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CNT-100 series

Multi-Channel Frequency Analyzers

U S E R M A N U A L

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Chapter 1

General Information

Revision 5

12NC 4031.601.10401

1.1 About this Manual

This manual contains directions for use that apply to the CNT-100 series Multi-Channel Frequency Analyzers, such as CNT-104S, CNT-104R, CNT-104B, CNT-102, CNT-102B and measurement option of FTR-210R GNSS disciplined Frequency and Time Reference.

This manual targets Firmware release v1.6.6 and higher.

1.2 Warranty

The Warranty Statement is part of the folder *Important Information* that is included with the shipment.

1.3 Declaration of Conformity

The complete text with formal statements concerning product identification, manufacturer and standards used for certification type testing is available on request.

Chapter 2

Preparation for Use

2.1 Preface

2.1.1 Introduction

Congratulations on your choice of Measurement Instrument - CNT-100 series Multi-Channel Frequency Analyzer!

It will serve you well and give you today's ultimate performance for many years to come, whether you work with advanced ultra-high resolution frequency analysis in R&D, high-precision calibration in Metrology, or high speed testing of time & frequency in test systems.

Your instrument is the industry's first bench-top multichannel frequency counter/analyzer designed to bring a new dimension to bench-top and system frequency counting and analysis. It gives significantly increased performance compared to traditional Timer/Counters. Depending of the model you have chosen, your instrument may have 4 or 2 channels (1 - for measurement option of FTR-210R GNSS disciplined Frequency and Time Reference).

The CNT-100 series Multi-Channel Frequency Analyzers offer for example the following benefits:

- Four (CNT-104S, CNT-104R, CNT-104B) or two (CNT-102, CNT-102B) parallel time-stamping input channels means you have multiple independent frequency counters in one box. An enormous save of money and space in test systems
- Phase-compare 4 (CNT-104S, CNT-104R, CNT-104B) or 2 (CNT-102, CNT-102B) stable frequencies continuously in real time in a time metrology lab, without the need for external signal switching
- The parallel-channel time-stamping design, where all channels run on the same time scale, allows to measure Time Interval with multiple stop channels, which is very valuable for exact timing of one-shot events
- Graphical intuitive User Interface
- Large 5" color touch-screen control (except CNT-104B, CNT-102B)
- Easy control of instrument via mouse, web interface or VNC client
- Up to 13 digits of frequency resolution per second
- Resolution per timestamp: up 7 ps for CNT-104S, CNT-104R, or instruments with Option 121 or 121F or 14 ps for base CNT-102, CNT-102B, CNT-104B, FTR-210R
- A high measurement rate of up to 20M readings/s to internal memory for CNT-104S, CNT-104R, or instruments with Option 122 or 122F or 1M readings/s for base CNT-102, CNT-102B, CNT-104B, FTR-210R
- Optional oven-controlled timebase oscillators
- Choice of RF prescaler options with upper frequency limits ranging from 3 GHz to 24 GHz
- Integrated 1Gbit Ethernet and USB (always available), Wi-Fi (with external dongle) and GPIB (with Option 26) interfaces with SCPI commands support. Please check current datasheet for a list of officially supported Wi-Fi dongles.

- The ADEV Graph (option 161) to quantify noise, analyze input signal and estimate stability over different timescales.

2.1.1.1 Powerful and Versatile Functions

In addition to the traditional measurement functions of legacy timer/counters, these instruments have a multitude of other functions such as Multi-stop Time Interval, Phase, Duty factor, Rise/Fall time, Slew Rate, TIE (Time Interval Error), Totalize and Peak Voltage. The CNT-100 series Multi-Channel Frequency Analyzers introduce the concept of parallel measurements, for example 4 frequency measurements in parallel, or one rise time plus one fall time measurement in parallel on the same pulse. Even on single-shot pulses!

By using the built-in mathematics and statistics functions, the instrument can process the measurement results on your benchtop, without the need for a controller. Math functions include inversion, scaling and offset. Statistics functions include Max, Min and Mean as well as Standard and Allan Deviation on sample sizes up to 32×10^6 .

2.1.1.2 No Mistakes

You will soon find that your instrument is self-explanatory with an intuitive user interface. A settings menu tree with few levels makes the CNT-100 series Multi-Channel Frequency Analyzers easy to operate. The graphical user interface is the center of information and can show you several signal parameters at the same time as well as status.

Measurement samples are presented as numeric values, or graphically over time, to reveal signal stability, trends, or modulation. Stability information can easily be presented as value distribution or trend plots in addition to complete numerical calculation results like max, min, mean and standard deviation.

The Autoset function is available on any input waveform and can make best settings of the currently selected measurement function. Use the built-in web server interface or VNC to get an enlarged view of the front panel on your desktop or laptop PC, tablet or even mobile phone. You can control every setting, start & stop measurements, and even download measurement data.

2.1.2 Design Innovations

2.1.2.1 State of the Art Technology Gives Durable Use

These instruments are designed for quality and durability. The modern design with high integration and low component count reduces power consumption. A rugged mechanical construction, including a metal cabinet that withstands mechanical shocks and protects against EMI, is also a valuable feature.

2.1.2.2 High Resolution

The use of reciprocal interpolating time-stamping counting, combined with a smart calibration algorithm, results in excellent resolution: <7 ps per timestamp or 12-13 digits/s in frequency measurements for all frequencies (for CNT-104S, CNT-104R, or instruments with Option 121 or 121F).

Timestamps of trigger events are taken continuously, and the frequency values are calculated on the fly, while the set measurement is running without interruption in the background, thereby assuring gap-free zero-dead-time measurements between samples. Minimum time between calculated values is 50 ns or 1 μ s (depending on particular model and corresponding license installed), meaning a sampling speed of 20 MSa/s or 1 MSa/s correspondingly.

2.1.3 Remote Control

This instrument is programmable via Ethernet. With external Wi-Fi dongle it can also be accessed via Wi-Fi and with Option 26 – via GPIB interface.

Ethernet is the primary interface intended for use in test systems, on lab benches, and fully remote control and monitoring from “anywhere in the world”.

Back panel USB interface provides the full set of features that are available over Ethernet (including web-server and VNC) and can be used as a replacement. When connected to a PC with a USB cable, the instrument appears as a new network interface on the PC, which can then be used to access it.

The web interface and VNC server are included. For devices that have a screen, this gives you an exact copy, pixel by pixel, of the instrument's screen. All instrument settings can be controlled from the web interface or VNC, and result data can be read.

In test systems, the instrument uses the standardized SCPI language for programming the instrument's functions and reading the results.

2.1.3.1 Fast Data transfer over remote interfaces

The Ethernet bus transfer rate is up to 425 measurements/s for individually triggered measurements, and 170k measurements/s in block transfer mode. Array measurements to the internal memory can reach 20M measurements/s (for CNT-104S, CNT-104R, or instruments with Option 122 or 122F) or 1M measurements/s (for base CNT-102, CNT-102B, CNT-104B, FTR-210R).

This very high measurement rate makes new measurements possible. For example, you can perform jitter analysis on several tens of thousands of pulse width measurements and capture and transfer them in less than a second.

Multi-channel parallel frequency measurement architecture significantly improves measurement speed, compared to using separate frequency counters, and individually addressing them in a sequence.

Programmer's Handbook helps you understand SCPI and the instrument's programming. Complete counter settings can be stored and can easily be recalled on a later occasion.

2.2 Safety

2.2.1 Introduction

Please take a few minutes to read through this part of the introductory chapter carefully before plugging the line connector into the wall outlet.

This instrument has been designed and tested for Installation/overvoltage category II, Measurement Category I, Pollution Degree 2, in accordance with EN 61010-1:2011, and CSA C22.2 No 61010-1-12 (including approval). It has been supplied in a safe condition. Study this manual thoroughly to acquire adequate knowledge of the instrument, especially the section on Safety Precautions hereafter and the section [Installation](#).

2.2.2 Safety Precautions

All equipment that can be connected to line power is a potential danger to life. Handling restrictions imposed on such equipment should be observed.

To ensure the correct and safe operation of the instrument, it is essential that you follow generally accepted safety procedures in addition to the safety precautions specified in this manual.

The instrument is designed to be used by trained personnel only.

2.2.3 Serviceable parts

There are no parts or components inside the instrument that are serviceable by user.

Removing the cover for repair, maintenance, and adjustment of the instrument must be done by qualified personnel who are aware of the hazards involved.

The warranty commitments are rendered void if unauthorized access to the interior of the instrument has taken place during the given warranty period.

To prevent electrical shock or damage to the device, do not insert foreign objects into any openings or ports except as explicitly instructed in this User Manual for the intended replacement of parts or the installation of approved accessories.

2.2.4 Caution and Warning Statements

Caution

Shows where incorrect procedures can cause damage to, or destruction of equipment or other property.

Warning

Shows a potential danger that requires correct procedures or practices to prevent personal injury.

2.2.5 Symbols

Several symbols are depicted on various parts of the instrument.



Shows where the protective ground terminal is connected inside the instrument. Never remove or loosen this screw.

Grounding faults in the line voltage supply will make any instrument connected to it dangerous. Before connecting any unit to the power line, you must make sure that the protective ground functions correctly. Only then can a unit be connected to the power line and only by using a three-wire line cord. No other method of grounding is permitted. Extension cords must always have a protective ground conductor.

Caution

If a unit is moved from a cold to a warm environment, condensation may cause a shock hazard. Ensure, therefore, that the grounding requirements are strictly met.

Warning

Never interrupt the grounding cord. Any interruption of the protective ground connection inside or outside the instrument or disconnection of the protective ground terminal is likely to make the instrument dangerous.



This symbol is used for identifying the chassis terminal. It is always connected to the instrument chassis.



Caution, risk of danger. User manual must be consulted when any action is made with any connector/terminal which this symbol refers to, in order to find out the nature of the potential hazards and any actions which have to be taken to avoid them.

Personal safety is ensured when the input signal level is below $30 V_{\text{rms}}$ (when accidentally touching the input signal lead)

Damage level for the input decreases from $350 V_p$ to $12V_{\text{rms}}$ when you switch the input impedance from $1 M\Omega$ to 50Ω .

Measurement BNC cables length shall be kept below 3m.

Circuits of external devices connected to BNC sockets, USB, GPIB and Ethernet sockets must be separated from the power supply network (and from other sources of dangerous voltage) at the level of reinforced insulation. This separation should not be confused with the permissible voltage of the external signal, including the voltage of $350 V_p$ referred to in the manual. If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

Fuse

The secondary supply voltages are electronically protected against overload or short circuit. The primary line voltage side is protected by a fuse located on the power supply unit. The fuse rating covers the full voltage range. Consequently, there is no need for the user to replace the fuse under any operating conditions, nor is it accessible from the outside.

Caution

If this fuse is blown, it is likely that the power supply is badly damaged. Do not replace the fuse. Send the instrument to the local Service Center.

Removing the cover for repair, maintenance and adjustment must be done by qualified and trained personnel only, who are fully aware of the hazards involved.

Detachable mains supply cords

Detachable mains supply cords must be 3-wire IEC 60320 cords having connector type C13 on the side connectable to the instrument, rated for at least 10A, 250 VAC. Don't use damaged or inappropriate cables.

Environmental requirements

The instrument is designed for indoor use only. The instrument must not be placed in potentially explosive atmospheres.

Operating temperature and relative humidity: 0°C to +50°C at 5% to 75% relative humidity (when using in bench-top installation), 0°C to +40°C at 5% to 75% relative humidity (when using in rack-mount installation)

Maximum operation altitude: 2000 m. Storage temperature: -40°C to +71°C.

See [Specifications](#) for more information about environmental data.

2.2.6 Position, Orientation, Cooling and Connection of the Instrument

Recommended orientation for the instrument operation is horizontal, with all text labels on front panel oriented parallel to the floor.

In case of bench-top use the instrument's feet (optionally unfolded) should be standing on a horizontal surface. In case of rack-mounted use, the mounting holes for the feet are supposed to be under the cabinet, all located in a plane, parallel to the floor.

Make sure that the air flow through the ventilation slots at the side panels is not obstructed. Leave 5 centimeters (2 inches) of space around the instrument.

Avoid positioning the instrument in a way that makes it difficult to disconnect it from the AC mains.

Never block access to power cords or power switches. Do not rely solely on unplugging the power cord as a mean of emergency disconnection. Always ensure a readily accessible external power disconnection method is available.

When laying out the mains cable be careful that you avoid tripping hazards and prevent damage to the electric main.

2.2.6.1 Rack-mounting

When rack-mounting this instrument, it's crucial to ensure easy access to power disconnection in case of emergencies, malfunctions, or maintenance needs. Failure to do so can lead to extended, potential equipment damage, or even safety hazards.

Power Strip Placement. Utilize a rack-mounted power strip with readily accessible power outlets. Position the power strip so its power switch and individual outlet switches are easily reachable, even when the rack is fully populated. Consider using a power strip with remote management capabilities.

Emergency Disconnect. Consider installing a dedicated Emergency Power Off (EPO) switch within easy reach of the rack. This switch should disconnect power to the entire rack or specific sections in an emergency. Clearly mark the location of the main power breaker or disconnect for the rack in the facility's electrical panel. Ensure personnel are aware of its location.

2.2.7 Disposal of Hazardous Materials

This instrument uses a 3 V cell lithium battery to power real time clock. It is installed in a dedicated holder and can be replaced by qualified personnel aware of potential hazards involved.

Warning

Disposal of lithium cells requires special attention. Do not expose them to heat or to excessive pressure, which may cause the cell explode. Make sure they are recycled according to the local regulations.

You should dispose of your worn-out instrument, after a long and happily life, at an authorized recycling station or return it to Pendulum Instruments.



2.2.8 Potentially poisonous or injurious substances

This instrument uses a 3 V cell lithium battery which is hermetically sealed and does not have any hazard potential except if damaged or dismantled. Never try to disassemble or damage the battery! Do not allow battery contact with water or other liquids. Never swallow. Keep beyond the reach of infants. In case of mistreatment or damage the substances contained inside the battery may be released, which can lead to distortion, leakage (unintended escape of liquid from a battery), overheating, explosion, or fire and cause human injury or equipment trouble. The battery contains Lithium / Manganese Dioxide, with Li component less than 0.3 g.

2.2.9 If in Doubt about Safety

Whenever you suspect that it is unsafe to use the instrument, you must make it inoperative by doing the following:

- Disconnect the line cord
- Clearly mark the instrument to prevent its further operation
- Inform your Pendulum Instruments representative.

Do not overlook the safety instructions!



For example, the instrument is likely to be unsafe if it is visibly damaged.

2.3 Unpacking

Check that the shipment is complete and that no damage has occurred during transportation. If the contents are incomplete or damaged, file a claim with the carrier immediately. Also notify your local Pendulum Instruments sales or service organization in case repair or replacement may be required.

2.3.1 Check List

The shipment should contain the following:

- Power supply Line cord
- Printed version of the Getting Started Manual Brochure with Important Information Certificate of Calibration
- Options you ordered should be installed. See *Identification* below.

Note: To ensure always up-to-date user documentation, the User Manual (this document) and Programmer's Handbook are not included on any media in the shipment. Instead, the user documentation can be read on-line or downloaded as PDF from manuals.pendulum-instruments.com

2.3.2 Identification

The type plate on the rear panel shows type number and serial number. Installed options are listed under the menu About, where you can also find information on firmware version and calibration date.

2.3.2.1 Product code (for CNT series only)

Product code (also called 12NC): **9446 101 0NXYZ.W**

The instrument is configured using factory installed HW options, and customer installable options via SW license keys. **The 12NC code only describes the HW configuration.** SW enabled options and built-in measurement apps are coded separately, and not shown in the HW configuration 12NC code

N = Number of 400 MHz inputs / Front panel screen presence

- 2 = two inputs, screen-equipped version
- 3 = two inputs, blind panel version (without screen)
- 4 = four inputs, screen-equipped version
- 5 = four inputs, blind panel version (without screen)

X = RF/Microwave frequency option

- 0 = None
- 6 = 3 GHz (Option 10)
- 7 = 10 to 24 GHz CW (Option 110, SW upgradable from 10 to 24 GHz)
- 9 = Customer special

Y = Oscillator option

- 2 = TCXO (standard oscillator in CNT-100 series Multi-Channel Frequency Analyzers, except CNT-104R)
- 5 = OCXO, High stability (Option 30)
- 6 = OCXO, Ultra-high stability (Option 40)
- 7 = Rubidium (standard oscillator for CNT-104R)
- D = GNSS-disciplined Rubidium (Option 55 GNSS receiver and Rubidium)

Z = Front/rear panel inputs and other hardware options

- 1 = Standard
- 2 = Alternate location for inputs A, B, D, E, C:

- For CNT-104S and CNT-104R: rear panel inputs A, B, D, E, C
- For CNT-102: rear panel inputs A, B, C
- For CNT-104B: front panel inputs A, B, D, E, C
- For CNT-102B: front panel inputs A, B, C
- 9 = Customer special
- **A = Alternate location for inputs A, B, D, E:**
 - For CNT-104S and CNT-104R: rear panel inputs A, B, D, E
 - For CNT-102: rear panel inputs A, B
 - For CNT-104B: front panel inputs A, B, D, E
 - For CNT-102B: front panel inputs A, B
- **C = Alternate location for input C:**
 - For CNT-104S, CNT-104R, CNT-102: rear panel input C
 - For CNT-104B, CNT-102B: front panel input C

W = special bundles

- R = Bundle CNT-104R
- S = Bundle CNT-104S

2.3.2.2 Software options

Product code for ordered software licenses (12NC): **9446 101 XXXYY**

XXX/YY = Main option / Version. *NOTE: the first "X" cannot be a 0*

110 group - Prescaler frequency upgrade

- 110/15 = upgrade from 10 to 15 GHz CW input C SW
- 110/20 = upgrade from 15 to 20 GHz CW input C SW
- 110/24 = upgrade from 20 to 24 GHz CW input C SW

130 group - Enable HW inputs/outputs

- 132 = Enable Pulse output SW

150 group - Enable measurement functions

- 151 = Enable TIE measurements
- 152 = Frequency Calibration app (Frequency offset) SW

160 group - Measurement Apps

- 161 = Enable ADEV calculation and graph

2.3.2.3 Hardware Accessories

Product code for ordered accessories (12NC): ****9446 108 XXYYY**

XX/YYY = Main option / Version

9446 108 01200 Option 01/200 Multi-GNSS antenna with mounting kit, N-connector

9446 108 0200A Option 02/A Antenna cable adapter SMA to TNC

9446 108 02020.T Option 02/20T Antenna Cable, 20 m, N to TNC

9446 108 02050.T Option 02/50T Antenna Cable, 50 m, N to TNC

9446 108 02130.T Option 02/130T Antenna Cable, 130 m, N to TNC

2.4 Installation

2.4.1 Safety precautions

Please carefully study *Safety* chapter before installation of the instrument.

2.4.2 Supply Voltage

The instrument may be connected to any AC supply with a voltage rating 100-240 V_{AC}, 50-60 Hz (Nom.). Allowed fluctuation limit to supply voltage is $\pm 10\%$.

The instrument automatically adjusts itself to the input line voltage.

2.4.3 Fold-Down Support

For bench-top use, a fold-down support is available for use underneath the instrument.

