nanoMCA-II

125 MHz ULTRA-HIGH PERFORMANCE DIGITAL MCA
# Model Number: NM8000

I. FEATURES

- Finger-sized, ultra-high performance digital MCA.

- 16k channels utilizing smart spectrum-size technology -- all spectra are recorded and stored as 16k spectra with instant, distortion-free downsizing during or after spectra acquisition.

- Two analog inputs - A) preamplifier signals and B) user-shaped analog pulses, including pulses from traditional spectroscopy amplifiers e.g. semi-Gaussian (PHA Mode).

- Support for reset and resistive feedback preamplifiers on input A.

- State-of-the-art digital pulse processor with 16-bit low power ADC with sampling frequency 125MHz.

- Digitally synthesized pulse shapes.

- Adjustable flat top for all shapes 0 to 2 µs.

- Pulse shape rise time from 50ns to 16 µs (optional 32µs).

- Multiple-pole compensation technique for complete elimination of the pulse tailing.
- Novel incoming count-rate estimator with fast discriminator dead time correction.
- Static and dynamic(automatic) control of the ADC input offset.
- Automatic thresholds based on statistical noise estimation.
- Automatic or manual Pole-Zero adjustment.
- Built-in and signal-interference free Digital Pulser for noise and base-line estimation.
- One configurable digital input (preamplifier inhibit, coincidence etc.).
- One configurable digital or analog input. Analog input is digitized by a slow 12-bit ADC and can be used for measuring detector temperature or other voltage signals.
- One configurable general purpose digital input or output. The output driver can be configured as push-pull, open drain or tri-stated.
- Two configurable digital outputs. The output drivers can be configured as push-pull, open drain or tri-stated.
- Full featured coincidence circuit.
- Trace Viewer (Mixed Signal Oscilloscope) with unique peak magnification feature.
- Interchangeable interface modules for either wired or wireless connectivity. Supports USB, Ethernet, WiFi, Bluetooth.
- Single mini USB I/O connector for all interfaces.
- Power source requirement 5V/300mA.
- Power via I/O connector (USB interface) or through a dedicated mini USB power-connector.
- Power consumption < 1400mW@25°C (USB interface).
- Exceptional Temperature Stability: Gain < 10 ppm/°C (±5 ppm/°C), Base Line < 1 ppm/°C.
- Temperature Operating Range: -20°C to +60°C.
- Optional Extended Temperature Operating Range: -40°C to +100°C.
- Weight <135g.
- Dimensions 3.6" x 1.5" x 1" (92 mm x 38 mm x 25 mm).
- Free *labZY-MCA* software for configuration, spectra acquisition and basic analysis.

II. DESCRIPTION

The nanoMCA-II is part of the nanoMCA family of high-performance multichannel analyzers (MCA). nanoMCA-II offers unmatched low noise performance optimized for semiconductor detectors such as High Purity Germanium detectors (HPGE). The nanoMCA family of MCAs are based on the world's first open platform, high-performance digital pulse processors. The core technology of the nanoMCA-II is and advanced Digital Pulse Processing (DPP) operating at 125 MHz, which is a result of more than 20 years of development and innovation. Being an open platform, the nanoMCA-II can easily be adapted to specific radiation measurement applications. The DPP algorithms are in-system programmable which makes nanoMCA-II extremely flexible system. Functionality of nanoMCA-II can be changed by programming FPGA design. The program process takes about one minute. labZY provides free standard DPP FPGA designs that support a variety of detectors such as HPGE, Silicon drift detectors, LaBr scintillators and other traditional or non-traditional detectors. The nanoMCA-II has two detector signal inputs A and B. Input A accepts signals from preamplifiers with either pure capacitive (reset type) or RC feedback. Input B accepts signals that are user conditioned for DPP or analog shaped pulses from traditional analog pulse shapers.
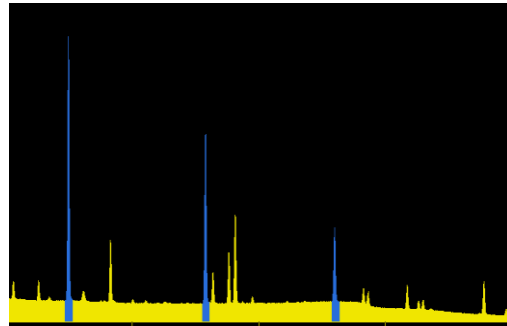
A unique feature of the nanoMCA-II is the smart spectrum-size acquisition implementation which always stores the spectra in a 16k spectrum size (*hard size*). The labZY-MCA software allows instant, distortion-free conversion of the *hard size* spectrum into smaller spectrum sizes (*soft size*) for display or data processing purposes. Spectra are always stored in files as hard size spectra (16k channels). The labZY-MCA software allows exporting the *soft size* spectra for off-line analyses by applications that require spectra with sizes smaller than the *hard size*.

The DPP of the nanoMCA-II employs advanced algorithms for pulse shaping and pile-up rejection. Multiple-pole unfolding technique allows the achieving of well-defined pulse shapes, which is essential for the accurate accounting for the pile-up losses. The throughput of the nanoMCA approaches the theoretical limit of the pile-up free spectroscopy throughput. labZY's proprietary digital technique allows accurate incoming count rate (ICR) estimation, which is important for proper setting of the radiation measurement systems.

