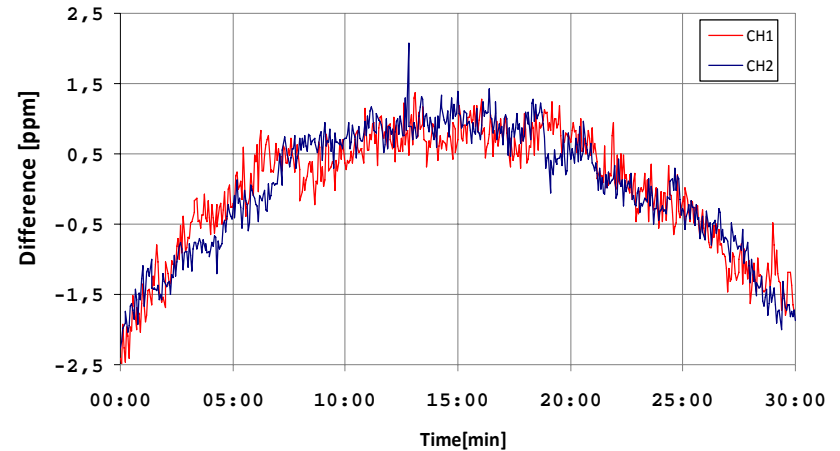
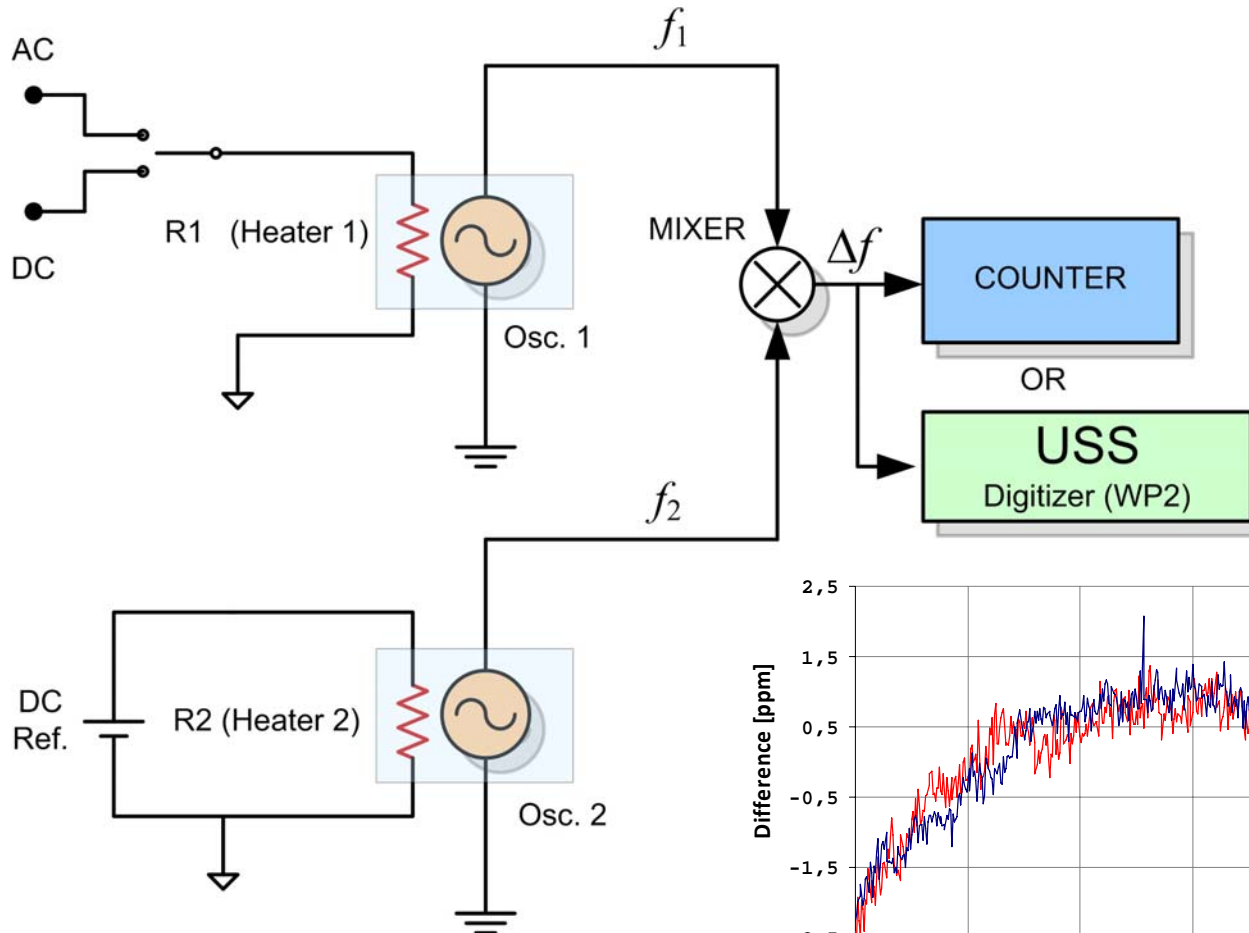


## Future work



- Improvements: Synchronizer with FPGA.
- Multiple ADCs to be read by FPGA & USB 2.0.
- Replacement of Agilent 3458A by USS (PTB).
- Improvements on ultra-pure sinewave generator.

## THERMALLY COUPLED OSCILLATORS AS PRECISION THERMAL CONVERTERS



THANK YOU!