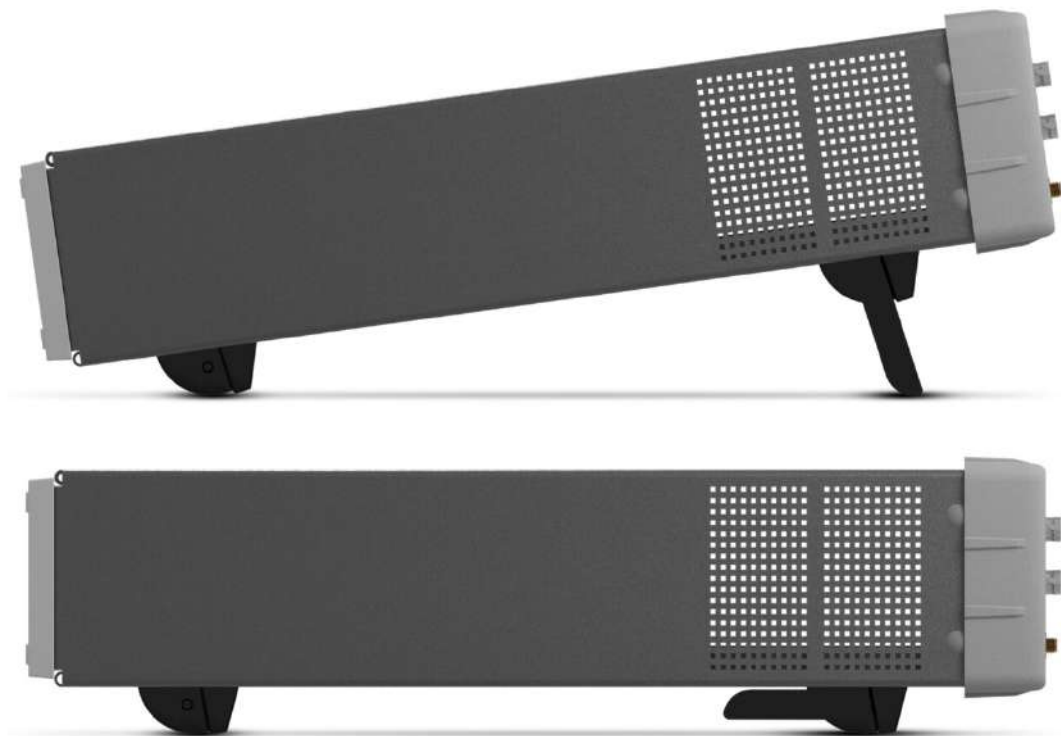


Fig. 2.1: Fold-down support for comfortable bench-top use.

2.4.4 Rackmount Adapter - one unit



Fig. 2.2: Dimensions for rackmounting hardware.

If you have ordered a 19-inch rack-mount kit for your instrument, Option 22/90 for one instrument, it has to be assembled after delivery of the instrument. The rackmount kit consists of the following:

- 2 brackets, (short, left; long, right)
- 4 screws, M5 x 8
- 4 screws, M6 x 8

Warning

Do not perform any internal service or adjustment of this instrument unless you are qualified to do so.



Fig. 2.3: Fitting the rack mount brackets on the instrument.

2.4.5 Assembling the Rackmount Kit (Option 22/90)

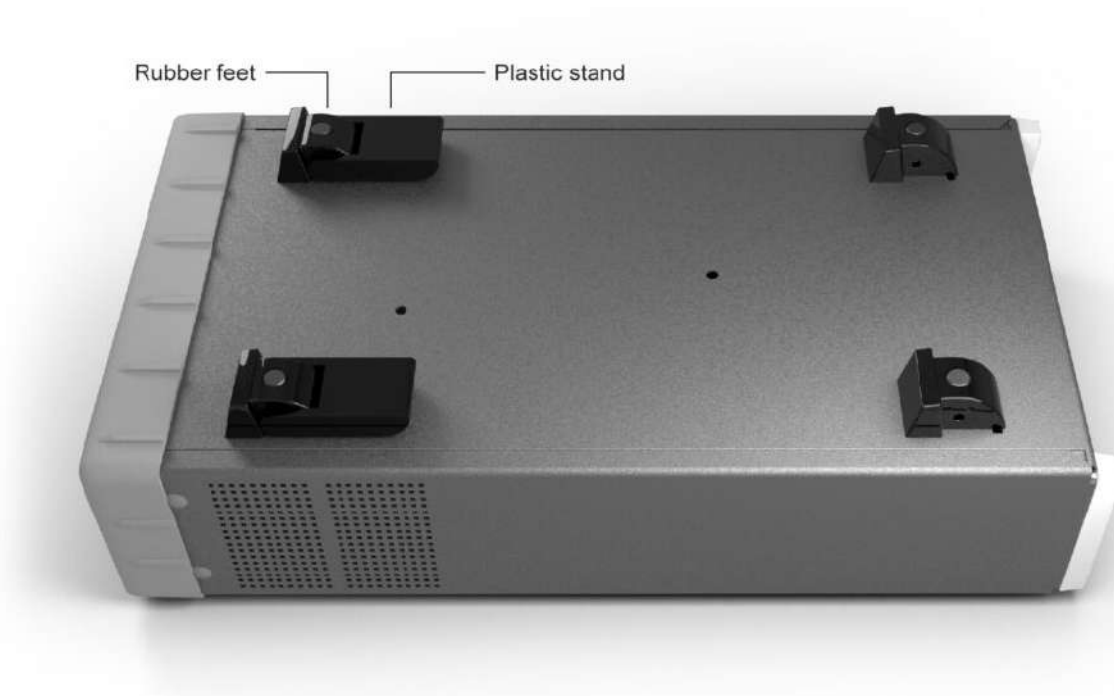


Fig. 2.4: Assembling the Rackmount Kit (Option 22/90)

- Turn the device upside down
- Remove the rubber feet in the plastic stand
- Loosen the screws underneath the rubber feet
- Remove the plastic stands
- Remove the four decorative plugs that cover the screw holes on the right and left side of the front panel.
- The long bracket in Option 22/90 has an opening so that cables for Input signals can be routed inside the rack.

- Mount the rackmount kit with the included screws

2.4.6 Reversing the Rackmount Kit

The instrument may also be mounted to the right in the rack. To do so, swap the position of the two brackets.

2.4.7 Rackmount Adapter - two units

This rackmount adapter can hold any two standard Pendulum $\frac{1}{2}$ x 19" units.



Fig. 2.5: Rackmount Adapter - two units

If you have ordered the Option 22/05 rack-mount kit for two instruments, it has to be also assembled after delivery of the instrument. The rackmount kit consists of the following:

- 4 Brackets, rear
- 1 Hinge Spring Latch
- 2 Ear, rack
- 1 Assembly instruction, SXS Rack kit
- 2 Screws M4x8
- 8 Screws M5x10
- 1 Spacer M4x16

2.4.8 Assembling the Rackmount Kit (Option 22/05)

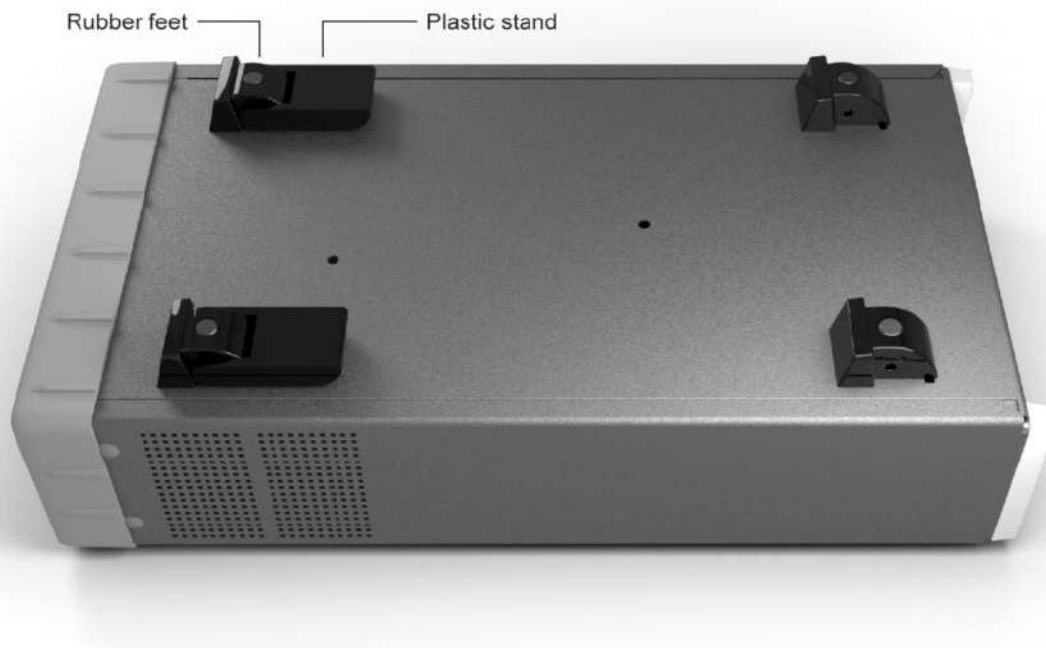


Fig. 2.6: Assembling the Rackmount Kit (Option 22/05)

- Turn the devices upside down
- Remove the rubber feet in the plastic stand
- Loosen the screws underneath the rubber feet
- Remove the plastic stands
- Remove the four decorative plugs that cover the screw holes on the right and left side of the front panel.

Use the following steps to complete the side by side rack mount installation for your products. If necessary, refer to the item numbers in the following diagram for additional detail.

- Determine where you would like each unit positioned (i.e., on the right or left side)
- If plugs exist on the mounting holes on the front left and right side of product cover, remove and discard them
- Using screwdriver, screw the rack ear (Item #2) into place using the supplied 10mm screws (Item #5)
- Pinch the hinge pins together to separate the right and left hinge halves (Items #3 and 4)
- Attach hinge halves to the unit with hinge facing towards the front (as displayed in diagram)
- Using a screwdriver, remove the existing rear brackets on the back of each unit
- Using existing machine screws removed in previous steps, attach the rear brackets supplied with the mounting kit (Item #1)
- Pinch the hinge pins together into the stored position. Align the hinge halves together between the two units, and swing together side by side. The hinge pins should snap into place securing the front of the two units together
- Take the supplied Hex Spacer (Item #7) and place between middle rear brackets, and secure using the supplied 8mm screws (Item #6)
- Assembly is now ready for installation into standard 19" rack



Fig. 2.7: Rackmount Adapter - two units

2.4.9 Antenna Installation

Note

Only for CNT-104R with Option 55 (GNSS).

2.4.9.1 What antenna and cabling to choose?

It is possible to order matching antenna, mounting kit and antenna cabling directly from Pendulum Instruments. For ordering information please see [Hardware Accessories](#).

For choosing third-party antenna and cable please consider the following:

- GNSS antenna input located at the rear panel of the instrument is SMA connector. Use antenna cable with male type of SMA connector or appropriate adaptor.
- The instrument supports L1 and L5 bands. Choose antenna accordingly.
- The instrument outputs 5V supply voltage on antenna connector for powering active antennas. Choose active antennas with 5V power.
- Use high-quality antenna cables to minimize the losses. Use low noise amplifiers if antenna cable has to be long. Make sure that the total external gain at the antenna input of the instrument is in the range of 17 to 50 dB.

2.4.9.2 Where and how to mount the antenna?

A GNSS receiver needs to receive signals from as many satellites as possible. Optimal performance will not be available in narrow streets and underground parking lots or if objects cover the antenna. Poor visibility may result in large time phase variation and long self-survey time.

Mounting Location - Key Principles:

- Unobstructed View of the Sky (360°)
 - In urban areas mount on a rooftop or tall mast, ideally the highest point nearby.
 - Avoid obstructions like buildings, trees, poles, or satellite dishes.

- You need an unobstructed view of the sky above $\sim 10^\circ$ elevation angle from the horizon in all directions (e.g., 10° to 90° elevation).
- Minimize Multipath Effects

Multipath happens when signals reflect off nearby surfaces and interfere with direct signals. Avoid mounting near metal surfaces, HVAC units, fences, railings and other reflective objects and surfaces. If unavoidable, use a ground plane or a choke ring antenna to reduce multipath.
- Stable, Vibration-Free Surface

Mount on a rigid, stable surface to prevent movement that could affect accuracy. For high-precision timing, even tiny movements can degrade time stability.
- Away From RF Interference
 - Keep away from high-power transmitters (cell towers, radar, TV, etc.).
 - Also avoid electronics that may emit EMI (electromagnetic interference).

How to Mount the GNSS Antenna:

- Use a Ground Plane (if not included).

Helps reduce multipath. A 10-30 cm metal disk or plate under the antenna is often sufficient. Some antennas (like choke ring types) have this built-in.
- Mount Vertically (Upward Facing)
- Avoid cable sharp bends or kinks.
- Weatherproofing
 - Use a weather-rated antenna (IP65 or better).
 - Use weatherproof connectors.
 - Install the antenna near a lightning rod, so that it lies within 45° angle from the top of the lightning rod, below it.
 - Bond the antenna mount to the building protection earth.
 - Install an inline GNSS lightning arrestor indoors at the building entry point of the cable.

Note

It must be at least 8 m of cable after the lightning arrestor to guarantee its proper function.

Chapter 3

Getting Familiar with the Instrument

3.1 Front Panel

3.1.1 Front Panel



Fig. 3.1: Front panel of CNT-104S and CNT-104R. Two-channel devices include less measurement inputs. Blind panel versions do not have a screen.

1. **USB Host ports.** The ports allow to use keyboard/mouse to control the device, Wi-Fi dongle for wireless connection, USB Mass Storage that holds measurement results, settings presets, firmware update files.
2. **Stand-by LED.** The LED lights up when the instrument is in Stand-by mode and blinks when the display is off, but the device is powered on. In Stand-by mode internal timebase oscillator and GNSS receiver are kept powered on.
3. **Stand-by button.** Holding this button puts the instrument into Stand-by mode. For waking it up again, press the button again.
4. **Hard keys.** Present in CNT-104S, CNT-104R, CNT-102.
 - Auto Set (best settings)
 - RUN/HOLD measurements
 - Restart measurements
 - Home key (goto start screen)
 - Back (go to previous screen)

5. Input Connectors.

These connectors can be placed on the rear or front panel depending on model (with display or not) and options 11A, 11C, 12A, 12C.

- A, B: 400 MHz channels with BNC Inputs.
- D, E: 400 MHz channels with BNC Inputs. Only present in CNT-104S, CNT-104R, CNT-104B.
- C: 400 MHz to 3/24 GHz optional microwave input with 2.92 mm input (compatible with SMA)

6. **Graphical display with touch panel.** For result readout, graphs, status indication and more.. Present in CNT-104S, CNT-104R, CNT-102.

3.2 Stand-by button



Stand-by button is located in the left side of the front panel and is intended for switching stand-by mode of the instrument.

For putting the instrument into stand-by mode, please hold the button for 3 seconds. For waking it up again, pressing the button is enough.

In stand-by mode, the instrument is not completely disconnected from the AC mains, but remains in a state of low power consumption.

The instrument's internal oscillator continues to operate. For CNT-104R with Option 55 (GNSS), FTR-210R the GNSS receiver also remains active, and oscillator disciplining settings are maintained in stand-by mode.

Stand-by mode is indicated by the illuminated LED indicator above the stand-by button.

3.3 Rear Panel

Attention

When using GPIB interface, please pay attention that a most commonly used IEEE-488.2/GPIB cable with a side connector might overlap with Ethernet cable when both are connected. If both cables must be connected simultaneously, please use a standard straight GPIB cable or a GPIB port extender, that moves the connector out to the back of the unit. This will prevent cables overlapping. Another possible solution is to use Wi-Fi connection instead of Ethernet.

Attention

When ordering GNSS antenna cable options with TNC connector, please pay attention that Option 02/A (antenna cable adapter SMA to TNC) is required. See [Hardware Accessories](#) for more information.

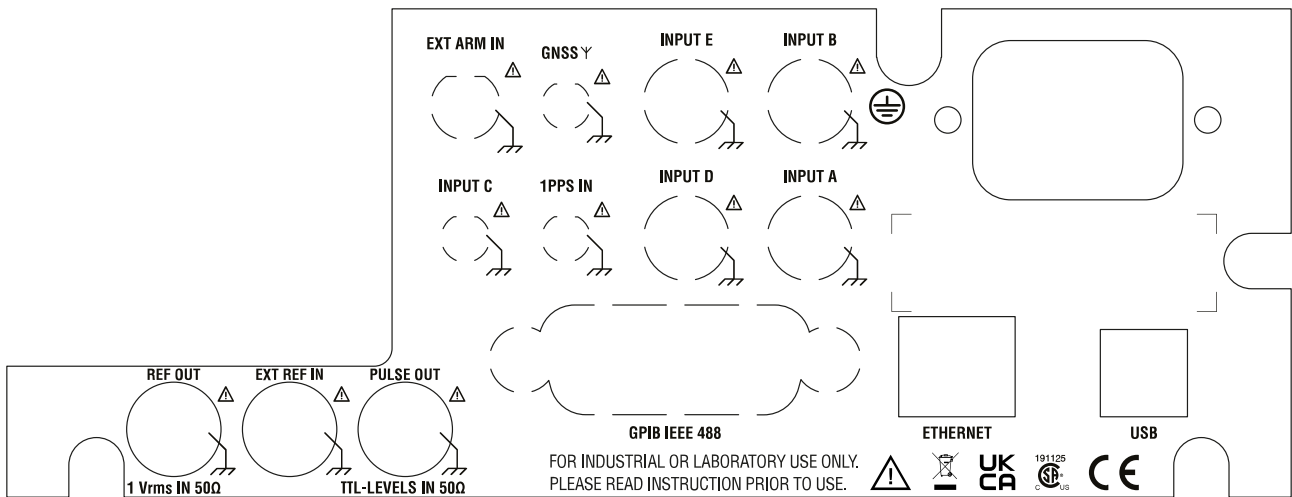


Fig. 3.2: Rear panel of CNT-104S, CNT-104R, CNT-104B

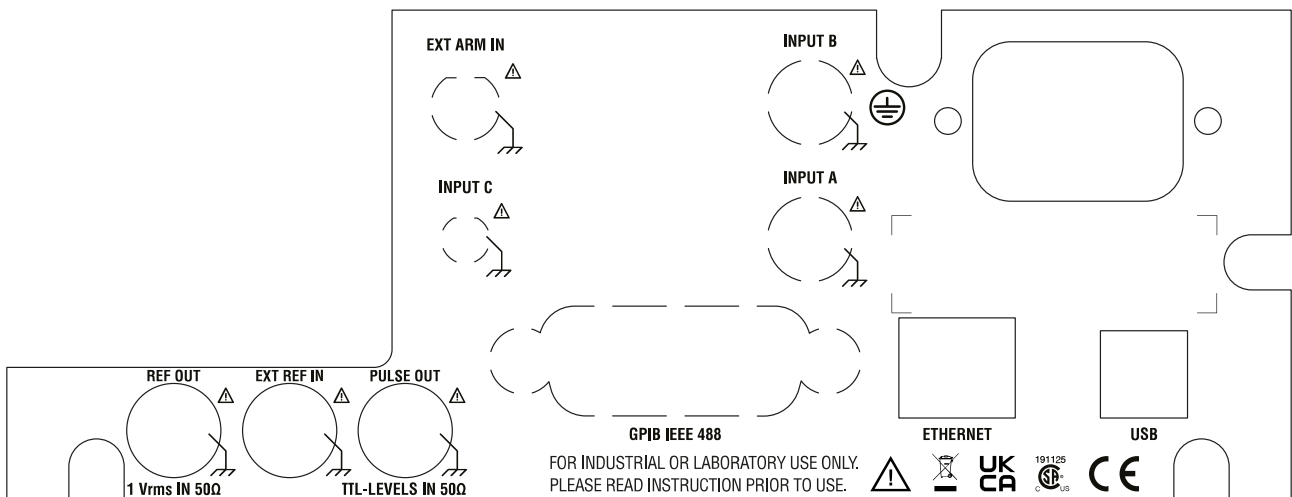


Fig. 3.3: Rear panel of CNT-102, CNT-102B

Rear panel has the following connectors (depending on model and rear panel options):

- Inputs A, B, D, E (if they are not placed on the front panel), BNC connectors
- Input C (if it is not placed on the front panel), 2.92 mm connector (compatible with SMA)
- REF OUT – reference frequency output with BNC connector. Output frequency corresponds to currently used timebase frequency: internal or external
- EXT REF IN – reference frequency input with BNC connector
- PULSE OUT – programmable pulse output with BNC connector. SW Option 132 is required for operation
- 1PPS IN – external disciplining input with SMA connector for CNT-104R

Inputs A, B, D, E, C locations (front or rear) depend on device model (with display or not) and ordered options: 11A, 11C, 12A, 12C.

3.4 Home Screen

Note

Pictures below illustrate display of CNT-104S model.

For CNT-102, CNT-102B, channels D, E are not available and areas, fields and graphical objects for corresponding to these channel are not present. Up to 2 signals can be measured in parallel.

For FTR-210R with Option 230, channels B, D, E, C are not available and areas, fields and graphical objects for corresponding to these channel are not present. Only one signal can be measured in parallel.