Unique feature of the nanoMCA-II is the **Digital Pulser**. The Digital Pulser allows noise-free estimation of the intrinsic resolution (electronic noise). The Digital Pulser may also be used to verify the base line of the MCA. The Digital Pulser does not interfere with the signals from the detector.
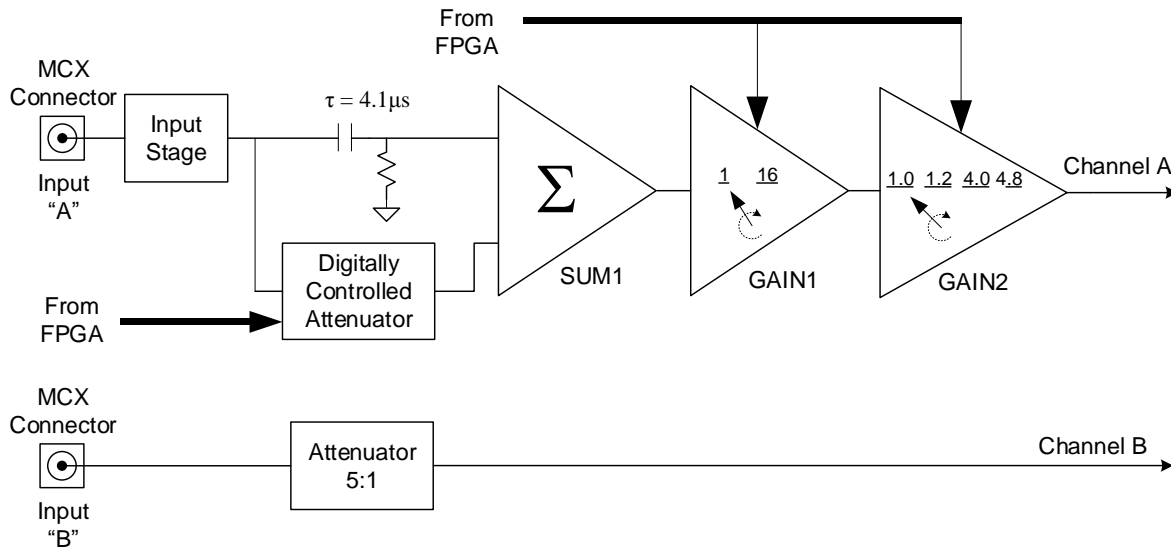
III. BLOCK DIAGRAMS

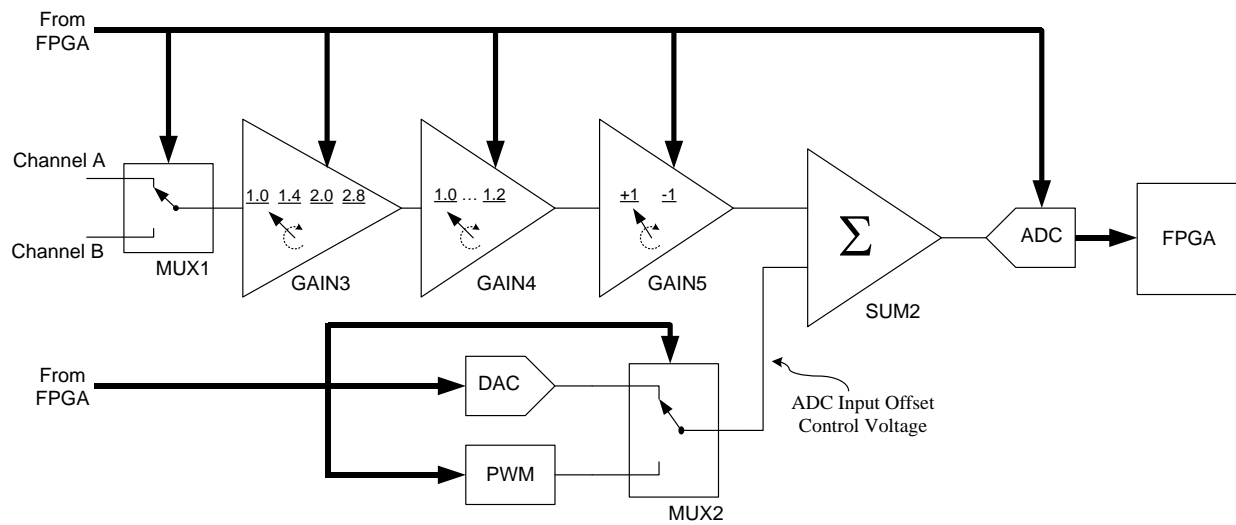Fig. 1 Functional Block Diagram of the **nanoMCA-II** Analog Front-End.

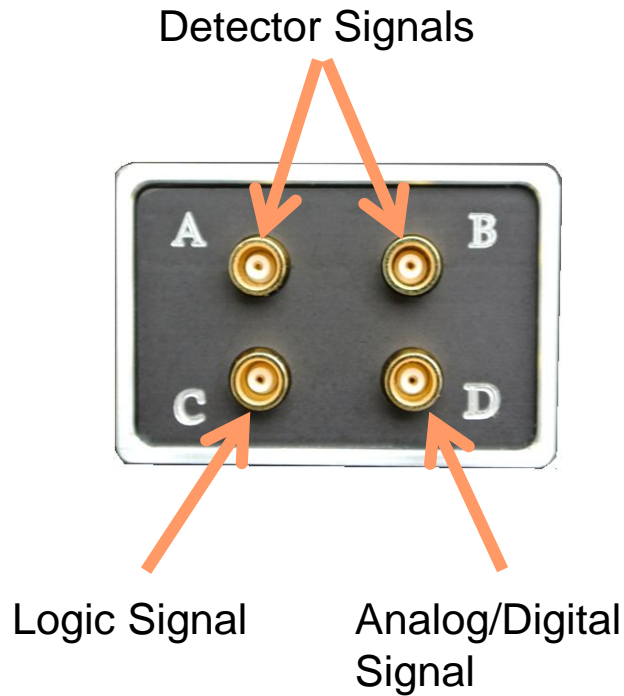Fig. 2 Functional Block Diagram of the Digital Pulse Processor

IV. CONNECTIONS
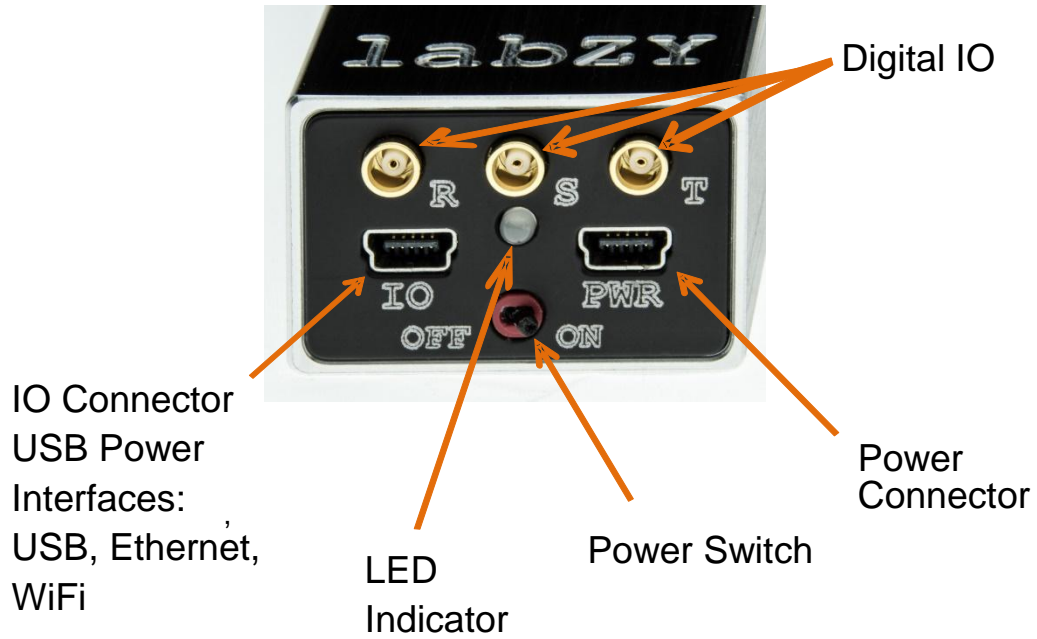
Digital IO

R   S   T

IO Connector
USB Power
Interfaces:
USB, Ethernet,
WiFi

LED
Indicator

Power Switch

Power
Connector

Detector Signals

A   B

C   D

Logic Signal

Analog/Digital
Signal

Fig. 3 nanoMCA-II connectors.

V. SPECIFICATIONS - DPP MODE

Input A:

Signals from RC Feedback Preamplifiers: Exponential signal time constant: 25µs to ∞.

Signals from Rest Type Preamplifiers: Step signal.

Signal Input Range: ±0.85V ±5% @ minimum gain, full spectrum range.

Signal Polarity: Automatic, Positive or Negative, Software selectable.

Reset Preamplifier Maximum Ramp Range: -6V to +6V.

DC Input Offset: ±6V less signal or ramp range.

Maximum Input Voltage (protected): ±12V.

Input Impedance: 920Ω.

Coarse Gain: 1.00, 1.19, 1.41, 1.68, 2.00, 2.38, 2.83, 3.36, 4.00, 4.76, 5.66, 6.73, 8.00, 9.51, 11.31, 13.45, 16.00, 19.03, 22.63, 26.91, 32.00, 38.05, 45.25, 53.82, 64.00, 76.11, 90.51, 107.63, 128.00, 152.22, 181.02, 215.27

Fine Gain: 1.00 to 1.20 in 65536 steps.

Differentiation Time Constant: 4.1 µs ±5%;

Pole/Zero Compensation: from 25µs to ∞ in 4096 steps. Automatic or Manual adjustment.
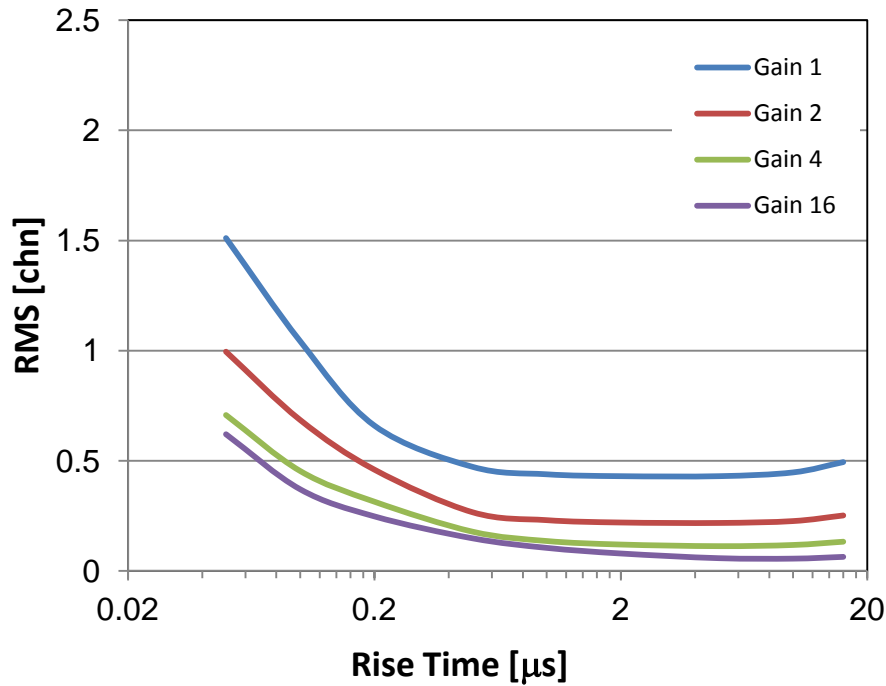
Fig. 4 nanoMCA - II - input A referred noise for triangular shape with rise time from 50ns to 16μs, spectrum size 16k channels (DPP mode)

Input B:

User Conditioned Signals: Positive or negative exponential signal with primary decay time constant (preferred): 125ns, 250ns, 500ns, 1μs, 2μs and 4.1μs.