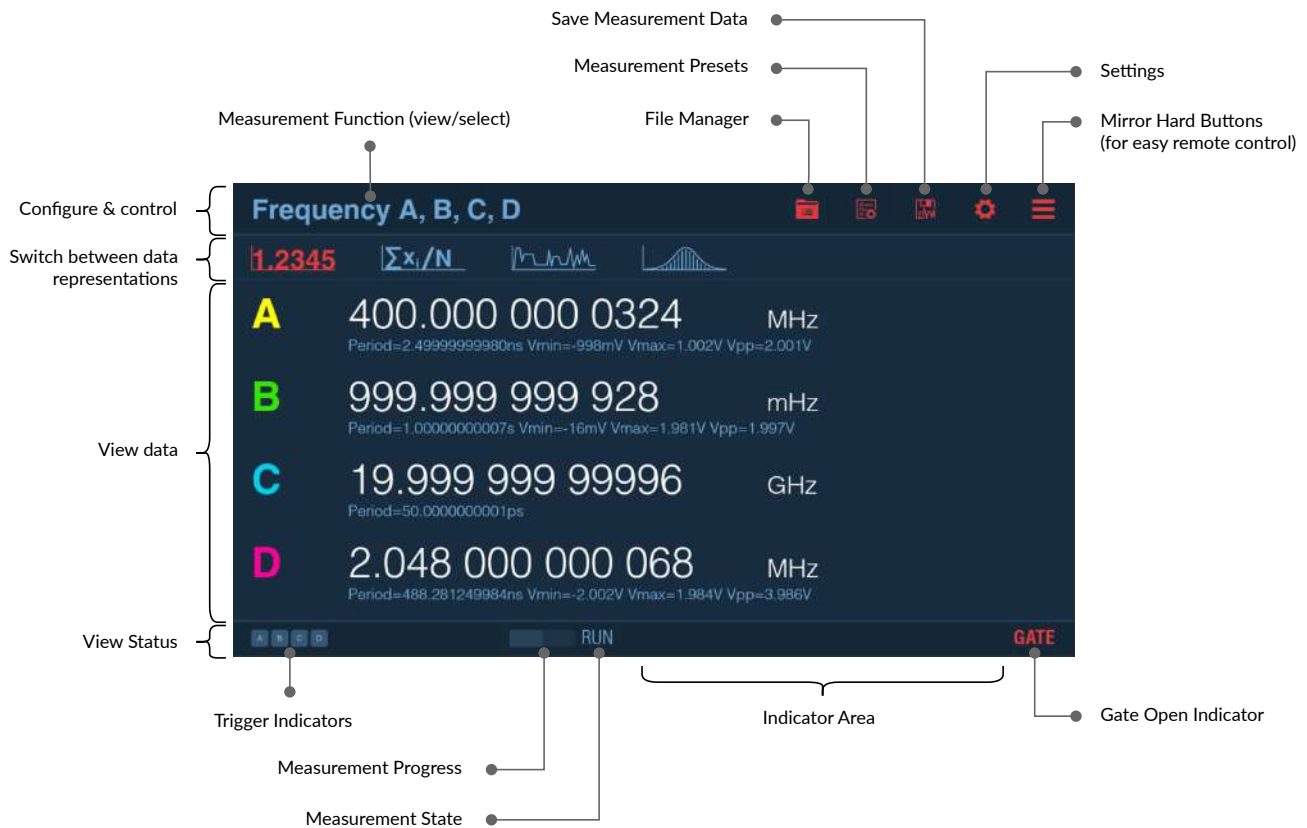


Fig. 3.4: Numeric screen of CNT-104S

Measurement State:

- **RUN** – next measurement will start automatically as soon as current one is over. Pressing RESTART in this state starts new measurement, measurement state remains RUN. Pressing RUN/HOLD in this state changes the state to SINGLE, but current measurement continues. Exception is Totalize measurement functions, when state is changed to HOLD.
- **SINGLE** – measurement is in progress. After measurement is over – measurement state will change to HOLD, no new measurement will start. Pressing RESTART in this mode starts new measurement, measurement state remains SINGLE. Pressing RUN/HOLD in this state stops the measurement and changes state to HOLD.
- **HOLD** – measurement is not active. Results of previous measurement are displayed. Pressing RESTART starts new measurement and changes state to SINGLE. Pressing RUN/HOLD in this state starts new measurement and changes state to RUN.
- **READY** – idle state, measurement is not active. When a new measurement starts, this state switches to RUN.

Indicators:

- **Trigger indicators** – if signal crosses set trigger level(s) for particular input, then corresponding trigger indicator is lit, otherwise it is grayed out.
- **GATE** – red when measurement is active, grayed out otherwise.
- **MATH** – Math function is active. User selectable formula is applied to one or all (depending on user choice) measurement series.

- LIM – Limits function is active. Values of one or all (depending on user choice) measurement series are checked against the limit(s) specified by the user. User can configure the desired behavior when measurement data exceeds the limit(s).
- ER – External Reference clock is used as a timebase for measurements.
- REM – instrument is now in Remote state (controlled by remote application). In this state the instrument can not be controlled from the front panel. Press BACK to switch to Local state and enable front panel control. Alternatively, tap/click the screen and push Unlock screen button in the message box that pops up. If REM! indicator is displayed, Remote Lockout mode is active and BACK button cannot be used to return to Local Mode. Only remote party can undo this state. In web interface or VNC client use F7 key in place of BACK.
- ARM – measurement configured to start and/or stop on arming signal.

3.5 Settings

Note

Pictures below illustrate display of CNT-104S model.

For CNT-102, CNT-102B, channels D, E are not available and areas, fields and graphical objects for corresponding to these channel are not present. Up to 2 signals can be measured in parallel.

For FTR-210R with Option 230, channels B, D, E, C are not available and areas, fields and graphical objects for corresponding to these channel are not present. Only one signal can be measured in parallel.

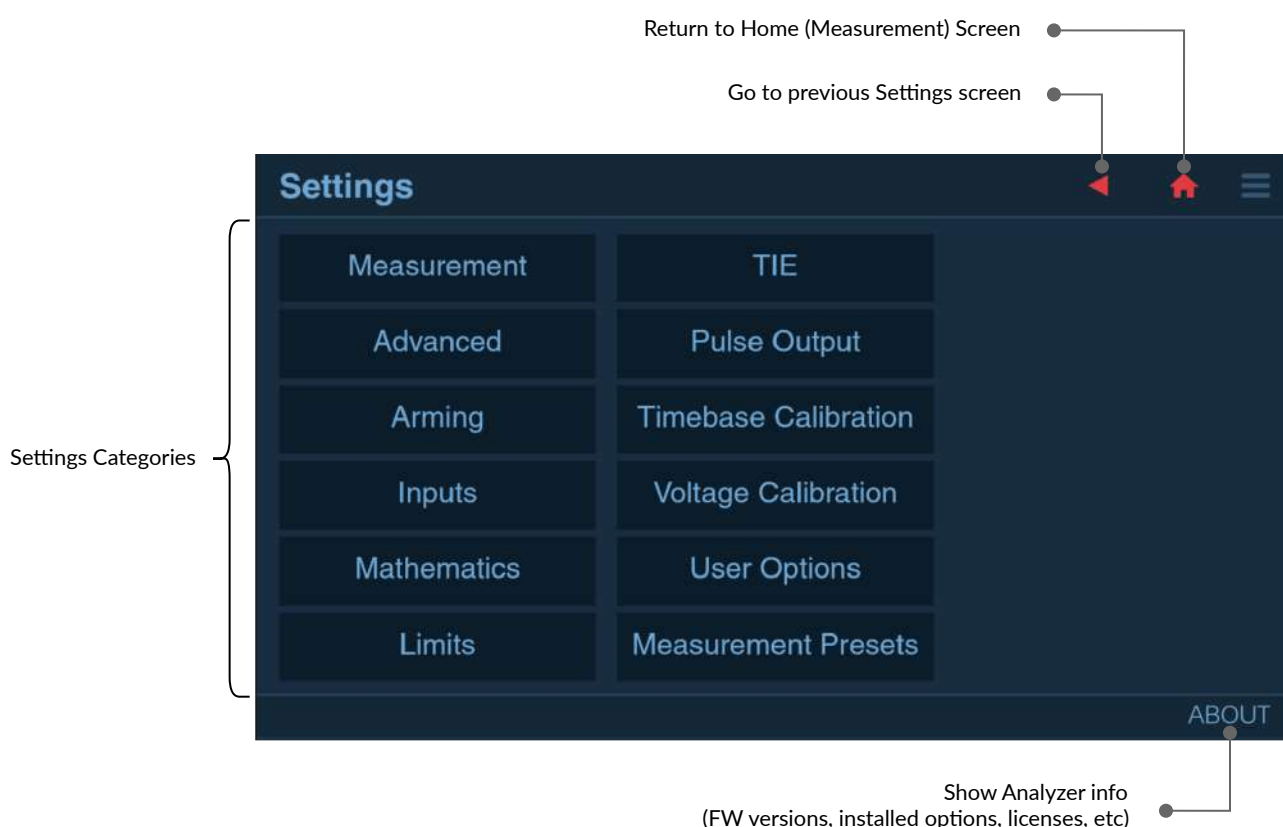


Fig. 3.5: Settings menu

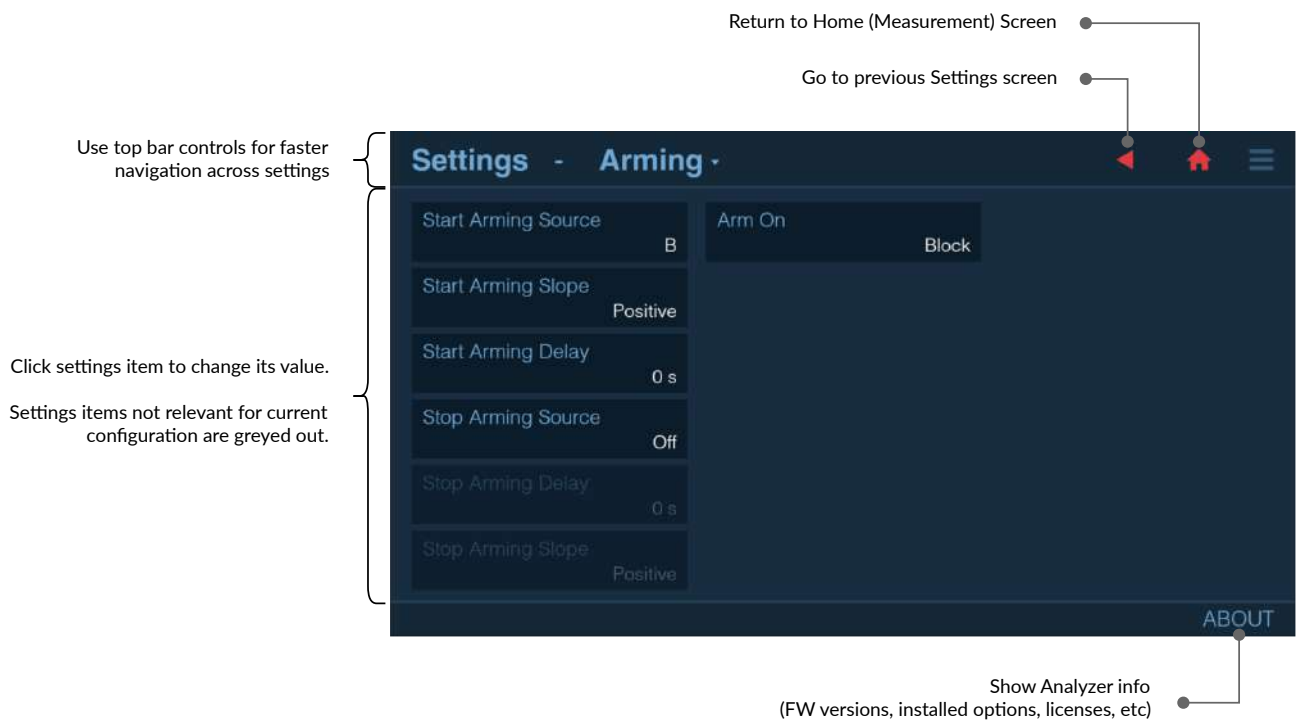


Fig. 3.6: Arming menu

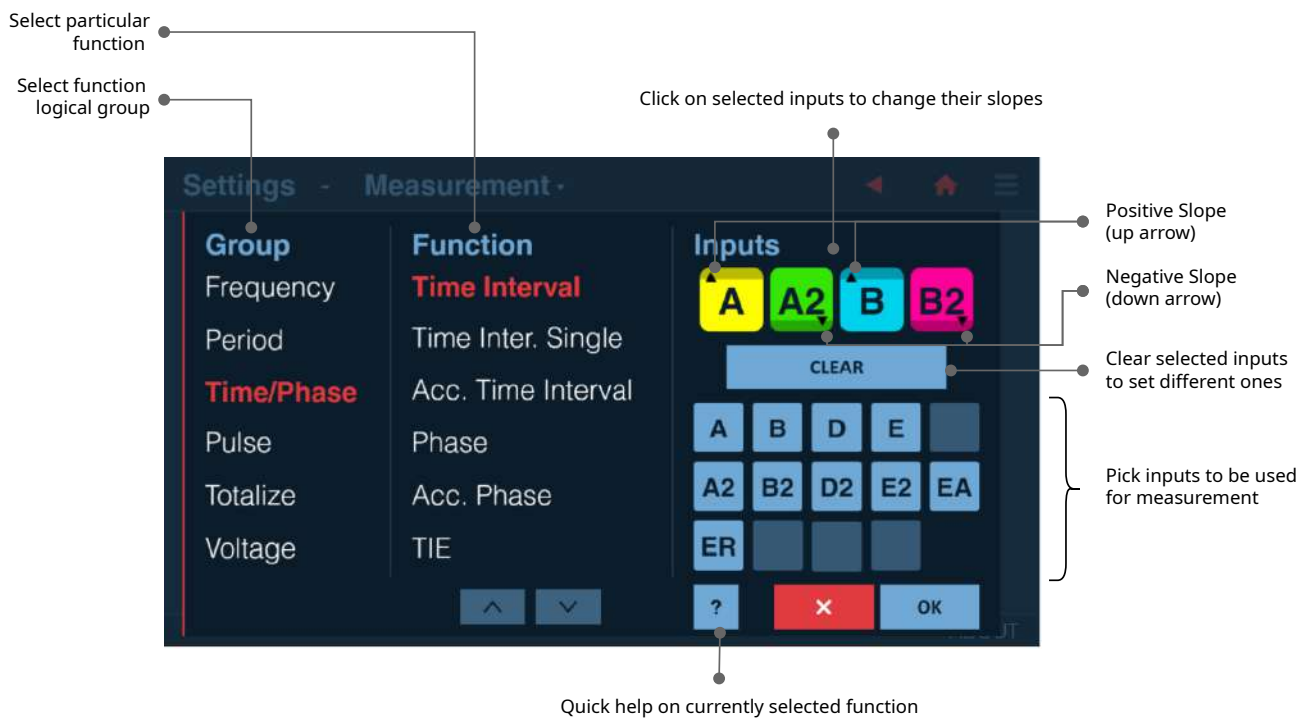


Fig. 3.7: Function and inputs selection menu

Inputs description:

- A, B, D, E – main inputs. D and E are available only on CNT-104S, CNT-104R, CNT-104B. B is available only on CNT-104S, CNT-104R, CNT-104B, CNT-102, CNT-102B.
- A2, B2, D2, E2 – supplementary comparators of main inputs (e.g. for measuring time intervals inside multi-level signals). D2 and E2 are available only on CNT-104S, CNT-104R, CNT-104B. B2 is available only on CNT-104S, CNT-104R, CNT-104B, CNT-102, CNT-102B.
- C – optional high frequency input. Available on CNT-104S, CNT-104R, CNT-104B, CNT-102, CNT-102B with options 10, 110.

- EA – External Arming input. Available on CNT-104S, CNT-104R, CNT-104B, CNT-102, CNT-102B.
- ER – External Reference Input. Available on CNT-104S, CNT-104R, CNT-104B, CNT-102, CNT-102B.
- Rb – 1-pps output of Rubidium timebase (internal signal). Available on CNT-104R, FTR-210R.
- G - 1-pps output of GNSS receiver (internal signal). Available on CNT-104R with Option 55 (GNSS), FTR-210R.

Use SI prefixes for fast value input

Built-in hints explain setting item meaning and constraints

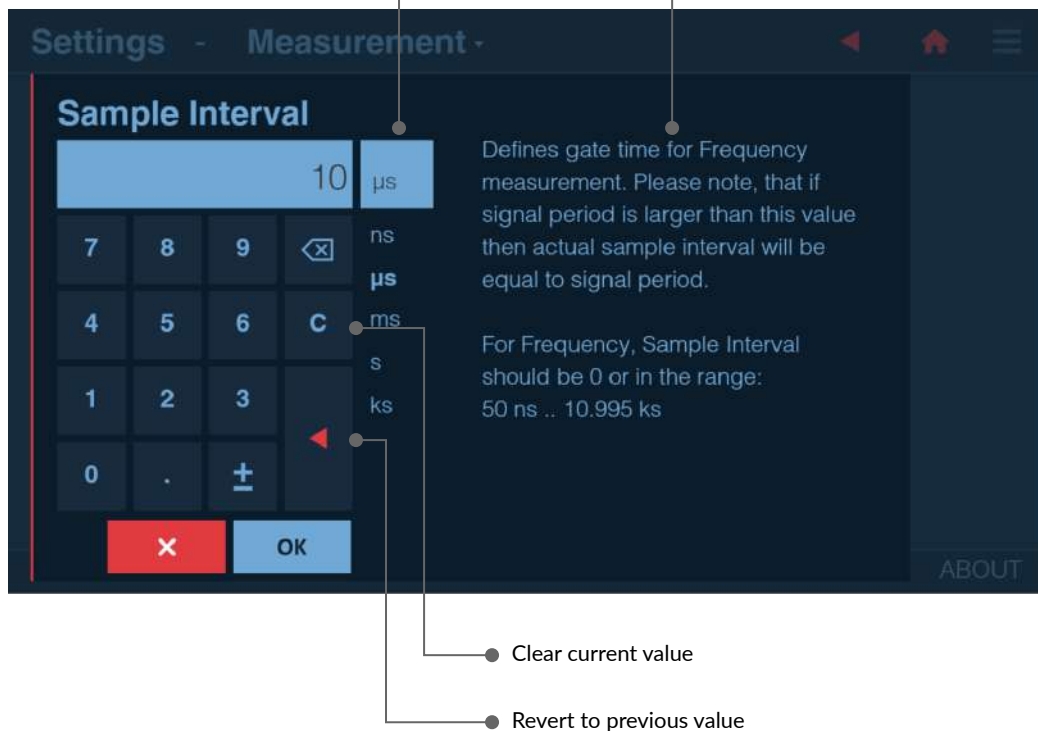


Fig. 3.8: Numeric keyboard

3.6 Measurement Data Display

Note

Pictures below illustrate display of CNT-104S model.

For CNT-102, CNT-102B, channels D, E are not available and areas, fields and graphical objects for corresponding to these channel are not present. Up to 2 signals can be measured in parallel.

For FTR-210R with Option 230, channels B, D, E, C are not available and areas, fields and graphical objects for corresponding to these channel are not present. Only one signal can be measured in parallel.

View large numeric data from 4 measurement channels at the same time along with auxiliary data (e.g. voltage):



Fig. 3.9: Numeric screen

View detailed statistics for all measurement channels (click numbers for particular channel to zoom):



Fig. 3.10: Statistics screen



Fig. 3.11: Graphs screen

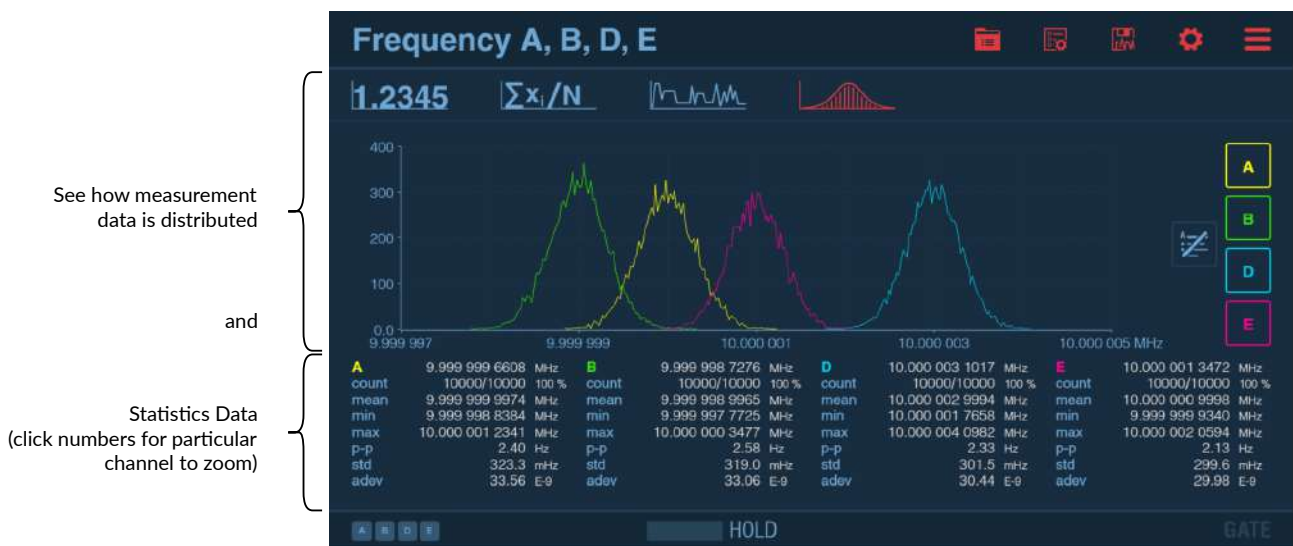


Fig. 3.12: Distribution graph screen

Chapter 4

Measurement principles and concepts

4.1 Time and Frequency measurement principles

Block diagram on [Fig. 4.1](#) demonstrates input signal transformation to series of time and frequency measurement data points.