Signals from Traditional Analog Pulse Shapers: Semi-Gaussian - see section VI (PHA)

Coarse Gain: 1.00, 1.41, 2.00, 2.83.

Fine Gain: 1.00 to 1.20 in 65536 steps.

Signal Polarity: Automatic, Positive or Negative, Software selectable.

Pole/Zero Compensation: NONE.

Signal Input Range: ±3.0V ±5% @ coarse gain of 1.00.

Signal Input Range: ±2.2V ±5% @ coarse gain of 1.41.

Signal Input Range: ±1.5V ±5% @ coarse gain of 2.00.

Signal Input Range: ±1.1V ±5% @ coarse gain of 2.83.

Maximum Input DC offset: ±2.00V ±5% @ coarse gain of 1.00.

Maximum Input DC offset: ±1.4V ±5% @ coarse gain of <u>1.41</u>.

Maximum Input DC offset: ±1.0V ±5% @ coarse gain of <u>2.00</u>.

Maximum Input DC offset: ±0.7V ±5% @ coarse gain of <u>2.83</u>.

Absolute Maximum Input Voltage: ±12V.

Input C:

Type: Digital Input, 3.3V CMOS.

Primary Function: Inhibits all of the following - spectrum acquisition, live timer, base line stabilization.

Default State: Inactive.

Active Logic Level: Automatic, High or Low, Software selectable.

Input D:

Type: Digital Input, 3.3V CMOS or Analog Input 0 to +2.5V.

Primary Function: Analog Input to a slow 12-bit ADC.

Secondary Function: Coincidence Logic Signal, 3.3V CMOS.

Default Unconnected Coincidence Logic State: None. Must be set externally.

Default Unconnected Analog Input: Internal Coincidence Logic Disabled.

Active Coincidence Logic Level: High or Low, Edge. Software selectable.

Input/Output R:

Type: Digital Input, 3.3V CMOS or Digital Output, 3.3V CMOS, Open Drain or Tristate.

Primary Input Function: Coincidence Logic Signal, 3.3V CMOS.

Primary Output Function: Acquisition Synchronization between Multiple Devices(refer to labZY-MCA manual).

Custom Function: Per customer requirements.

Output Drive: DISABLED, PUSH-PULL, OPEN DRAIN; STRAIGHT or INVERTED.

Output S:

Type: Digital Output, 3.3V CMOS, Open Drain or Tristate.

Primary Functions: Discriminator Signals, Counting Signals (refer to labZY-MCA manual).

Default Output Driver: 3.3V CMOS.

Custom Function: Per customer requirements.

Output Drive: DISABLED, PUSH-PULL, OPEN DRAIN; STRAIGHT or INVERTED.

Output T:

Type: Digital Output, 3.3V CMOS, Open Drain or Tristate.

Primary Function: Timing Signals – Peak Detector Signal, ROI Timing SCA.

Default Output Driver: 3.3V CMOS.

Custom Function: Per customer requirements.

Output Drive: DISABLED, PUSH-PULL, OPEN DRAIN; STRAIGHT or INVERTED.

Digital Pulse Processor:

Sampling Period: 8ns (Frequency125MHz).

Quantization: 16 bit, including offset and pile-up head room.

Primary Time Constant (Long TC) Cancelation: 125ns to 4.1μs, Adjustable in 1ns increments.

Secondary Time Constant (Short TC) Cancelation: 1ns to 255ns. Adjustable in 1ns increments.

Integral Nonlinearity: 0.006% (typ), 0.018% (max) over full scale.

Differential Nonlinearity: <0.1% for typical high-resolution setup[1].

Peak Detection: labZY's proprietary digital constant-fraction timing algorithm.

Base Line Stabilizer: Digital, Gated High-Pass Filter with Software adjustable response.

Main Filter Digital Pulse Shape: Trapezoidal – standard, other shapes optional.

Main Filter Rise Time: 16ns to 16µs, adjustable in increments of 8ns.

Main Filter Flat Top: 8ns to 2µs, adjustable in increments of 8ns.

Fast Filter Digital Pulse Shape: Trapezoidal – standard, other shapes optional.

Fast Filter Rise Time: 8ns to 2 µs, adjustable in increments of 8ns.

Fast Filter Flat Top: 8ns to 2µs, adjustable in increments of 8ns.

Digital Signal Thresholds (main and fast filters): Automatic or manual. Adjustment in increments of one **hard size** channel.

Coincidence Circuit:

Coincidence Sources: Internal timing signal and either the delayed direct logic signal at Input D or internally generated delayed logic signal (Coincidence Pulse) triggered by the edges of the logic signal at Input R or Input D. **Input R is the preferred source**.

Modes of Operation: Input R/D as coincidence/anti-coincidence window pulse; Input R/D edge triggered coincidence/anticoincidence pulse.

Internal Coincidence Signal Trigger: Selectable positive or negative edge of Input R/D.

Input D Delay: Adjustable 8ns to 32µs, in increments of 8ns.

Coincidence Window: Adjustable 8ns to 32µs, in increments of 8ns.

Internal Timing Signal: Constant Fraction Peak Detection (Peak Detect).

Peak Detect Pulse Width: 8ns.

Peak Detect Delay: Adjustable 8ns to 32µs, in increments of 8ns.

Coincidence Circuit Operation: Disabled when Input R/D is selected as analog input; Active in all other modes of Input R/D.

Data Acquisition:

*Hardware Spectrum Size (**hard size**)*: 16384 channels (16k) using smart spectrum size technology. Hard size spectra are always recorded and stored in files.

Soft Spectrum Size (Soft Size): Instant, distortion free size conversion for display or data processing: 512, 780, 1024, 1489, 2048, 3276, 4095, 5641, 8192 and 16384 channels. The soft size conversion does not cause destruction of the hard size spectra which allows an instant selection of any of the available soft sizes. A single acquisition allows display and/or data processing of the spectrum as any one of the soft spectrum sizes.

Counts per Channel: 4 bytes, 0 to 4.3 billion.

Time Measurement: Real and Live timers.

Preset Time: Real or Live.

Timer Resolution: 200 ns.

Timer Accuracy: ±10ppm. (Includes variations due to initial tolerance, temperature and power supply voltage)

Preset Time Resolution: 10ms.

Maximum Preset Time: 43×10^6s or 497 days.

Dead Time Correction Technique: Extended Paralyzable Dead Time.

ICR Estimation: Counting and correction for pile-up losses in either the fast channel or the main channel.

Pile-Up Rejection: Time between fast discriminator pulse and labZY's proprietary advanced fast discriminator pile-up detection.

Time Stamp: Start date and time.

Data Backup: Battery-less. Hard Size Spectrum and All Settings.

Communication Interfaces:

Wired: USB(also power source), Ethernet, Serial Low Voltage or RS-232.

Wireless: WiFi, Bluetooth.

Environmental:

Gain Temperature Stability: < 10 ppm/°C (typical), 20 ppm/°C (maximum)

Base Line Temperature Stability: Digitally stabilized, not subject to temperature drift. For comparison purposes with analog systems < 1 ppm/°C.

Operating Temperature Range: Normal Temperature Range -20°C to +60°C

Extended Temperature Range -40°C to +100°C[2,3].

Power:

Power Supply: Required for all interfaces other than USB: 5V@1A.

Power Supply Voltage: +5V ±10%.

Operating Power (typ) : 1350mW at 25°C and USB interface. 900mW to 1.8W over the full Extended Temperature Range.

Additional Power Requirements: *nanoWF* Interface - 500mW, *nanoET* Interface – 900mW.

Note 1: Differential Nonlinearity depends not only on the quantization properties of the digitizer, but also upon the noise level of the signal. Reference: V.T. Jordanov and K.V. Jordanova, "Quantization Effects in Radiation Spectroscopy Based on Digital Pulse Processing ", Nuclear Science, IEEE Transactions on, Vol 59, Issue 4, pp 1282 - 1288, Aug. 2012.

Note 2: The extended temperature devices undergo temperature profiling.

Note 3: To prevent burns do not handle nanoMCA-II when the device temperature is above 50°C. At temperatures below -10°C special care should be exercised handling connecting cables as their flexibility degrades substantially.

Mechanical:

Dimensions: 3.6" x 1.5" x 1" (92 mm x 38 mm x 25 mm).
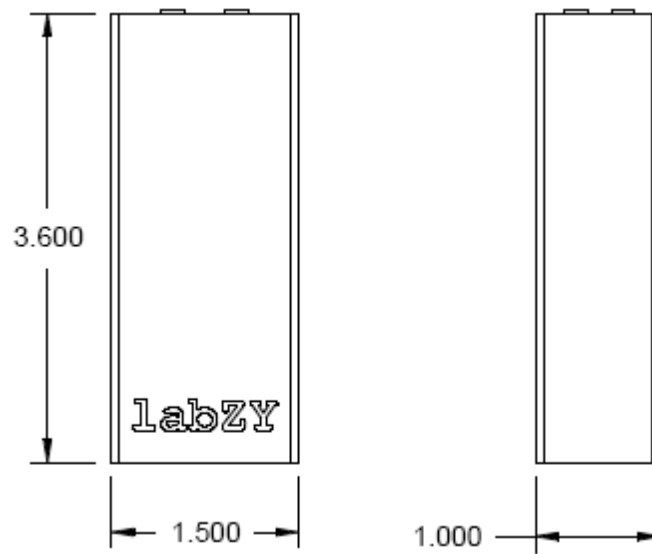
Weight: 135 g.

Fig. 5 nanoMCA-II dimensions.

VI. SPECIFICATIONS PHA MODE

The PHA mode on signals applied to Input B is part of FPGA design that also keeps the DPP functionality of Input A. Fig. 6 shows the specifications of the file that will configure PHA mode for the signals applied to Input B of the nanoMCA-II.

FPGA – NM8000 - 8_0 - 9 - PHA.lbf

PART NUMBER
nanoMCA-II
Part Number

CHANNEL B
PHA MODE

VERSION NUMBER
Design Version
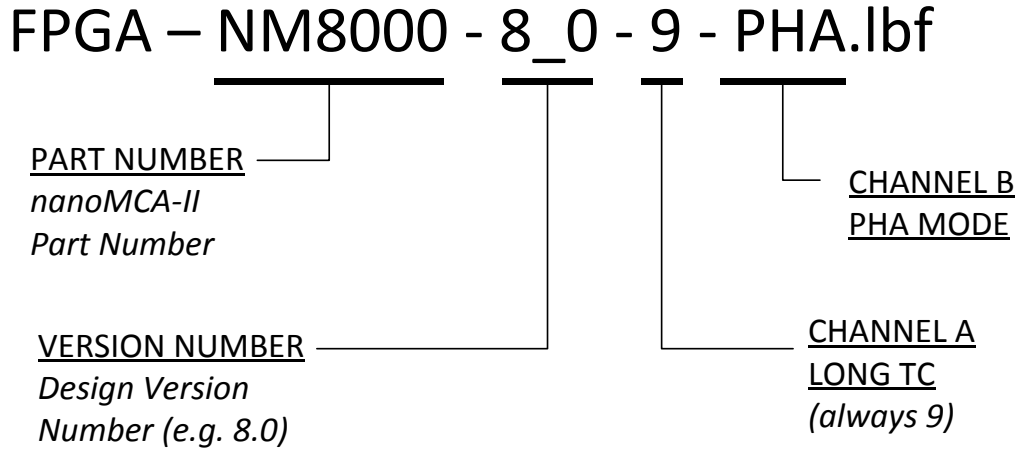*Number (e.g. 8.0)*

CHANNEL A
LONG TC
(always 9)

Fig. 6 FPGA design file specification for configuring nanoMCA-II with PHA functionality.