First, input signal gets into input amplifier. The generic role of input amplifier circuits is matching the input to signal source, and optionally: attenuate or amplify it, remove DC offset and/or filter out high-frequency noise.

Please note: There are several kinds of input amplifier circuits (configurable input amplifiers, prescalers, fixed input amplifiers), please refer to [Input signal conditioning/Input Amplifiers](#) chapter for more details about them.

After the input amplifiers the signal is digitized using one (inputs C, EA, ER, Rb, G) or 2 comparators (inputs A, B, D, E on four-channel models, inputs A, B on two-channel models). It works the following way: when the signal crosses the set trigger level, comparator generates a positive (in case of transition from below to above the trigger level) or negative (in case of transition from above to below the trigger level) slope. Please refer to [Fig. 4.2](#) for an example.

Please note: For most measurement modes on inputs with 2 comparators, output of only one comparator is used for measuring the signal from this input. However, there are measurement modes using both comparators implicitly:

- Rise/ Fall Time and Slew Rate measurements use 2 comparators for getting Time Interval between lowest (10%) and highest (90%) levels of the signal (see details in [Rise Time](#), [Fall Time](#), [Rise-Fall Time](#));
- Pulse width and Duty Cycle measurements use 2 comparators to produce pulses on positive and negative slope of a signal and measure Time Interval between these;
- Frequency and Period Average use 2 comparators to implement implicit wide hysteresis targeted on improving noisy signals measurements (see details in [Frequency/Period Average measurements](#) chapter).

Second comparator can also be explicitly selected for measurement. E.g., Time Interval A, A2 will measure time interval between signal level set by trigger level A and signal level set by trigger level A2 (can be useful for measuring characteristics of multi-level signals, e.g. TDR measurements – see [Dual Time Interval](#)). It can also be explicitly used as a source of start or stop arming.

Digitized signals from physical inputs are just pulse trains which can be multiplexed to 4 internal measurement channels. Each measurement channel starts with Wide Hysteresis block. Wide Hysteresis block just passes through the signal for most measurement functions except Frequency, Period Average, their Smart versions, TIE, and Frequency Ratio for which implicit wide hysteresis is used for better noise tolerance (see [Frequency/Period Average measurements](#)).

The resulting pulse train is then counted independently in each measurement channel. Measurement logic specific for each measurement mode makes snapshots of channel's pulse counter, timestamps it and adds channel number, forming series of so-called raw results.

Raw results are further post-processed in calculation block to form series of final value-timestamps pairs.

Note

Block diagram below illustrate logic of CNT-104S, CNT-104R, CNT-104B.

For CNT-102, CNT-102B, channel D, E circuits are not available.

For FTR-210R with Option 230, channel B, D, E, C circuits are not available.

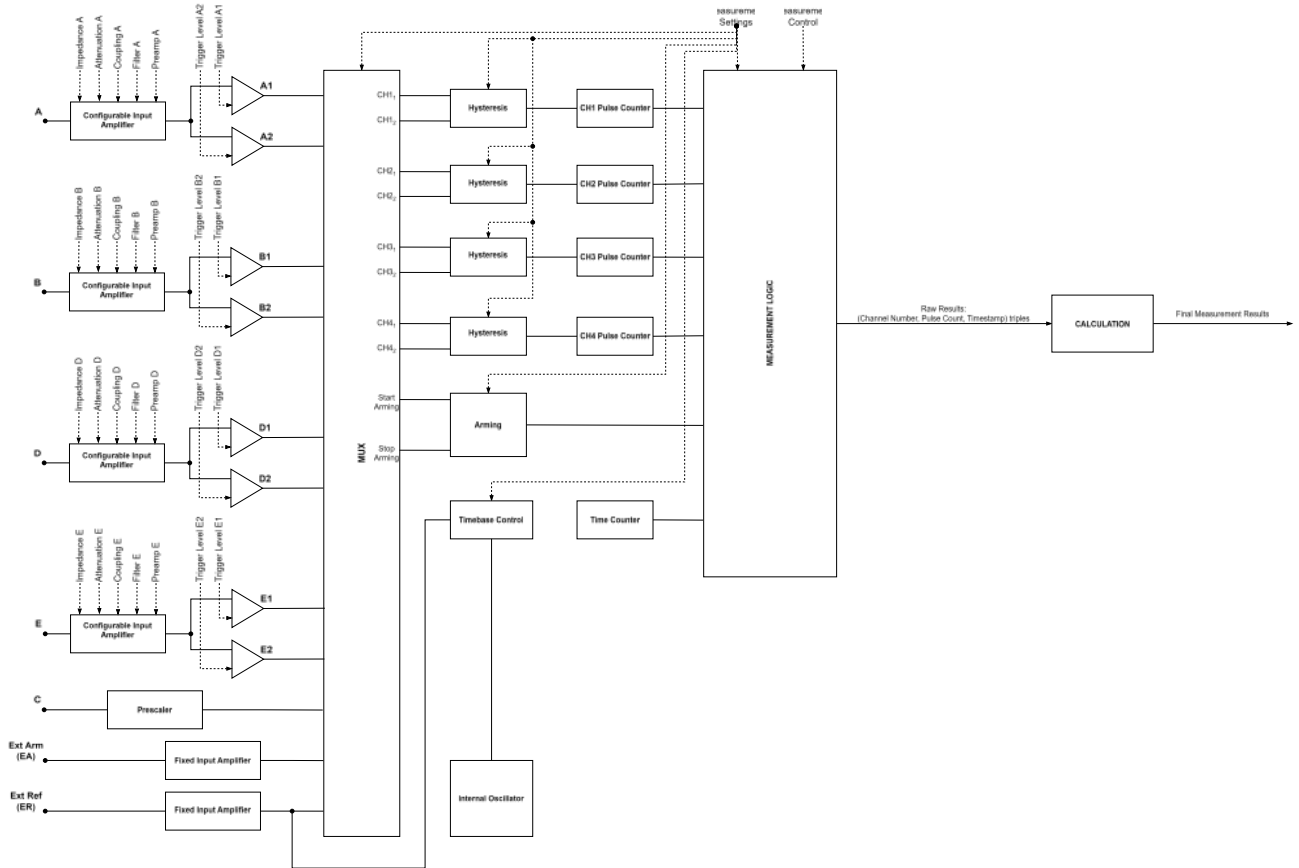


Fig. 4.1: Input signal to Time & Frequency measurement results transformation

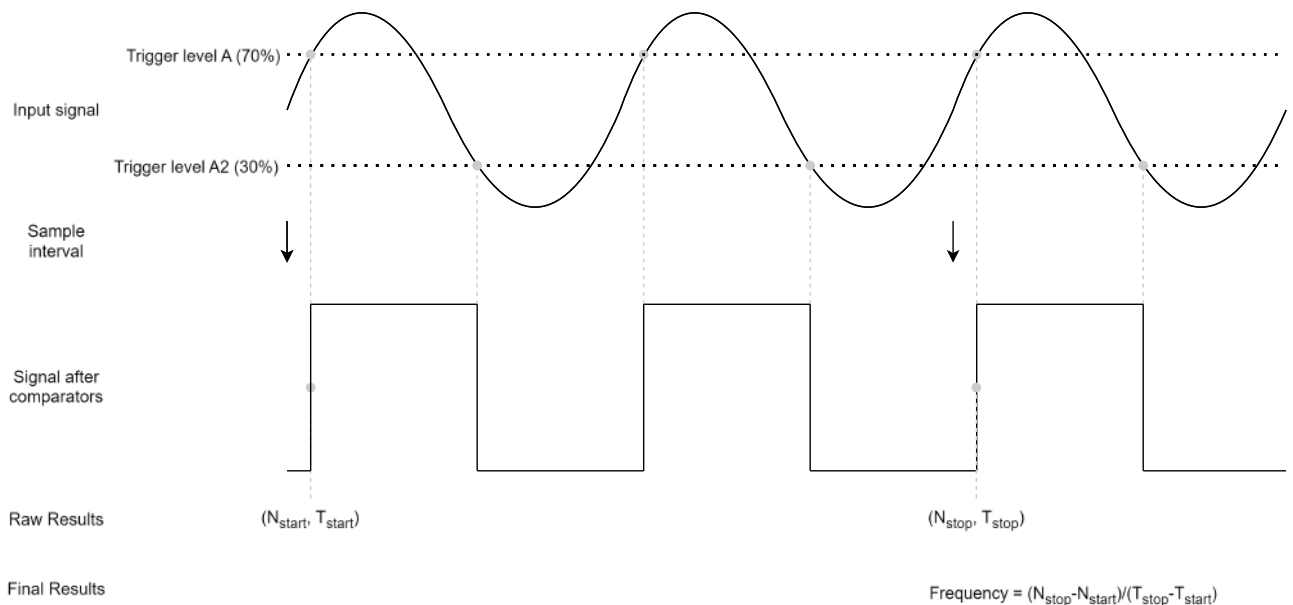


Fig. 4.2: Example of input signal to result transformation for Frequency measurement mode with Wide Hysteresis

4.2 Voltage measurement principles

Measuring voltage of the input signal is available only on inputs A, B, D, E (for CNT-104S, CNT-104R, CNT-104B) or on inputs A, B (for CNT-102, CNT-102B) or on input A (for FTR-210R with Option 230). On each input there are 2 comparators used to search for signal's lower and upper levels. Multiple inputs can be measured in parallel.

Adaptive search algorithm is used which depends on Voltage Mode setting. Each voltage mode implies minimum input signal frequency which the voltage measurement can handle. E.g. in Normal Voltage mode (default) instrument is able to measure voltage of signals with frequencies starting with 100 Hz and above. Allowing lower frequencies makes the voltage measurement slower so it is not recommended to set Voltage mode below Normal unless really needed (one might want to consider using Autoset instead).

Table below summarizes Voltage Modes available :

Table 4.1: Voltage Modes

Voltage Mode	Minimum Frequency	Average Time to measure 1 voltage sample
Very Slow	1 Hz	15 s
Slow	10 Hz	1.5 s
Normal	100 Hz	450 ms
Fast	1 kHz	65 ms
Very Fast	10 kHz	30 ms

4.3 Sample Interval

On each measurement channel instrument can produce gap-free samples back-to-back as fast as 1 sample per 50 ns or 1 μ s (depending on particular model and corresponding license installed). When Sample Interval is set below 50 ns on devices that allow it, it still implies 50 ns. However, for most cases one doesn't need samples to be generated with such a high frequency, then using larger Sample Interval can be considered. In this case samples in each measurement channel will be generated not faster than once per set Sample Interval.

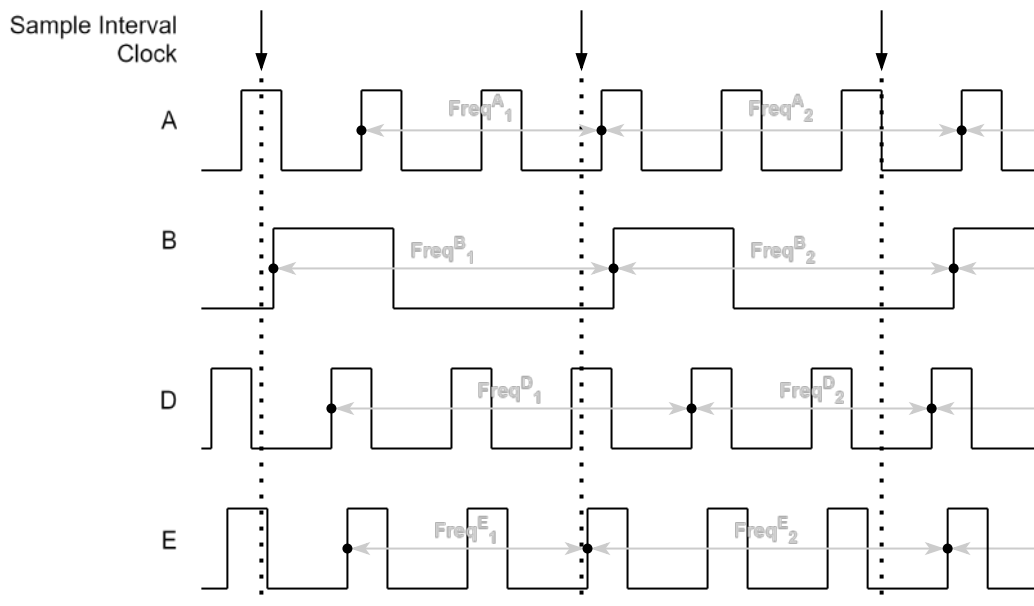


Fig. 4.3: Example of how sample interval works with 4-channels multi-channel Frequency measurement.

Sample Interval hints:

- Sample Interval clock is not synchronized to signal, meaning actual Sample Interval between 2 consecutive samples can be less or more than Sample Interval set by the user.
- When doing parallel measurement, Sample Interval is applied to each measured series independently. E.g., when measuring Frequency A, B, D, E and using 1 ms Sample Interval, one will get 1000 Frequency Samples per second from each input.

- Sample Interval for averaging measurement functions (Frequency, Period Average and their Smart alternatives) acts as an averaging gate. The larger the gate (Sample Interval) – the greater the resolution.
- The instrument contains two cascaded memories for result saving. The first is the cache buffer that can hold up to 20000 raw samples with a maximum writing speed of 20 million Samples/s. The second is the main memory, that can hold up to 32 million results, with a maximum writing speed of 12.5 million samples per second, or 80 ns between samples. The data is written to the cache buffer in *parallel* from up to 4 inputs, meaning the capture speed is independent of the number of inputs used. The data transfer from the fast cache buffer to the slower main memory is done in *serial*, so the maximum capture speed varies with the number of channels used for current Function setting: 20k for a single channel measurement or 5k for a 4 channel measurement, will guarantee a sampling rate of 20 million values/s or 1 million values/s, at a sample interval of 50 ns or 1 μ s (depending on particular model and corresponding license installed). When using a larger number of samples, the Sample Interval (given that signal period is less than or equal to the set Sample Interval) must be increased to minimum 80 ns for 1-channel and minimum 320 ns for 4-channel measurements, to avoid cache buffer overflow. If not, the measurement might be aborted to avoid data loss.

Example. Measurement function is Frequency A,B,D,E, Sample Interval is 50 ns, Sample Count is set to 10000 and period of all input signals is 50 MHz. 4 measurement channels are used in parallel, each supposed to deliver samples at a rate of 20 million samples per second, which is greater than the speed cache buffer can be fetched with (12.5 million samples). Total number of samples to be generated is $4 \times (10000 + 1) = 40004$ ($N + 1$ raw samples are needed to calculate N frequencies), which is twice greater than measurement logic buffer capacity. So, the buffer will overflow and measurement will be aborted. Solution would be to either increase Sample Interval to 320 ns (4 channels $\times$ 80 ns, giving 12.5 million samples per second total) or to decrease Sample Count to 4999 (giving $4 \times (4999 + 1) = 20000$ samples total).

To avoid this situation please watch out for warning text when setting Sample Count and/or Sample Interval or warning icon when choosing measurement function and inputs.

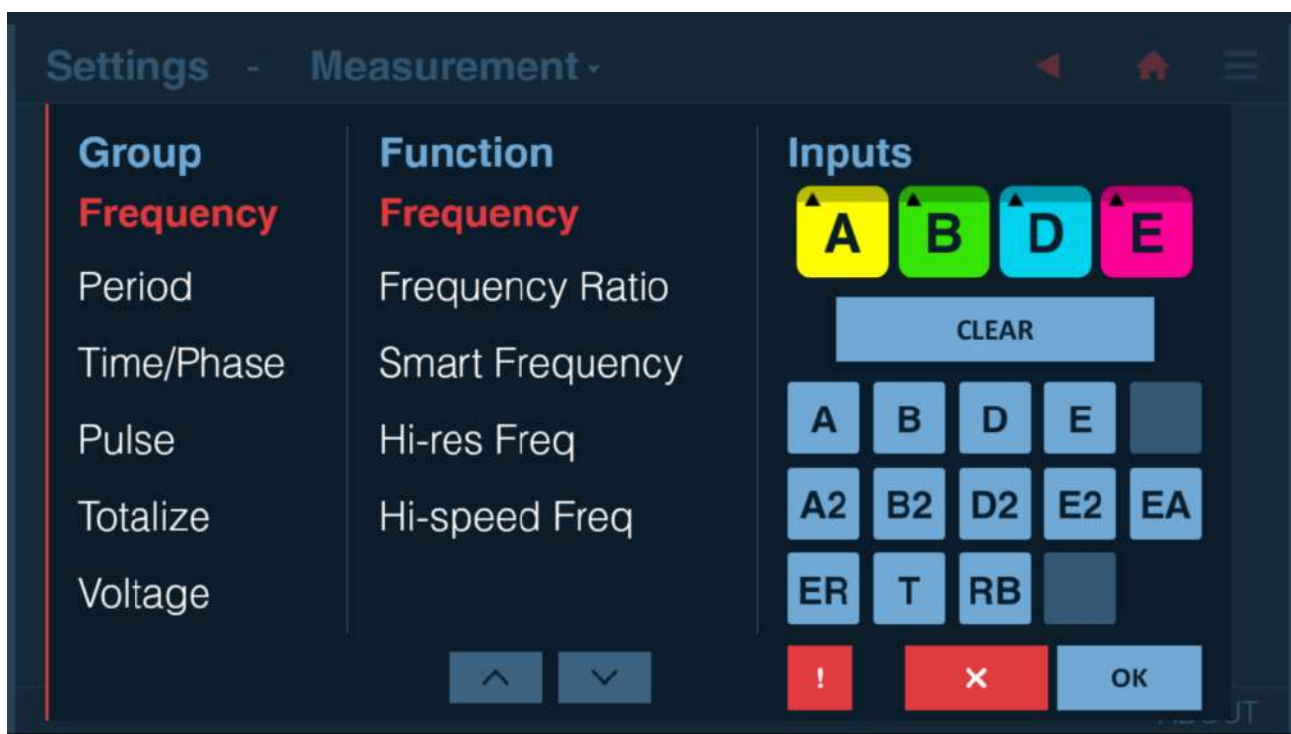


Fig. 4.4: Warning icon on Function/Inputs selection dialog (clickable red button with exclamation sign to the left of $\times$ button).

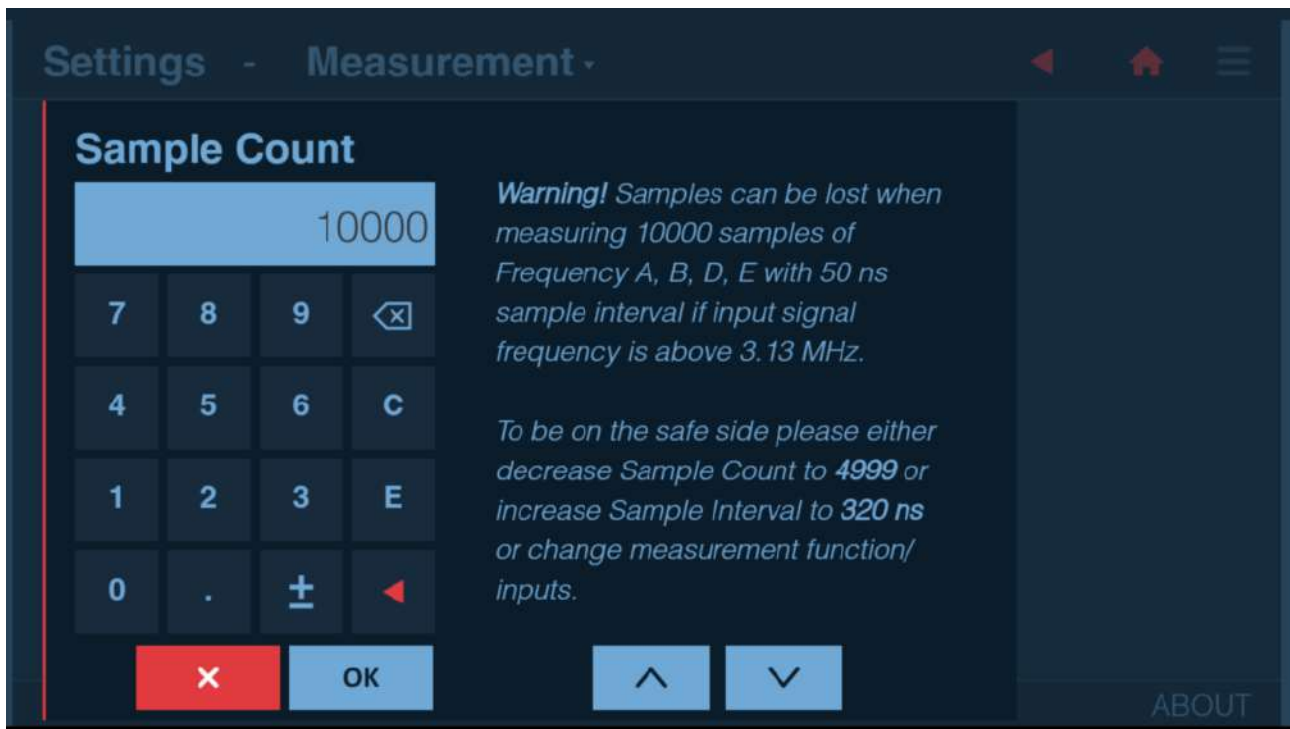


Fig. 4.5: Warning text when editing Sample Count

- When using Sample Interval close to 50 ns, actual sample interval might vary between 50 ns and 100 ns. In case of Time Interval measurement – it can result in generating less samples than was ordered by Sample Count setting. To avoid this please consider setting Sample Interval to 0 if you need minimal sample interval between samples. Setting Time Interval to 0 disables Sample Interval clock, meaning taking samples as fast as possible (close to 50 ns if signal period is 50 ns or greater).

Note

Above relates only to model and license combinations allowing sample interval of 50 ns.

- Sample Interval setting doesn't affect Voltage measurement where interval between samples directly depends on Voltage Mode (please see [Voltage measurement principles](#) for details).
- Sample Interval setting doesn't affect manual Totalize measurement where interval between samples is always 100 ms.

4.4 Input signal conditioning/Input Amplifiers

4.4.1 Overview

The input amplifiers are used for adapting the widely varying signals in the ambient world to the measuring logic of the instrument.

These amplifiers have many controls, and it is essential to understand how these controls work together and affect the signal.

4.4.2 Configurable amplifiers

Input amplifiers for inputs A, B, D, E (for CNT-104S, CNT-104R, CNT-104B) or A, B (for CNT-102, CNT-102B) or A (for FTR-210R with Option 230) are configurable (Inputs page of the Settings dialog) and allow to select a bunch of parameters described in the following sections.



Fig. 4.6: Input amplifiers configuration menu

4.4.2.1 Impedance

Impedance setting allows to match the impedance of the input to signal source. One can choose between 1 M Ω or 50 Ω impedance.

CAUTION: Switching the impedance to 50 Ω when the input voltage is above 12 Vrms may cause permanent damage to the input circuitry.

4.4.2.2 Attenuation

This setting allows attenuating the signal by factor of 10 if its dynamic range exceeds ± 5 V. 1x, 10x and Auto attenuation options are available. If Auto is selected then first sample of any voltage measurement (including the ones performed during Autoset and Auto-trigger) will be analyzed to determine the dynamic range of the signal. If the range exceeds ± 5 V then 10x attenuation will be switched on automatically. 1x will be used otherwise.

4.4.2.3 Coupling

Use the AC coupling feature to eliminate unwanted DC signal components or keep DC offset by using DC coupling.

Hint: Always use AC coupling when the AC signal is superimposed on a DC voltage that is higher than the trigger level setting range. However, we recommend AC coupling in many other measurement situations as well. When you measure symmetrical signals, such as sine and square/triangle waves, AC coupling filters out all DC components. This means that a 0 V trigger level is always centered around the middle of the signal where triggering is most stable.

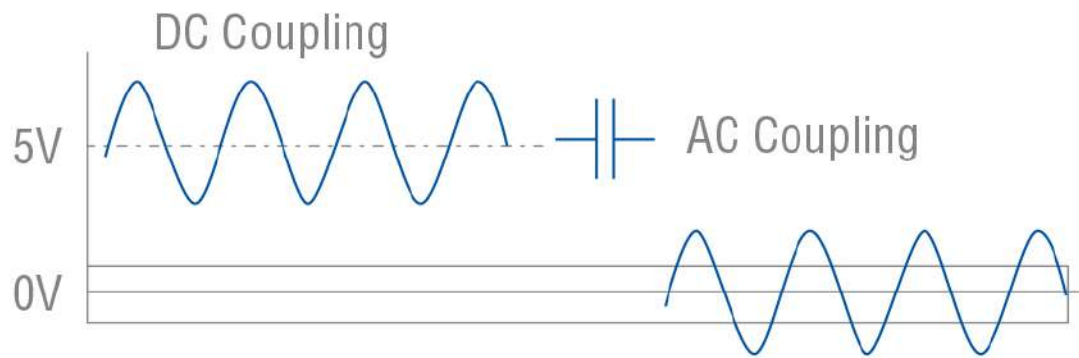


Fig. 4.7: AC coupling a symmetrical signal

Hint: Signals with changing duty cycle or with a very low or high duty cycle do require DC coupling. Fig. 4.8 shows how pulses can be missed, while Fig. 4.9 shows that triggering does not occur at all because the signal amplitude and the hysteresis band (please see for explanation of what is Hysteresis Band) are not centered.

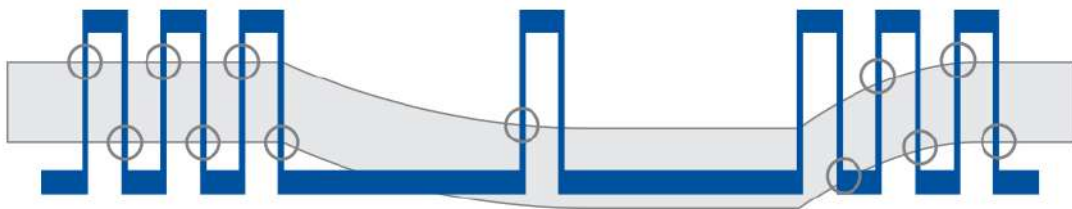


Fig. 4.8: Missing trigger events due to AC coupling of signal with varying duty cycle.

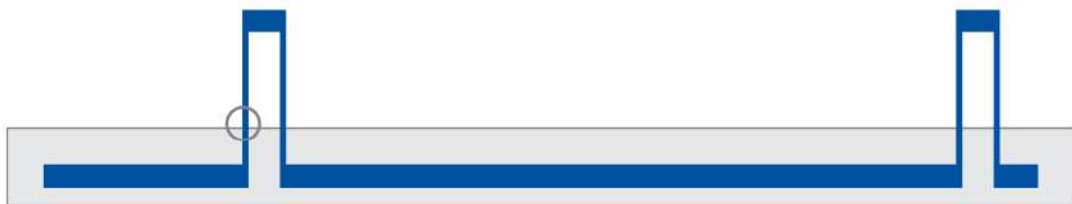


Fig. 4.9: No triggering due to AC coupling of signal with low duty cycle.

Hint

Always use DC coupling for signals below 10 Hz.

4.4.2.4 Filter

This setting allows you to apply analog low-pass filter for signals with high-frequency noise or interference. 10 kHz and 100 kHz low-pass filters are available. All filters have a signal rejection slope of approx. 20 dB / decade.

Hint: keep filters off unless you cannot obtain stable readings otherwise.

Hint: it is not recommended to use filters for pulse signals as filters affect pulse signal shape.

4.4.2.5 Preamplifier

Preamplifier allows to amplify the signal to improve sensitivity for signals with amplitudes below 100 mVpp.

Hint: avoid using pre-amplification if signal amplitude is above 100 mVpp. Prefer using Autoset instead – it will turn on pre-amplification only if necessary

4.4.2.6 Trigger Level

Set trigger level. Setting proper trigger level is essential for getting accurate and stable results. So it is advised to keep Trigger Mode Auto letting the instrument select adequate trigger levels. Please see [Measurement Functions](#).

In Auto and Relative Trigger Modes, the instrument performs voltage measurement (using current Voltage Mode setting) – so-called auto-trigger – before each Time or Frequency measurement which delays the measurement start. In cases when it is undesirable, please use Manual Trigger Mode.

When measuring non-continuous signals or single cycles, auto-trigger might fail to measure signal voltage range correctly which won't allow setting trigger levels properly and might result in wrong measurement results. It is advised to use Manual Trigger Mode in this case.

In Manual Trigger Mode in most cases one can get the best results if Trigger Level is set to the center of signal voltage range. It will help avoid capturing signal edge artifacts and in most cases the middle of the signal voltage range will be the point with maximum slew rate, which minimizes timing trigger error.

Setting trigger level close to signal minimum or maximum level can result in intermittent readings and/or unreliable result. For example, measured Frequency value twice greater or twice lower than actual can be a typical consequence of poor trigger level choice when measuring pulse signals with significant artifacts on edges.

Please note: Actual triggering does not occur when the input signal crosses the trigger level at 50 percent of the amplitude, but when the input signal has crossed the entire hysteresis band (Figure 11). Which causes measurement timing errors.

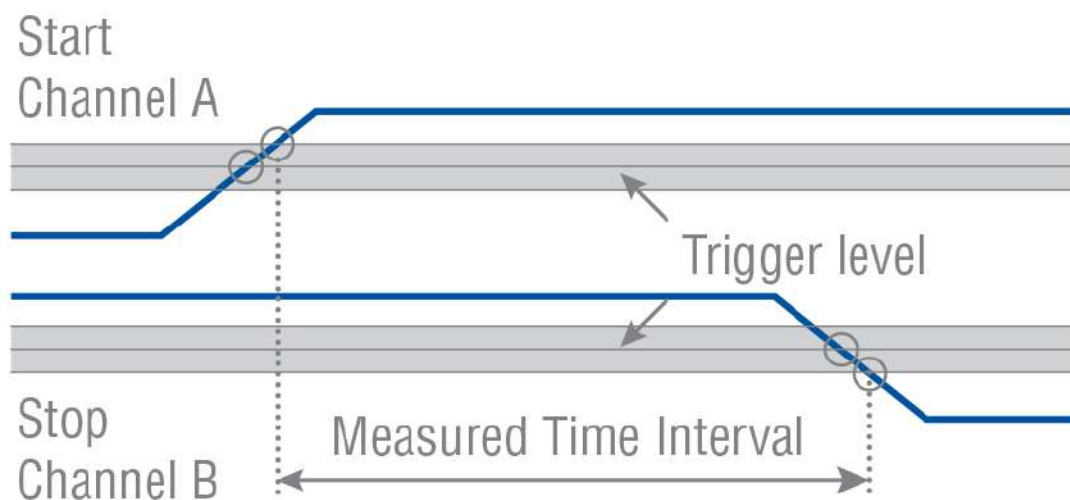


Fig. 4.10: Trigger hysteresis

The hysteresis band is about 20 mV with attenuation **1x**, and 200 mV with attenuation **10x**. The hysteresis compensation reduces hysteresis trigger error to <2 mV

To keep the hysteresis trigger error low, the attenuator setting should be **1x** when possible. Use the **10x** position only when input signals have excessively large amplitudes, or when you need to set trigger levels exceeding the -5 V to +5 V window.

4.4.3 Input Amplifiers with fixed configuration

The following inputs have fixed amplifier parameters:

- EA (External Arming) is fixed to 1 k Ω impedance and approx. 1.5 V trigger level;
- ER (External Reference) is fixed to 50 Ω impedance and accepts signals with 0.1 to 5 V_{rms} amplitude;
- C (Prescaler input) is fixed to 50 Ω impedance.

4.5 Arming

Note

Arming feature is not available in FTR-210R.

Arming, in general, gives the opportunity to start and stop a measurement when an external qualifier event occurs.

Arming can initialize either a single sample acquisition (Arm on Sample) or a single measurement session defined by sample count (Arm on Block). Measurement can be started and stopped by rising or falling edge of signals on instrument's inputs and delayed from 0 ns (delay off) to 2 s with 10 ns resolution step. In case of Totalize measurement mode, timer (set by a combination of Sample Interval and Stop Source set to Timer) can be used as a source of stop arming.

Table 4.2 shows possible arming modes and their specifics. Modes absent in this table are not supported.

Table 4.2: Arming modes and their specifics

Start Arm- ing Source	Stop Arm- ing Source	Arm on	Mea- surement Function	Comment
Off	Off	N/A	Any	Arming is not used, measurement is started and stopped normally

continues on next page

Table 4.2 – continued from previous page

Start Arm-ing Source	Stop Arm-ing Source	Arm on	Mea-surement Function	Comment
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In-put	Off	Block	Any, except To-talize	Start arming input initialize measurement session (block). Measurement session ends when all samples (number is set by Sample Count) have been collected.
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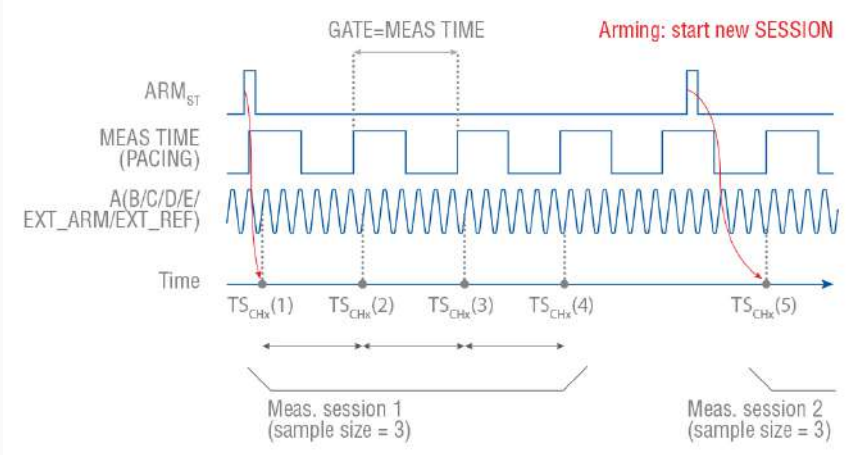


Fig. 4.11: Frequency measurement with measurement session repeated after start arming pulses
Arming start pulses that occur during measurement session are neglected.

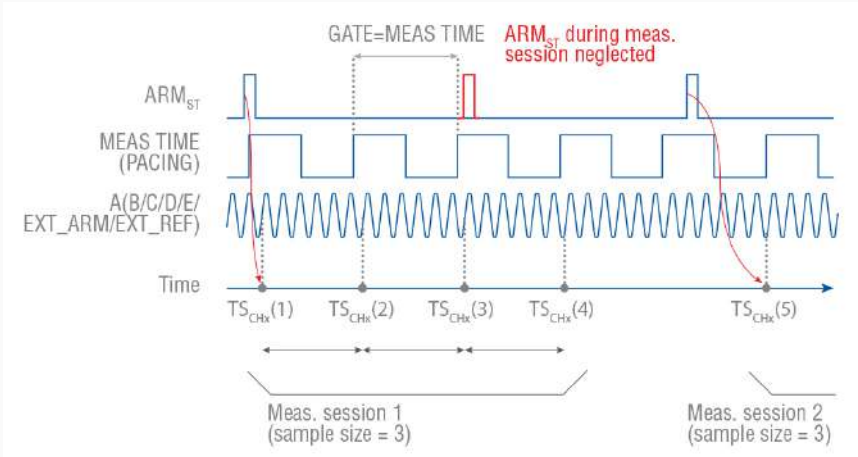


Fig. 4.12: Frequency measurement with arming start pulses occurring during the measurement session

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Table 4.2 – continued from previous page

Start Arm-ing Source	Stop Arm-ing Source	Arm on	Mea-surement Function	Comment
Input	Input	Block	Any, except Totalize	Start arming starts measurement session (block). Measurement session ends when either all samples (number is set by Sample Count) have been collected or by signal front on stop arming input (whatever comes first).
Off	Timer	Sample	Totalize	Totalize measurement is started by pressing Restart button, Sample Interval defines Totalize Gate length. The Analyzer counts number of events during the gate and produces single sample (1 sample per series).
Input	Timer	Sample	Totalize	Start arming pulses start Totalize Gates (gate length is defined by Sample Interval). Each gate produces 1 sample (per series). Measurement session ends once required number of samples (set by Sample Count) was collected.

continues on next page

Table 4.2 – continued from previous page

Start Arm-ing Source	Stop Arm-ing Source	Arm on	Mea-surement Function	Comment
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In-put	Off	Sam-ple	Any, ex-cept To-talize	Start arming is used as a pacing clock – single sample measurement is ex-ecuted just after the arming event.
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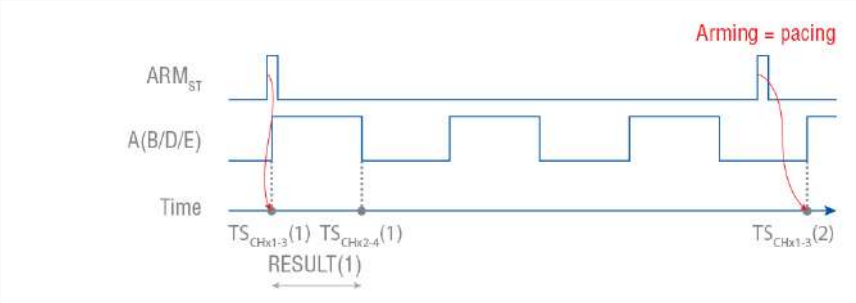


Fig. 4.15: Pulse width measurement with arming signal used as a pacing clock

In case of Frequency/Period Average measurement, samples are measured with dead-time, no back-to-back. Maximum total number of samples is reduced to up to 16 million.