The signals at input B can be either unipolar or bipolar. In general any shape can be applied. However, the PHA performance is optimized for typical spectroscopy pulses such as semi-Gaussian or shaped with RC-CR networks. Fig. 7 shows examples of unipolar and bipolar signals from analog spectroscopy shaping amplifiers.
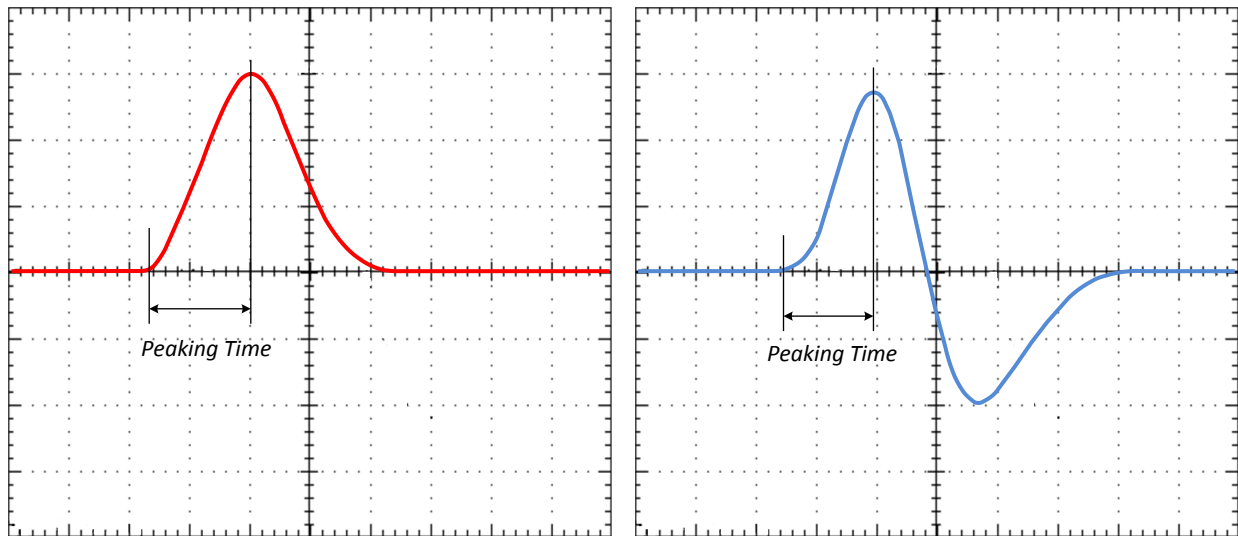
Peaking Time

Peaking Time

Fig. 7 Example of analog shaped pulses.

Input B PHA Mode:

Signals from Traditional Analog Pulse Shapers: Semi-Gaussian, CR-RC, Gated Integrator, others

Recommended Peaking Time: ≥ 100ns

Coarse Gain: 1.00, 1.41, 2.00, 2.83.

Fine Gain: 1.00 to 1.20 in 65536 steps.

Signal Polarity: Automatic, Positive or Negative, Software selectable.

Pole/Zero Compensation: NONE.

Signal Input Range: ±4.0V ±5% @ gain of 1.00.

Signal Input Range: ±2.8V ±5% @ gain of 1.41.

Signal Input Range: ±2.0V ±5% @ gain of 2.00.

Signal Input Range: ±1.4V ±5% @ gain of 2.83.

Maximum Input DC offset: 0.6 x Signal Input Range

Digital PHA Processor:

Sampling Period: 8ns (Frequency125MHz).

Quantization: 16 bit, including offset and pile-up head room.

Integral Nonlinearity: 0.006% (typ), 0.018% (max) over full scale.

Differential Nonlinearity: <0.2% for typical high-resolution setup[1].

Peak Measurement: Real-time peak fitting.

Spectroscopy Peak Detection: labZY's proprietary digital constant-fraction timing algorithm.

Particle Counting Peak Detection: Absolute peak above the threshold.

Base Line Stabilizer: Digital, Gated High-Pass Filter with Software adjustable response. Can be turned ON or OFF. Recommended setting OFF for bipolar signals.

ADC Offset: Automatic or manual. Must be set to manual for bipolar signals.

Digital Signal Thresholds (main and fast filters): Automatic or manual. Adjustment in increments of one **hard size** channel.

Data Acquisition PHA Mode:

*Hardware Spectrum Size (**hard size**)*: 16384 channels (16k) using smart spectrum size technology. Hard size spectra are always recorded and stored in files.

Soft Spectrum Size (Soft Size): Instant, distortion free size conversion for display or data processing: 512, 780, 1024, 1489, 2048, 3276, 4095, 5641, 8192 and 16384 channels. The soft size conversion does not cause destruction of the hard size spectra which allows an instant selection of any of the available soft sizes. A single acquisition allows display and/or data processing of the spectrum as any one of the soft spectrum sizes.

Counts per Channel: 4 bytes, 0 to 4.3 billion.

Time Measurement: Real and Live timers.

Preset Time: Real or Live.

Timer Resolution: 200 ns.

Timer Accuracy: ±10ppm. (Includes variations due to initial tolerance, temperature and power supply voltage)

Preset Time Resolution: 10ms.

Maximum Preset Time: 43×10^6 s or 497 days.

Dead Time Correction Technique: Extended Dead Time.

ICR Estimation: None.

Pile-Up Rejection: External anticoincidence signal at Input D.

Time Stamp: Start date and time.

Data Backup: Battery-less. Hard Size Spectrum and All Settings.