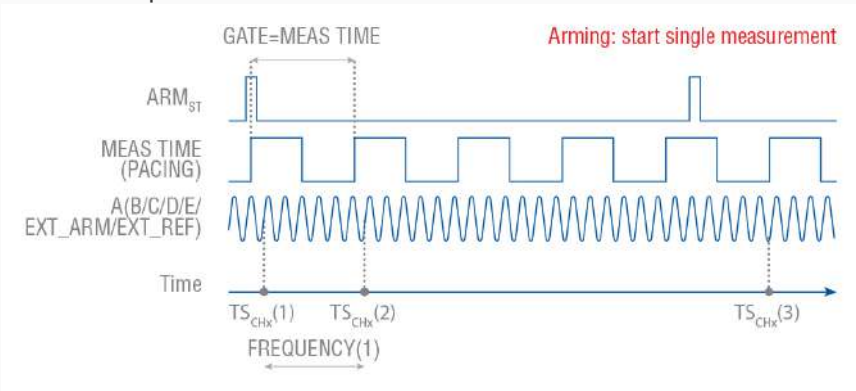
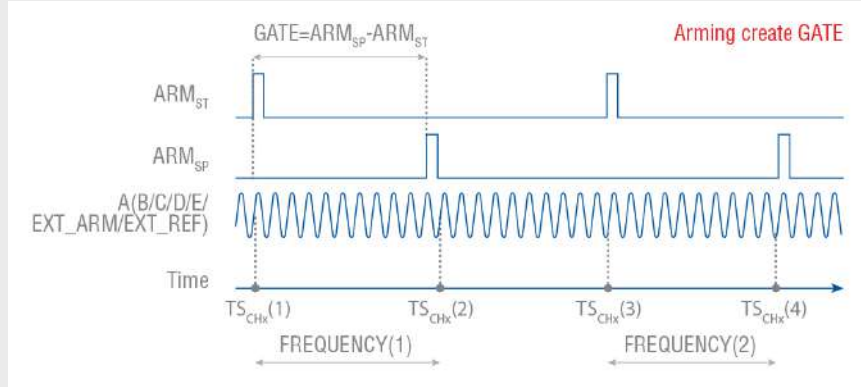
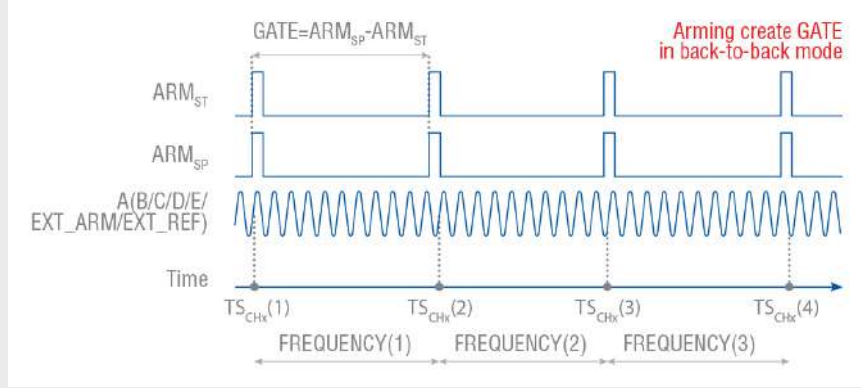


Fig. 4.16: Frequency measurement initialized by arming pulses

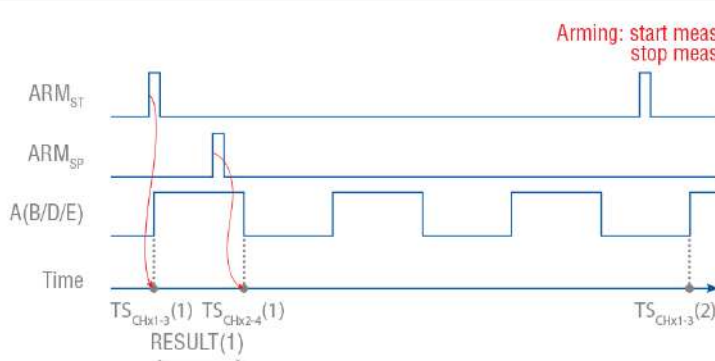
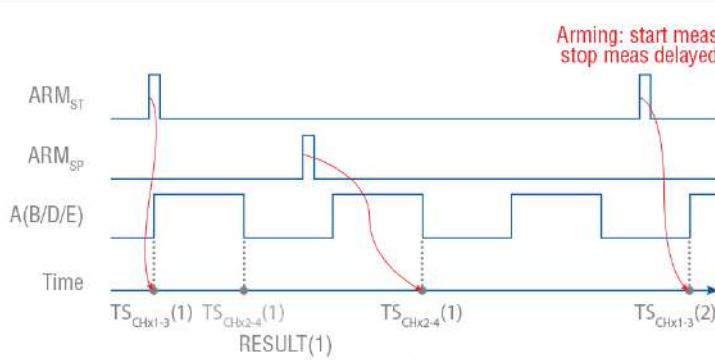
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Table 4.2 – continued from previous page

Start Arming Source	Stop Arming Source	Arming	Measurement Function	Comment
Input	Input	Sample	Totalize, Frequency, Period Average, Smart Frequency, Smart Period Average	Start arming events start Gate (gate length is defined by Sample Interval). Stop arming events end Gate. Each gate produces 1 sample (per series). Measurement session ends once required number of samples (set by Sample Count) was collected. In case start and stop arming settings are not the same, measurements are performed with dead-time, no back-to-back. Maximum total number of samples is reduced to up to 16 million. 
				Fig. 4.17: Frequency measurement in a gate created by arming signals When arming start and stop conditions are the same, measurements are performed continuously (back-to-back) with no dead-time. 

continues on next page

Table 4.2 – continued from previous page

Start Arm-ing Source	Stop Arm-ing Source	Arm on	Mea-surement Function	Comment
Input	Input	Sample	Any, except Totalize, Fre-quency, Period Aver-age, Smart Fre-quency, Smart Period Average	Start arming is used as a pacing clock – a single sample measurement is executed just after active edge of arming pulse. Stop arming delays registration of timestamps other than the first one. Depending on particular measurement mode, two, three or four timestamps are registered that give a single result.  Fig. 4.19: Pulse width measurement with arming on sample and start and stop arming active, case 1  Fig. 4.20: Pulse width measurement with arming on sample, start and stop arming active, case 2

Start arming is useful for measurement of frequency in signals, such as the following:

- Pulse modulated RF signals (bursts) Single-shot events or non-cyclic signals.
- Pulsed signals where pulse width or pulse positions can vary. Signals with frequency variations versus time ("profiling").
- A selected part of a complex waveform signal.

Signal sources that generate complex wave forms like pulsed RF, or sweep signals, usually also produce a sync signal that coincides with the start of a sweep, or start of a radar burst. These sync signals can be used to arm the instrument. See Fig. 4.21.

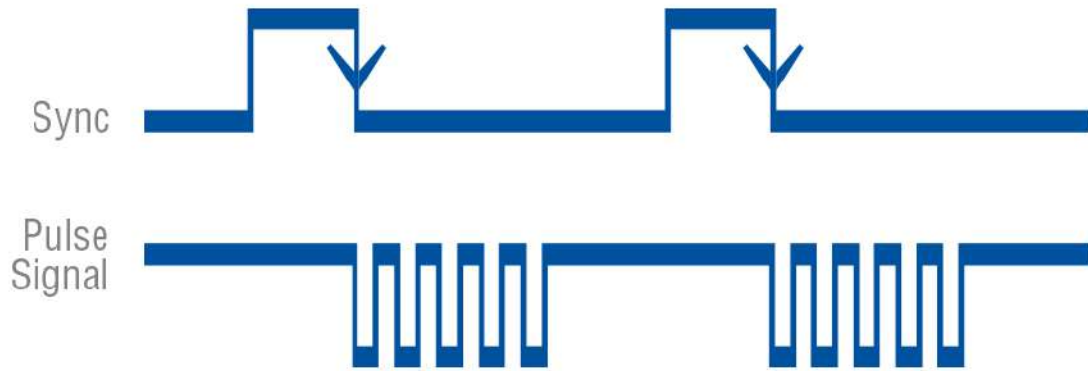


Fig. 4.21: Sync signal used as start arming starts the measurement.

You normally use stop arming together with start arming. That means that the external gating signal controls both the start and the stop of the measurement. Such a gating signal can be used to measure the frequency of an RF burst signal. Here the position of the external gate must be inside a burst. See Fig. 4.22.

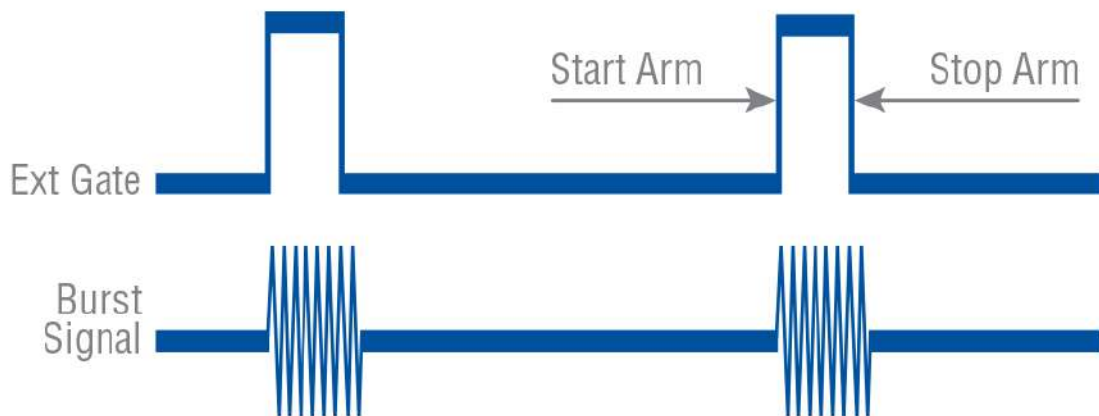


Fig. 4.22: Start and stop arming together is used for burst signal gating.

Note that burst measurements with access to an external sync signal are performed in the normal Frequency mode. In time interval measurements, you can use the stop arming signal as a sort of “external trigger Hold Off signal”, blocking stop trigger during the external period. See Fig. 4.23.

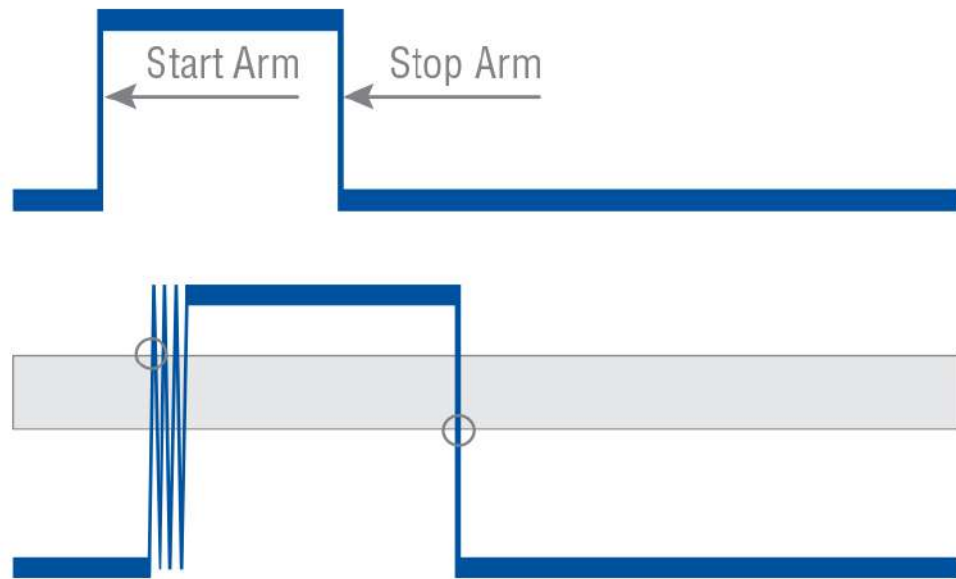


Fig. 4.23: Using start/stop arming as an external Hold-Off

Please note: start arming setup time is up to 5 ns. Which means that the measurement is actually started within 5 ns since start arming event.

Chapter 5

Measurement Functions

Note

Particular measurement function availability depends on particular model and licenses combination.

5.1 Frequency/Period

There are several functions suited for measuring Frequency or Period. Next sections provide details about each particular function and when one should be preferred over another.

5.1.1 Frequency/Period Average measurements

These are the most universal measurement functions for Frequency and Period. In this mode each sample is a Frequency/Period value averaged over sample interval (which acts as gate).

This is back-to-back measurement with no dead-time between the samples (see chapter [Arming](#) for exceptions). Multiple input signals can be measured in parallel. Minimal sample interval is 50 ns or 1 μ s (depending on particular model and corresponding license installed). Up to 32 million samples total can be measured in a single measurement session. Resolution is 12 digits per 1 s of gate time (Sample Interval).

If the signal period is greater or equal to the set Sample Interval – each signal period can be captured. When measuring Frequency/Period Average on inputs A, B, D, E and Trigger Mode is set to Auto or Relative, wide hysteresis (see details below) is used to improve noise tolerance. In this mode 2 comparators with different trigger levels are used for each input. First trigger level (e.g. Trigger Level A) defines the upper limit of wide hysteresis band and the second one (e.g. Trigger Level A2) defines the lower limit. Trigger Mode Auto sets trigger levels to 60% and 40% of signal's voltage range and Relative allows modifying them to fine tune the hysteresis band.

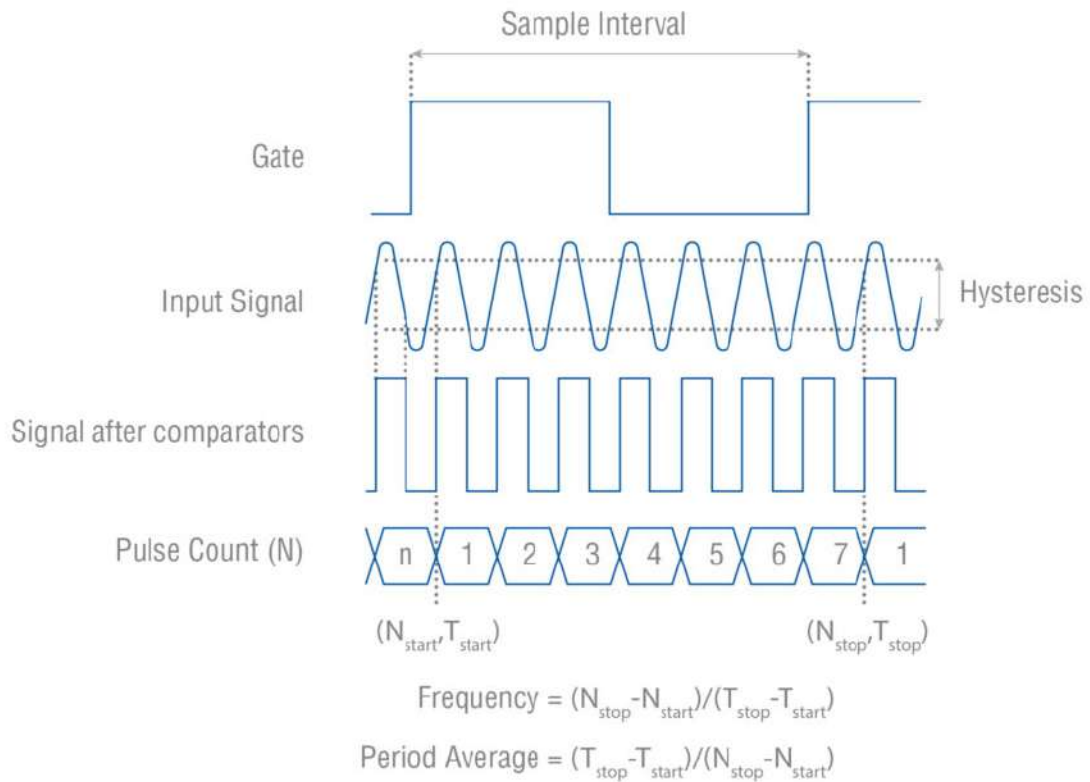


Fig. 5.1: Frequency/Period Average measurement with Wide Hysteresis

Without wide hysteresis, the signal needs to cross the approx. 20 mV in case of 1x Attenuation (200 mV in case of 10x) input hysteresis band before triggering occurs. This hysteresis prevents the input from self-oscillating and reduces its sensitivity to noise. If signal noise is comparable or higher than hysteresis band – it can result in false extra triggering producing erroneous counts. These could ruin the measurement.

Fig. 5.2 shows how spurious signals can cause the input signal to cross the trigger or hysteresis window more than once per input cycle and give erroneous counts. Fig. 5.3 shows that a wide enough hysteresis prevents false counts.

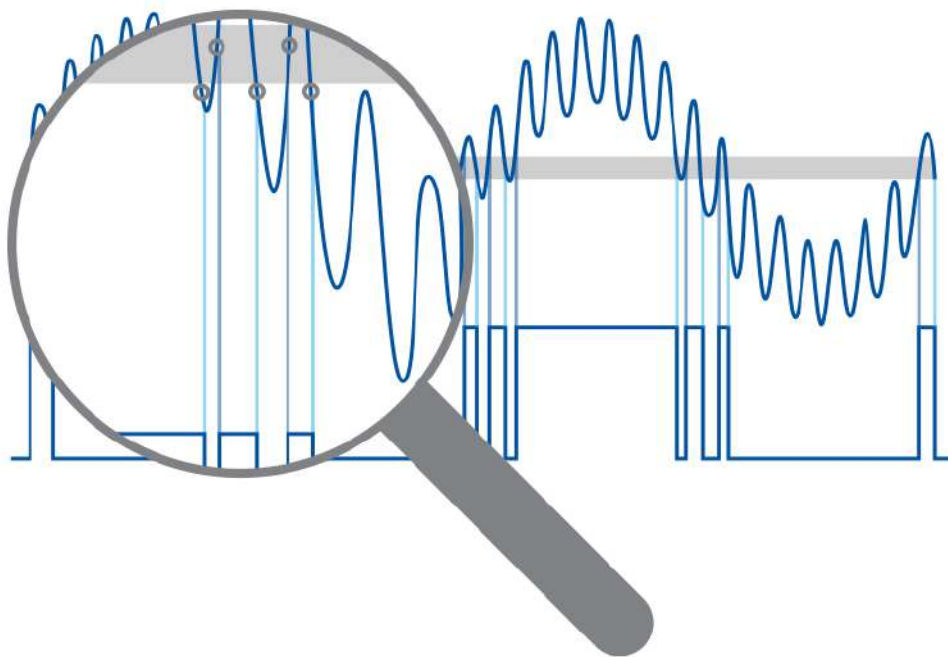


Fig. 5.2: Too narrow hysteresis gives erroneous triggering on noisy signals.

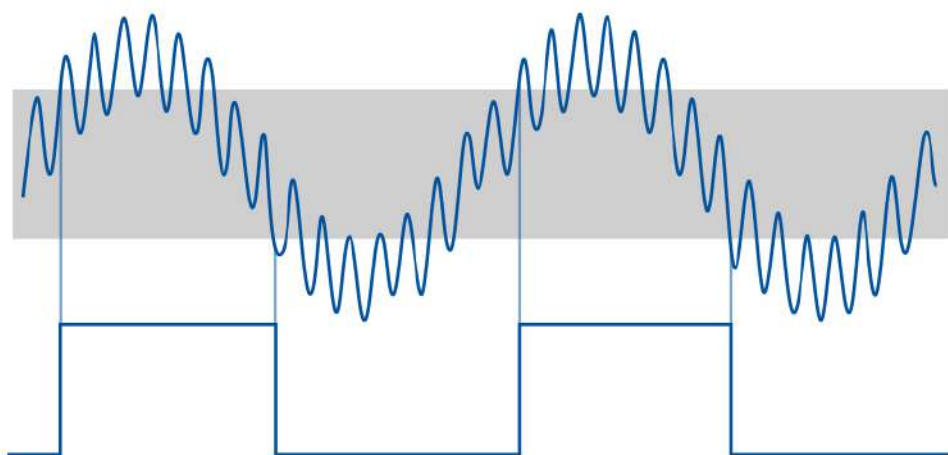


Fig. 5.3: Wide trigger hysteresis gives correct triggering.

5.1.1.1 Frequency C measurement

With an optional RF input prescaler the instrument can measure up to 3, 10, 15, 20, or 24 GHz on Input C. These RF inputs are fully automatic, and no trigger setup is required. Set Sample Interval to achieve optimal compromise between resolution (long Sample Interval) and speed (short Sample Interval). The optional RF input C contains a prescaler that divides the RF signal with an integer value (Prescaler factor), to enable the normal counting circuitry to measure the frequency. The Option 10 (3 GHz) divides by 16, and the option 110/xx (10 to 24 GHz) divides by 64.

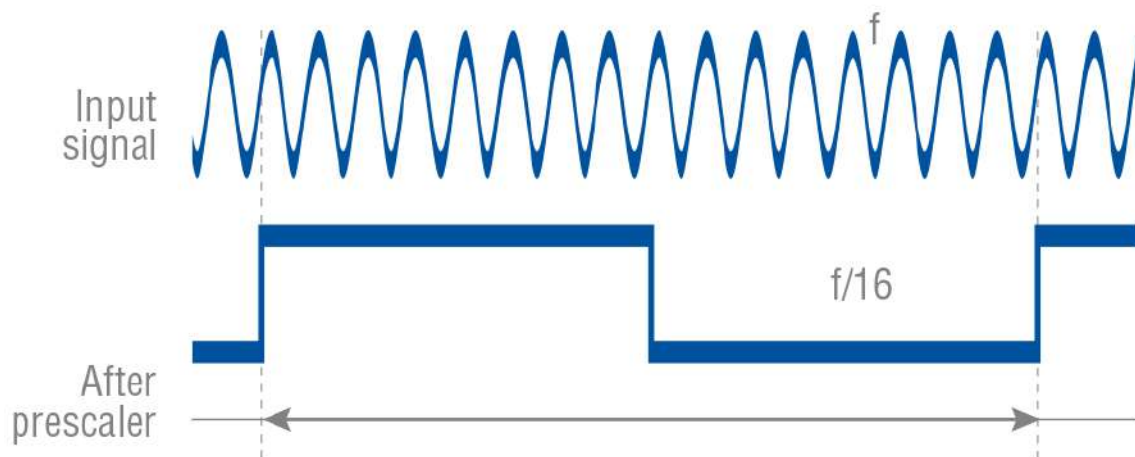


Fig. 5.4: Divide-by-16 Prescaler.