All other PHA specifications are identical to the specifications of the DPP mode.

VII. APPLICATION INFORMATION

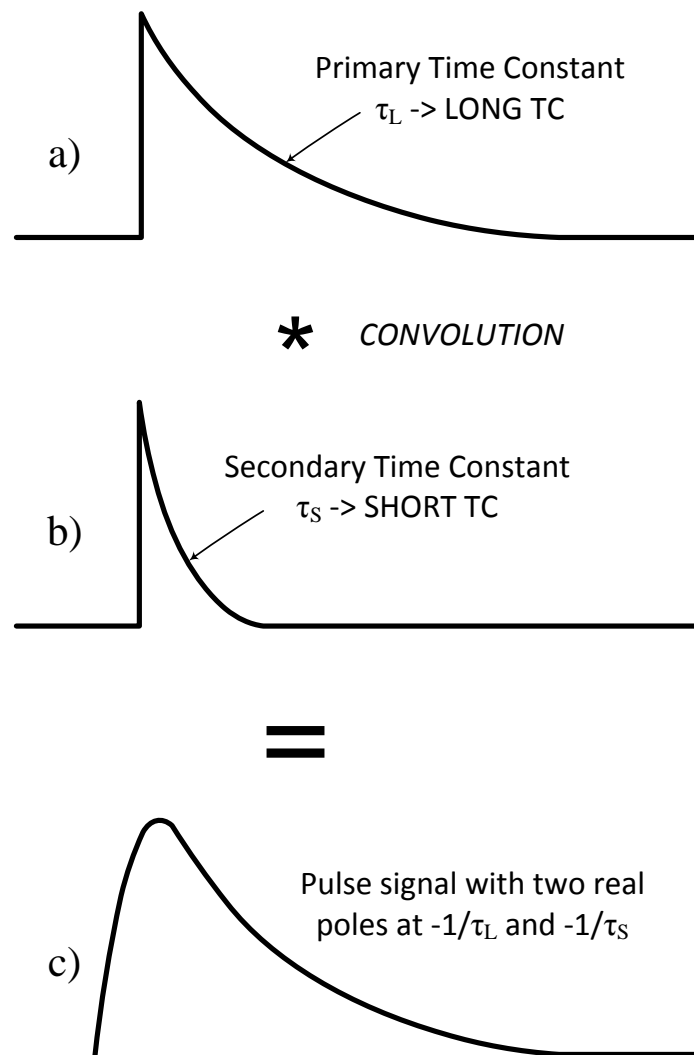**Optimal pulse signal at the input of the ADC in DPP mode:**

Fig. 8 The optimal shape of the pulse expected at the input of the ADC is depicted in trace c). This signal can be obtained by the convolution of two exponential pulses a) and b). Signals connected to Input A are conditioned internally by a differentiation (pole-zero compensating) circuit which determines the LONG TC. The expected optimal LONG TC of the exponential signals at Input B is one of the following: 125ns, 250ns, 500ns, 1μs, 2μs and 4.1μs. The SHORT TC normally depends on the response of the amplifiers in the amplification chain including the preamplifier connected to Input A. The LONG TC and the SHORT TC should be adjusted to minimize the tailing and/or the undershoot of the digitally shaped pulses - slow and fast shapers. SHORT TC has more influence on the fast shaper, while the LONG TC will affect both shapers.
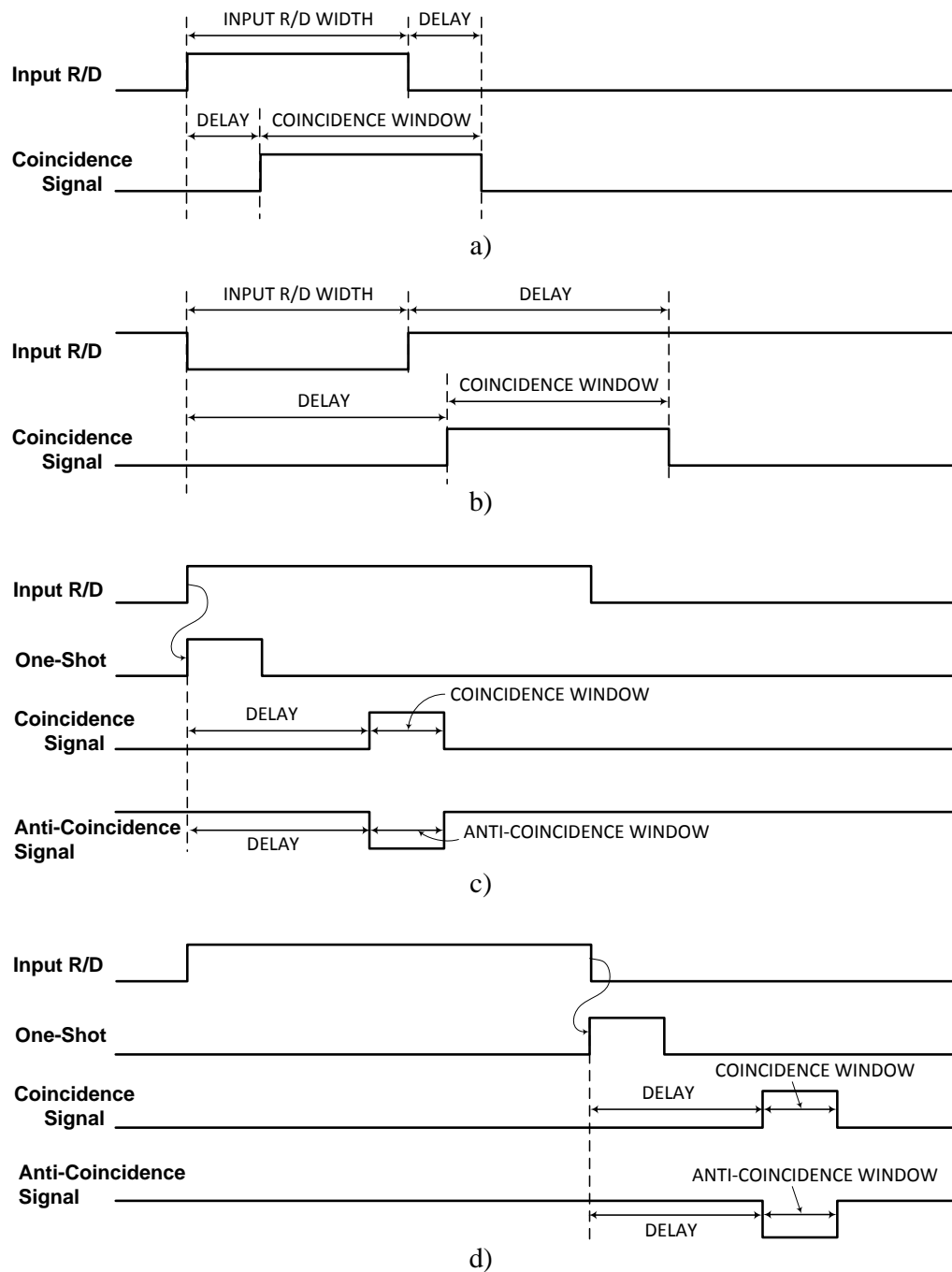
Timing diagram of the coincidence circuit:

Fig. 9 Timing diagrams of the built-in coincidence circuit: a) Input R/D as direct coincidence signal, active high or anti-coincidence signal, active low; b) Input R/D as direct coincidence signal, active low or anti-coincidence signal, active high.; positive edge c) and negative edge d) coincidence/anti-coincidence triggered signals.

FPGA Design Files:

labZY provides standard FPGA designs that can be uploaded to the nanoMCA-II using the FPGA programming utility of the labZY-MCA software. Each version of the FPGA design comes in different files addressing the choice of optimal LONG TC of channel B. It is recommended to upload an FPGA design optimized for a LONG TC that is the closest to the primary time constant of the exponential signals applied to Input B. For instance, if the primary decay time constant of the signal at Input B is 1.8μs then an FPGA design file optimized for 2μs should be uploaded to the nanoMCA-II. Fig. 10 shows the naming specification of the FPGA design files.

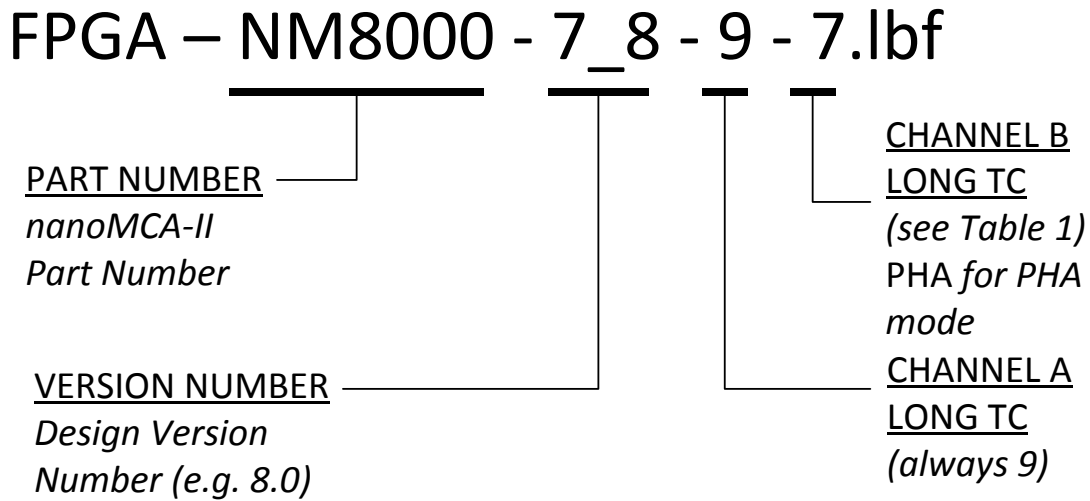# FPGA – NM8000 - 7_8 - 9 - 7.lbf

PART NUMBER
nanoMCA-II
Part Number

VERSION NUMBER
Design Version
Number (e.g. 8.0)

CHANNEL B
LONG TC
(see Table 1)
PHA *for PHA*
mode

CHANNEL A
LONG TC
(always 9)

Table 1

Digit	Time Constant [μs]
9	4.1
8	2
7	1
6	0.5
5	0.25
4	0.12
PHA	PHA

Fig. 10 Naming specification of the FPGA design files DPP mode.

VIII. ORDERING INFORMATION

nanoMCA-II Multichannel Analyzer Package NM8000

- One nanoMCA-II Part Number: **NM8000**

Including the following accessories:

- One USB Cable, Part Number: **NA0511**
- Two BNC male to MCX male cables, Part Number: **NA0512**
- One Flash Drive with software and documentation

XI. ACCESSORIES

BNC female to MCX male Adapter

Part Number NA0513

Length: 8cm

BNC male to MCX male Adapter

Part Numbers: NA0512, NA0514

Length: 100cm (NA0512), 40cm (NA0514)

USB Data Cable (3ft)

Part Number: NA0511-1

USB Data Cable (6ft)

Part Number: NA0511-2

USB Data Cable (15ft)

Part Number: NA0511-15

Bluetooth Interface Module

Part Number: NA0520

Ethernet Interface Module *nanoET*

Part Number: NA0523

WiFi Interface Module *nanoWF*

Part Number NA0521

***nanoWF* Extension Cable (30cm)**

Part Number: NA0511-E12

Power Adapter

(for use with *nanoET* and *nanoWF*)

Part Number: NA0510

Voltage: 110/240V Current: 1A