Fig. 5.4 shows the effect of the 3 GHz prescaler. For each 16 input cycles, the prescaler gives one square wave output cycle. An input frequency of let's say 1.6 GHz is divided down to 100 MHz and measured by the normal counting circuitry. The display shows the correct input frequency since the microcomputer compensates for the effect of the division factor.

Prescalers do not reduce resolution. The relative quantization error is the same: 12-13 digits for 1 s Sample Interval (Gate Time). See Table 5.1 to find the prescaler factors.

Table 5.1: Prescaler factors

Function	Prescaling Factor
All functions on inputs A, B, D, E (CNT-104S, CNT-104R, CNT-104B) or A, B (CNT-102, CNT-102B), also EA, ER, Rb, G	1
Frequency C (option 10: 3 GHz)	16
Frequency C (option 110: 10, 15, 20 or 24 GHz)	64

5.1.2 Smart Frequency/Period

Smart Frequency/Period is based on the same principle as normal Frequency/Period Average. Measurement gate is divided into 1000 sub-gates, giving additional samples and statistics resolution enhancement algorithm is applied on top of it. Thanks to that it allows to get up to 1 extra digit of resolution per 1 s of gate time (depending on input signal and measurement settings).

This comes with expense of additional constraints though. Minimal possible Sample Interval for Smart Frequency/Period is 50 μ s or 1 ms (depending on particular model and licenses installed). With Sample Interval less than 40 ms it is possible to measure up to 32000 samples per measurement session. Setting Sample Interval to 40 ms or more allows to get up to 4290000 samples per measurement session.

This is back-to-back measurement with no dead-time between the samples (see chapter [Arming](#) for exceptions). Multiple signals can be measured in parallel. Wide Hysteresis is used in Trigger Modes Auto and Relative.

Smart Frequency/Period is the best choice when one needs maximal possible resolution and can bear with lower sampling rate and sample count per session.

Please, note: resolution enhancement algorithm is based on the assumption that signal frequency is static. If it is not the case – the algorithm won't be effective and it might make sense to fall back to normal Frequency/Period Average. Please note: section Frequency C measurement. Applies to Smart Frequency C as well.

5.1.3 Period Single

This measurement function is handy if one needs to capture individual periods of continuous signals or single cycles which are less than 50 ns. Individual periods starting from 2.5 ns can be captured.

This is not a back-to-back measurement, meaning that there is a dead-time of 50 ns or 1 μ s (depending on particular model and corresponding license installed). Up to 2 signals can be measured in parallel (depending on particular model). Up to 16 million samples total can be measured in a single measurement session.

Unlike Frequency/Period Average and their Smart versions, Period Single doesn't use wide hysteresis. So only one comparator is used on A, B, D, E (CNT-104S, CNT-104R, CNT-104B) or on A, B (CNT-102, CNT-102B) and Trigger Mode Auto sets trigger level to the middle of signal voltage range (Relative Trigger Level 50%).

Please, note: when measuring non-continuous signal or single cycles, Trigger Mode Auto/Relative might fail to find proper trigger level. One need to fall back to Manual Trigger Mode in this case.

5.1.4 Frequency Ratio/Difference

In Frequency Ratio/Difference mode, the instrument measures Frequency Average of up to 4 signals in parallel (depending on particular model and settings) and then divides/subtracts resulting frequencies.

This is back-to-back measurement with no dead-time between the samples. 4 input signals can be measured in parallel for CNT-104S, CNT-104R, CNT-104B, 2 - for CNT-102, CNT-102B. Minimal sample interval is 50 ns or 1 μ s (depending on particular model and corresponding license installed). Up to 16 million samples total can be measured in a single measurement session.

5.1.5 Frequency Offset measurements (Calibrator Use-case)

Note

License is needed to unlock Frequency Offset option (Option 152).

Using the Frequency Offset function, the Frequency of the device under test can be displayed as relative deviation with automatic tolerance limits control.

When using Frequency Offset function the user can use Settings → Measurement → Frequency Tolerance to specify the required DUT tolerance limits and Sample Interval will be set automatically based on the tolerance value.

Settings for reference frequency can be accessed in Settings → Frequency Offset (sometimes called "TIE / Frequency Offset" if TIE license is installed).



Fig. 5.5: Setting calibration tolerance for Frequency Offset function (Frequency Tolerance setting)

The Limits function is automatically activated with limits set to calibration tolerance. In combination with clear pass/fail indicators this further simplifies the manual or semi-automatic calibration. Please refer to [Limits Pass/Fail indication for Frequency Offset function](#) section for description of the indicators.



Fig. 5.6: Example of calibration measurement trend graph

5.2 Time Interval and Phase

5.2.1 Time Interval

This function allows to measure phase delay between clock signals with the same nominal frequency. At least $N + 1$ signal cycles are needed on each measurement input to get N Time Interval samples.

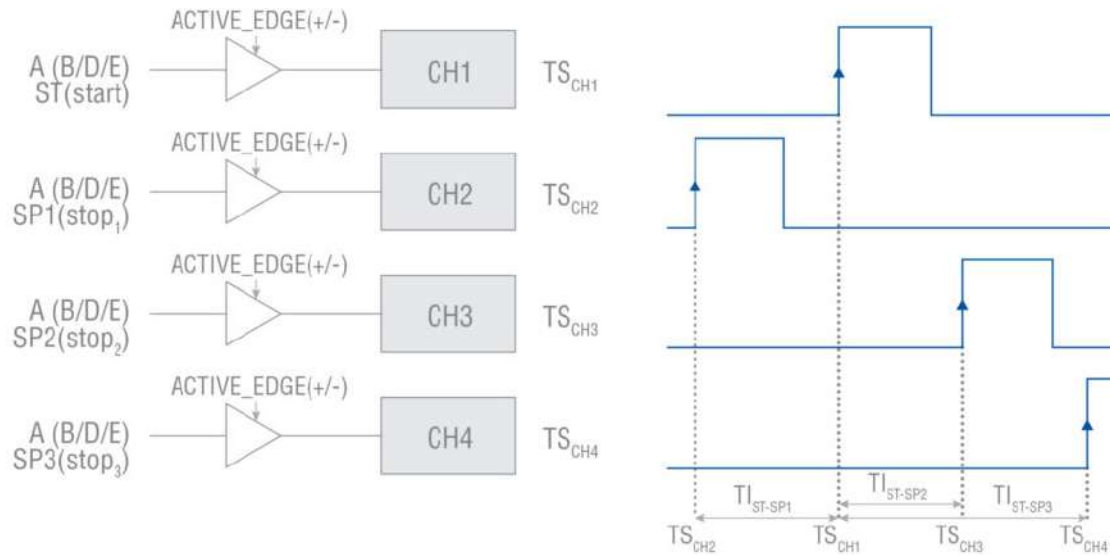


Fig. 5.7: Time Interval Continuous measurement mode

Time intervals in the range $[-1000 \text{ s} .. 1000 \text{ s}]$ can be measured. Resulting values are normalized to always be in the range $[-0.5 * \text{Period} .. \text{Period}]$.

4 input signals can be measured in parallel for CNT-104S, CNT-104R, CNT-104B, 2 - for CNT-102, CNT-102B. Minimal sample interval is 50 ns or 1 μs (depending on particular model and corresponding license installed). Up to 16 million samples total can be measured in a single measurement session.

Please note: Time Interval Continuous is not suitable for measuring time interval between single shot events, use Time Interval Single instead.

When using Sample Interval close to 50 ns, actual sample interval might vary between 50 ns and 100 ns. In case of Time Interval measurement – it can result in generating less samples than was ordered by Sample Count setting. To avoid this please consider setting Sample Interval to 0 if you need minimal sample interval between samples. Setting Time Interval to 0 disables Sample Interval clock, meaning taking samples as fast as possible (close to 50 ns if signal period is 50 ns or greater).

Note

Above relates only to model and license combinations allowing sample interval of 50 ns.

5.2.2 Accumulated Time Interval (Accumulated TI)

Accumulated Time Interval is useful for comparing phase delay between signals with the same nominal frequencies, but when frequencies of individual signals have small constant offset to each other. Time Interval will gradually increase over time and then drop after reaching value equal to signal Period, thus forming a sawtooth like graph. Accumulated Time Interval corrects this by adding or subtracting signal Period to Time Interval values when necessary. Other than that, it is exactly the same measurement as Time Interval Continuous.



Fig. 5.8: Time Interval Continuous of 2 clock signals with constant frequency offset

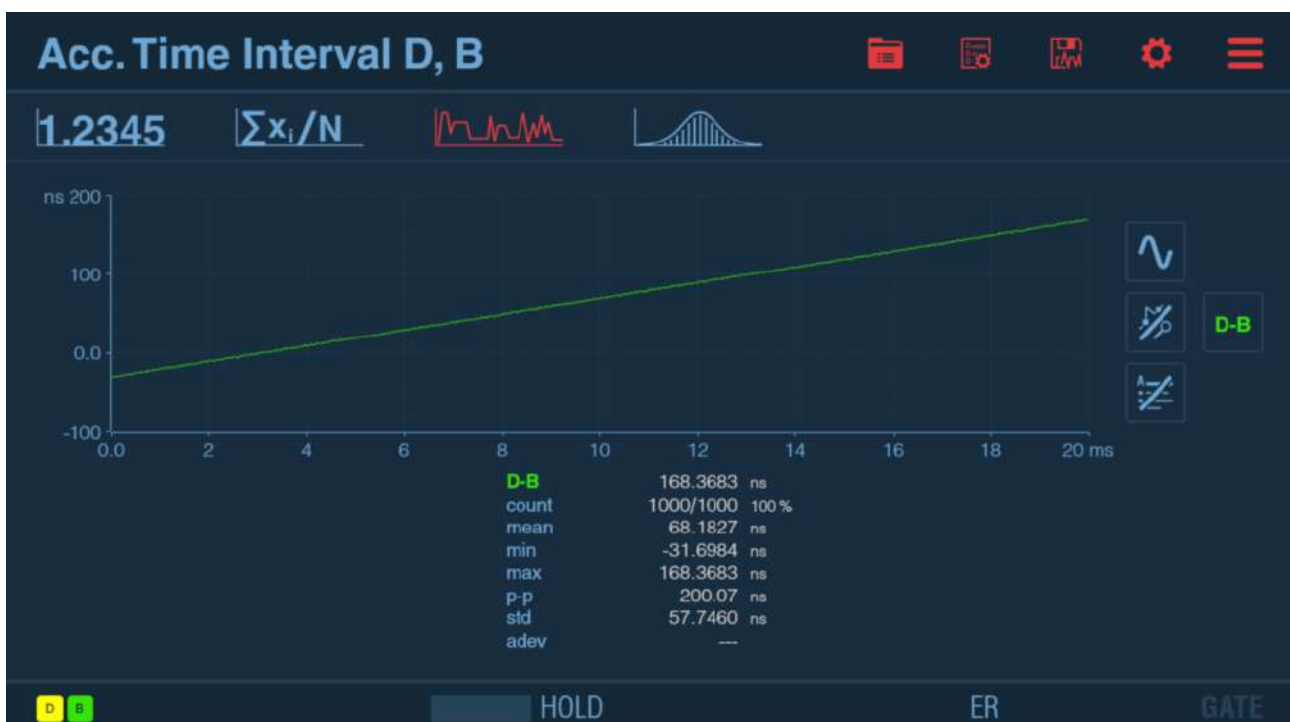


Fig. 5.9: Accumulated Time Interval of the same clock signals

As can be seen on Fig. 5.8 and Fig. 5.9, Accumulated Time Interval gives much better view on relative clock drift over time.

5.2.3 Time Interval Single (TI Single)

This function should be used to measure Time Interval between single events. Sample Interval setting is discarded, samples are captured as fast as it is possible.

Time intervals in the range $[-1000 \text{ s} .. 1000 \text{ s}]$ can be measured. Resulting values are not normalized.

4 input signals can be measured in parallel for CNT-104S, CNT-104R, CNT-104B, 2 - for CNT-102, CNT-102B. Minimal sample interval is 50 ns or 1 μ s (depending on particular model and corresponding license installed). Up to 16 million samples total can be measured in a single measurement session.

5.2.4 Dual Time Interval

Same as Time Interval, but measures interval for X-Y pair and Z-W pair, given that inputs X,Y,Z and W are chosen for measurement. Only available on CNT-104S, CNT-104R, CNT-104B.

5.2.5 Start-Stop Time Interval (Start-Stop TI)

Emulates Time Interval function of legacy counters. Guarantees that stop event is timestamped after start event (at expense of 1.5 ns dead-time between start and stop).

In most cases normal Time Interval or Time Interval Single should be preferred, except for specific usage scenarios, e.g.:

- Measuring Time Interval between signals of different nominal frequency, so that there should be a guarantee that the instrument timestamps the next front on the stop channel after the front on the start channel.
- When there is a need to delay the registration of the stop event relative to registration of the start event by using Hold-Off function (see [Hold-off](#)) to e.g. skip contact bouncing effects between the events. Other Time Interval functions use independent timestamping, so Hold-Off only delays next event registration only inside the same channel, but not between the channels.

Note

It is not possible to measure Time Intervals below 1.5 ns with this measurement function (exact limit might be less on particular unit).

5.2.6 Measuring Time Interval between different trigger points of the same signal

Thanks to the presence of two comparators on each of A, B, D, E (CNT-104S, CNT-104R, CNT-104B) or A, B (CNT-102, CNT-102B) inputs it is possible to measure Time Interval, Accumulated Time Interval, Time Interval Single, Phase and Accumulated Phase between two trigger points inside the same signal.

This can be useful for measuring intervals inside multi-level a signal, e.g. TDR measurement.



Fig. 5.10: Measuring Time Interval between 2 levels of reflected signal in TDR measurement allows to calculate the distance to cable break

Note

Pictures below illustrate display of CNT-104S model.

For CNT-102, CNT-102B, channels D, E are not available and areas, fields and graphical objects for corresponding to these channel are not present. Up to 2 signals can be measured in parallel.

For FTR-210R with Option 230, channels B, D, E, C are not available and areas, fields and graphical objects for corresponding to these channel are not present. Only one signal can be measured in parallel.

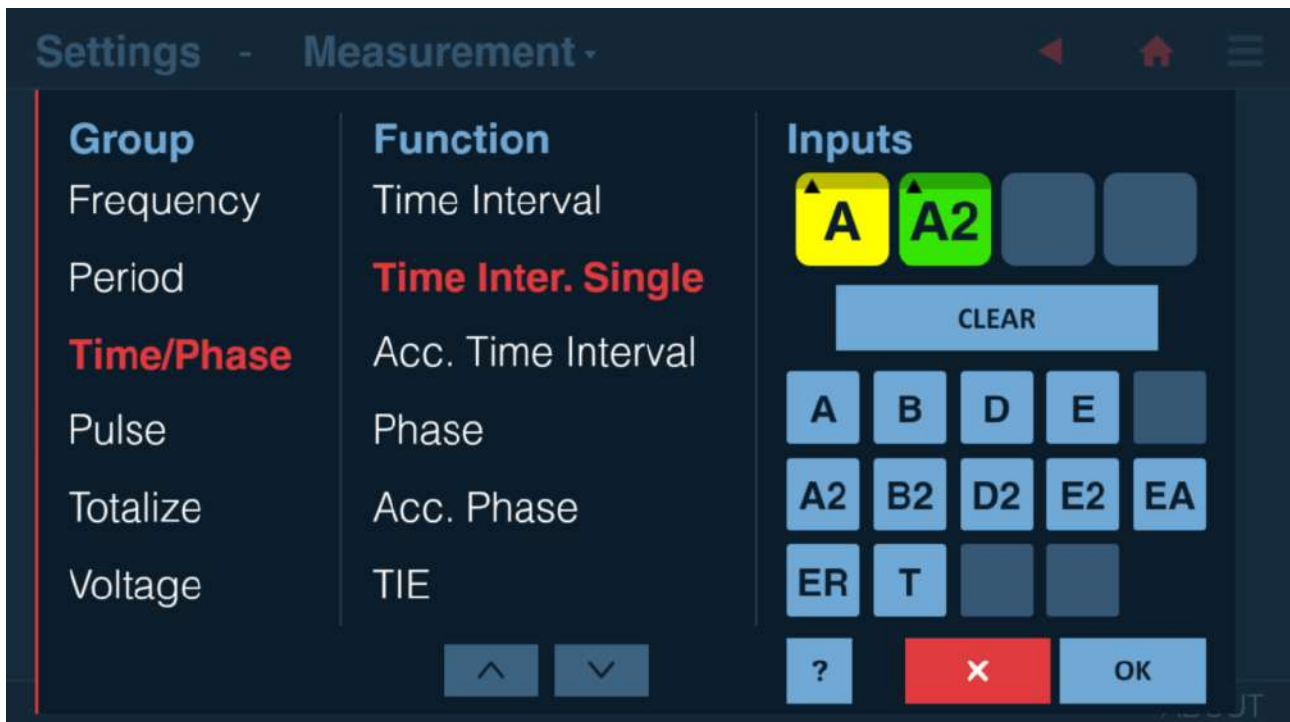


Fig. 5.11: Instrument's configuration for TDR measurement on Figure 28

Another example is measuring time interval from start on input A positive slope to input A negative slope to input B positive slope to input B negative slope. This can be achieved by selecting Time Interval A, A2, B, B2 and specifying trigger levels and slopes accordingly (see Fig. 5.12).

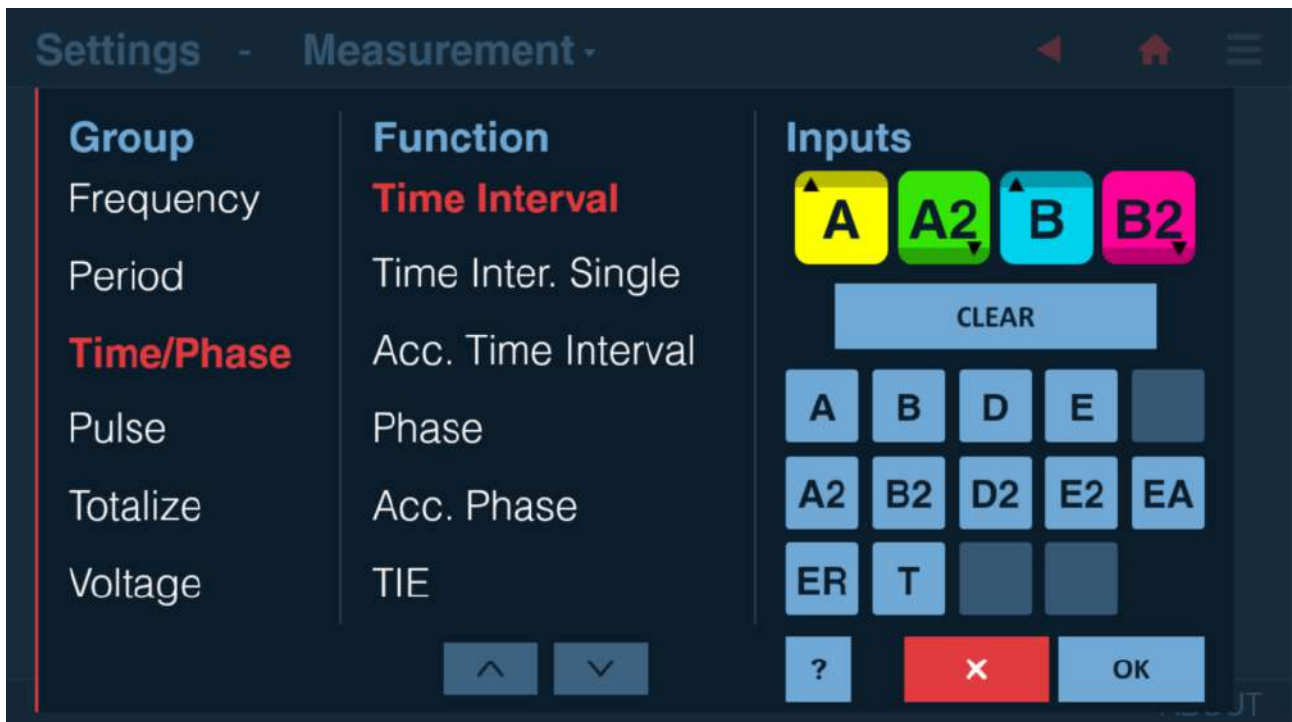


Fig. 5.12: Time interval A-A2-B-B2 function selection



Fig. 5.13: Example configuration for Time Interval A to A to B to B measurement



Fig. 5.14: Example configuration for Time Interval A to A to B to B measurement

However, Time Interval A to A to A to A is not possible since that would require 4 different trigger conditions on input channel A, while only 2 comparators are present.

5.2.7 Phase

Phase is similar to Time Interval but with phase delay expressed as angle. This measurement assumes same nominal frequency on all measured inputs. At least $N + 1$ signal cycles are needed on each measurement input to get N Phase samples.

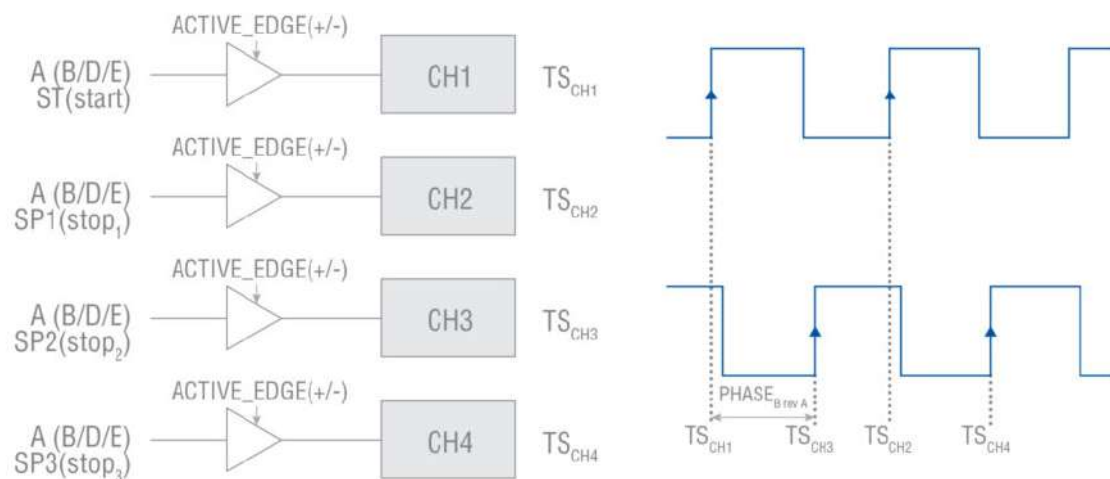


Fig. 5.15: Phase measurement mode

During this measurement, the instrument estimates continuous Time Interval and clock Period and calculates Phase as following:

$$\text{Phase} = 360^\circ \times ((\text{Time Interval}) / \text{Period})$$

where

Time Interval= $TS_{CH3}-TS_{CH1}$ Period= $TS_{CH2}-TS_{CH1}$

Resulting Phase values are normalized to always be in the range $[-180^\circ .. 360^\circ]$.

2 input signals can be measured in parallel for CNT-104S, CNT-104R, CNT-104B, 1 - for CNT-102, CNT-102B.. Minimal sample interval is 50 ns or 1 μ s (depending on particular model and corresponding license installed). Up to 16 million samples total can be measured in a single measurement session.

The typical measurement case is to measure the phase shift in various electronic components or systems, for example, filters or amplifiers. In this case, the input A signal is the input signal to the filter/amplifier, and the input B signal is the output signal from the filter/amplifier. That means that the input A and B signals are typically sine waves, with exactly the same frequency per test point, and the phase should be constant with zero drift (per test point).

Another typical use case is to compare two ultra-stable signals from different sources, but with the same nominal frequency, and express their phase difference in degrees. Then the signal shape could be both sine or pulse, and there is a possibility for a small phase drift between the signals.

5.2.8 Accumulated Phase

The same as for Time Interval, there is an Accumulated version of Phase measurement function to ease drift visualization over time when clock signals in comparison have same nominal frequency with a slow phase drift. But it has no meaning for phase measurements on sources with a more erratic behavior, or when the two frequencies are not the same.

5.3 Time Interval Error (TIE)

Please note: license is needed to unlock TIE option.

TIE measurement uses continuous back-to-back time-stamping to observe slow phase shifts (wander) in nominally stable signals during extended periods of time. The measurement itself is performed the same way as Frequency/Period Average but different processing is applied.

TIE is only applicable to clock signals, not data signals. Monitoring distributed PLL clocks in synchronous data transmission systems is a typical application.

The nominal frequency of the signal under test can be either manually or automatically set. Auto detects the frequency from the first samples, and rounds to number of digits set by the user (5 by default). TIE is measured as the period deviation of the input signal from the "ideal" reference period, and the accumulated deviation, up or down, is calculated for each Sample Interval, and displayed.

4 input signals can be measured in parallel for CNT-104S, CNT-104R, CNT-104B, 2 - for CNT-102, CNT-102B. Minimal sample interval is 50 ns or 1 μ s (depending on particular model and corresponding license installed). Up to 32 million samples total can be measured in a single measurement session. Resolution is 12 digits per 1 s of gate time (Sample Interval).

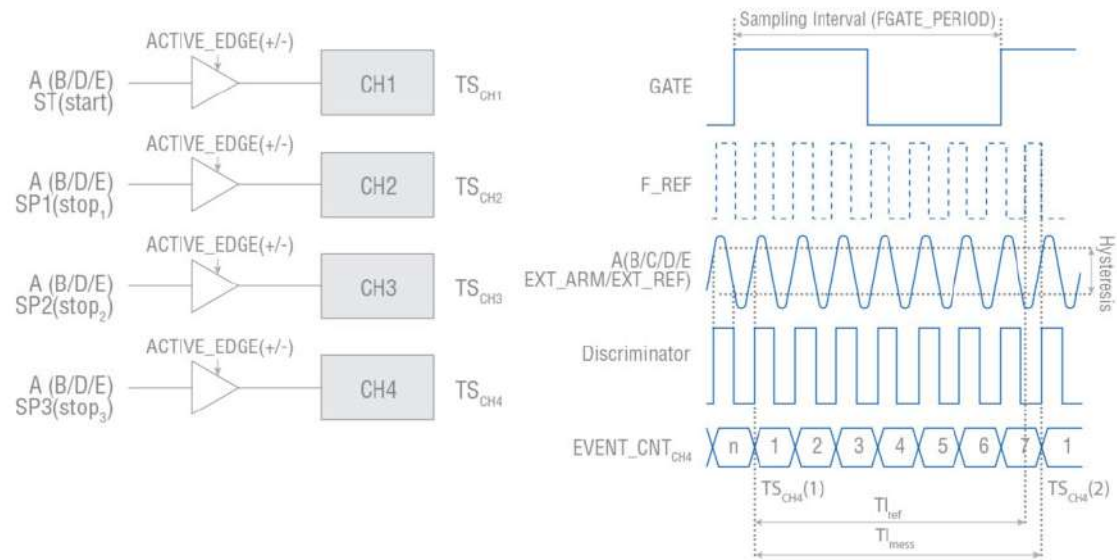


Fig. 5.16: TIE measurement

$$TIE_{A(B/D/E)(i)} = TS_{CHx}(i) - TS_{CHx}(1) - ((EVENT_CNT_{CHx}(i) - EVENT_CNT_{CHx}(1)) / F_ref)$$

5.4 Pulse characterization

5.4.1 Positive and Negative Pulse Width

Positive pulse width measures the time between a rising edge and the next falling edge of the signal. Negative pulse width measures the time between a falling edge and the next rising edge of the signal.

The selected trigger slope is the start trigger slope. The instrument automatically selects the inverse polarity as stop slope.

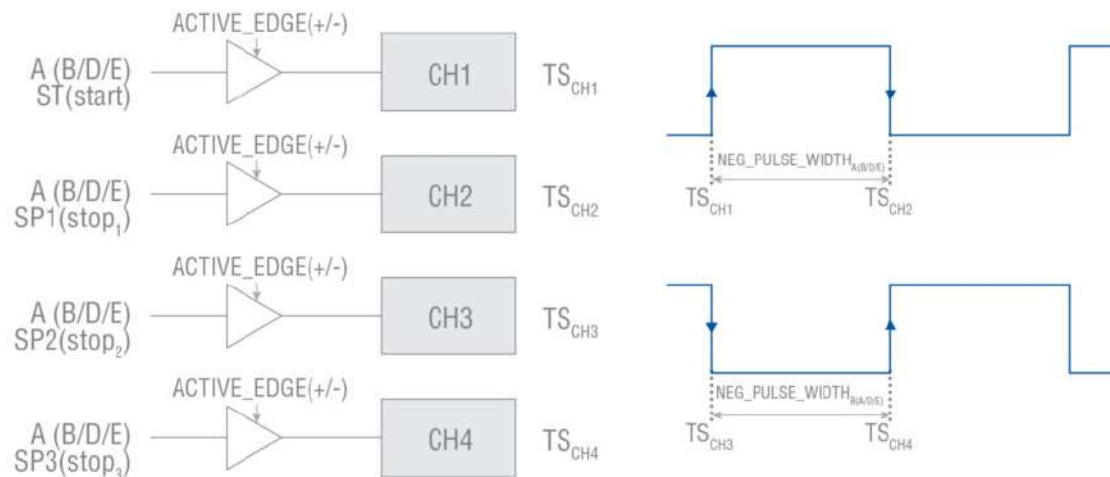


Fig. 5.17: Pulse width measurement

This is not a back-to-back measurement, meaning that there is a dead-time of 50 ns or 1 μs (depending on particular model and corresponding license installed) between the samples. 2 input signals can be measured in parallel for CNT-104S, CNT-104R, CNT-104B, 1 - for CNT-102, CNT-102B.. Up to 16 million samples total can be measured in a single measurement session.

5.4.2 Positive and Negative Duty Cycle

Duty cycle (or duty factor) is the ratio between pulse width and period time. The instrument determines this ratio by simultaneously making a pulse width measurement and a period measurement, and calculates the duty factor as:

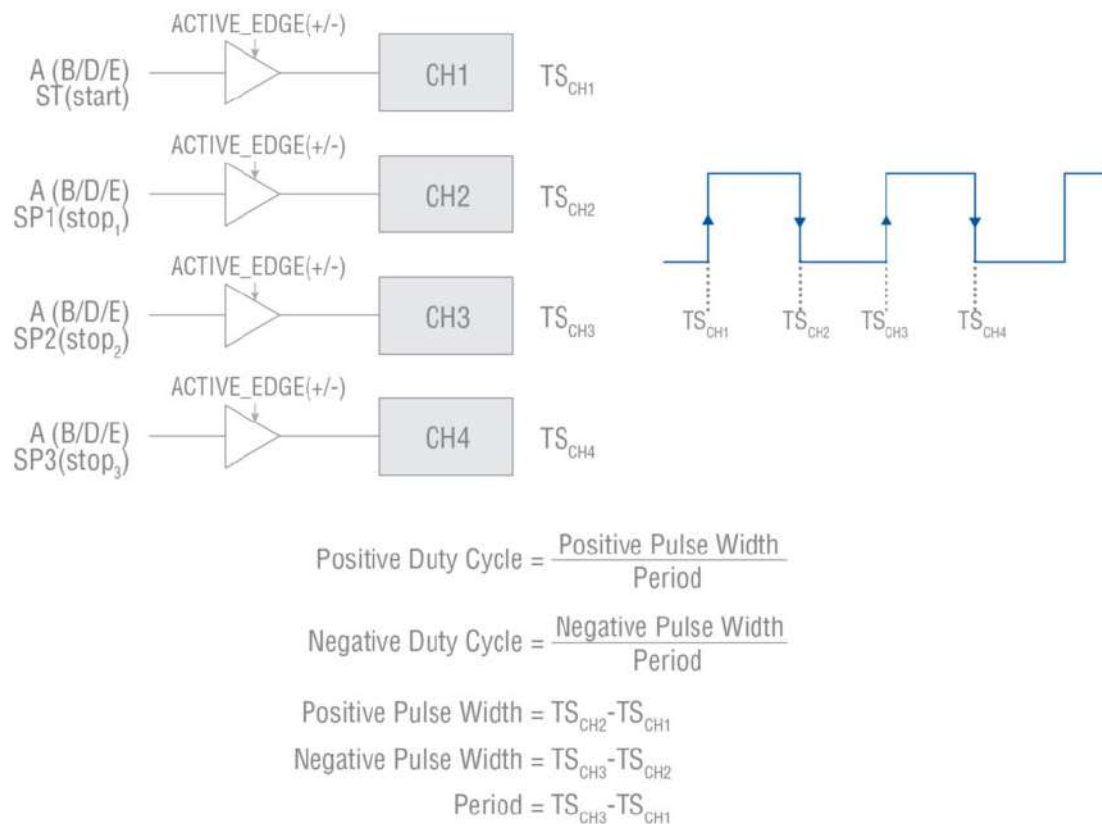


Fig. 5.18: Duty cycle measurement

This is not a back-to-back measurement, meaning that there is a dead-time of 50 ns or 1 μ s (depending on particular model and corresponding license installed) between the samples. 1 signal can be measured in parallel. Up to 16 million samples total can be measured in a single measurement session.

5.4.3 Rise Time, Fall Time, Rise-Fall Time

By convention, rise/fall time measurements are made with the trigger levels set to 10% (start) and 90% (stop) of the maximum pulse amplitude. For ECL circuits, the reference levels are instead nominally 20 % (start) and 80 % (stop). In this case one can use Relative Trigger Levels mode and set trigger levels to 20% and 80% respectively.

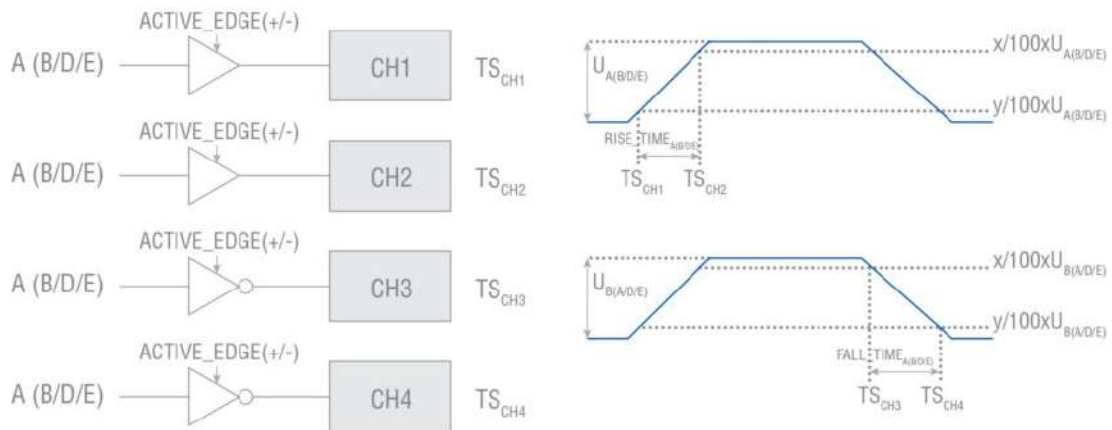


Fig. 5.19: Rise Time and Fall Time measurement

These are not a back-to-back measurement, meaning that there is a dead-time of 50 ns or 1 μ s (depending on particular model and corresponding license installed) between the samples.

Rise Time and Fall Time functions can measure up to 2 input signals in parallel for CNT-104S, CNT-104R, CNT-104B, 1 - for CNT-102, CNT-102B, with up to 16 million samples per session total.

Rise-Fall Time function (only available for CNT-104S, CNT-104R, CNT-104B) can measure only 1 signal but provides both rise and fall time at once. Up to 8 million samples total can be measured in one measurement session.



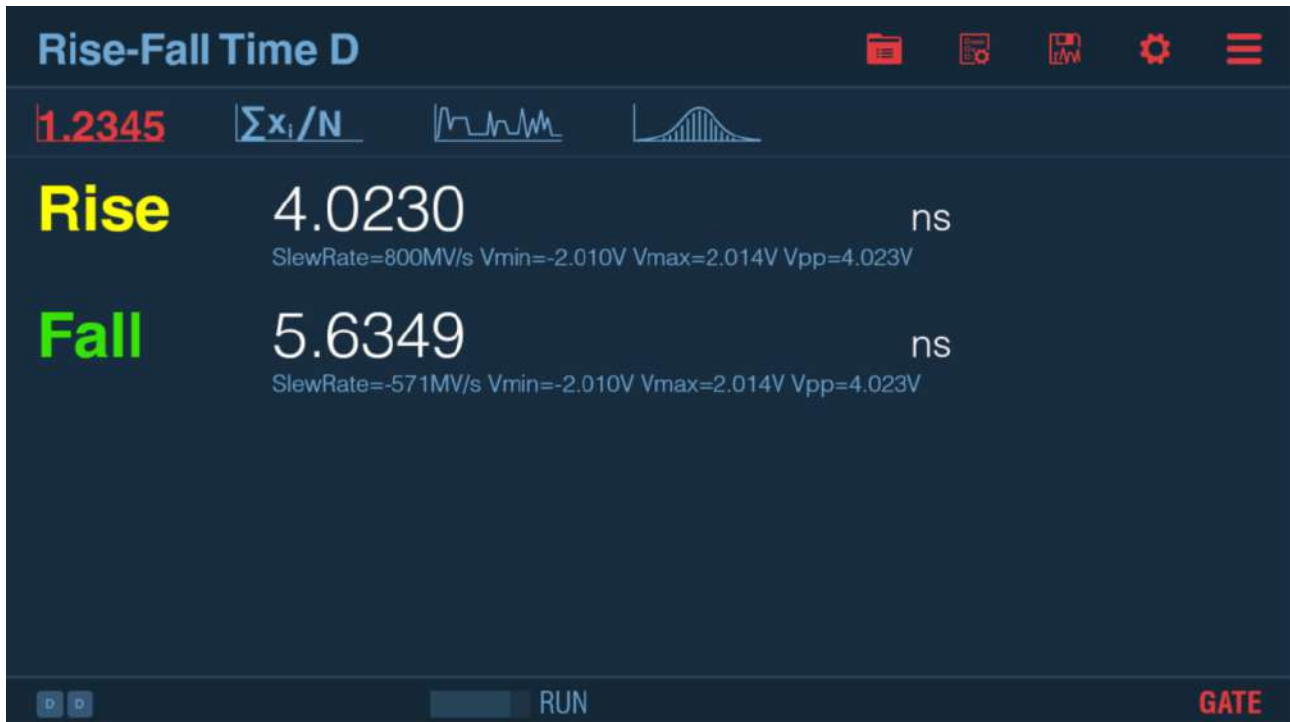


Fig. 5.20: Rise Time vs Rise-Fall Time

5.4.4 Positive and Negative Slew Rate

Slew rate is the speed of voltage change on pulse positive or negative edge. Hence, Positive and Negative Slew Rate are based on Rise Time and Fall Time measurements, the following formulae are applied (5.1):

$$\begin{aligned} \text{PositiveSlewRate} &= \text{RiseTime} / (0.8 * (V_{max} - V_{min})) \\ \text{NegativeSlewRate} &= \text{FallTime} / (0.8 * (V_{max} - V_{min})) \end{aligned} \quad (5.1)$$

5.5 Totalize

Totalize functions count the number of trigger events on instrument inputs. There are few modes Totalize can operate in. See next sections for details. In each of these modes the user can choose between Totalize, Totalize X+Y, Totalize X-Y or Totalize X/Y.

5.5.1 Manual Totalize

If neither Start nor Stop Arming is used, Totalize operates in so-called Manual Totalize mode.

In this mode RESTART button start counting trigger events, while HOLD/RUN button is used to pause and resume the counting. Sample Interval setting has no effect, samples are generated each 100 ms.

5.5.2 Timed Totalize

Setting Start Arming Source to Off and Stop Arming Source to Timer enables so-called Totalize Timed Mode.

In this mode RESTART button start counting trigger events for time duration set by Sample Interval (which defines the length of Totalize Gate). Single sample is generated after the end of the Gate.

5.5.3 Armed Totalize

If both Start Arming Source and Stop Arming Source are set, then start and stop arming events define start and stop of Totalize Gate for each Sample (Arm On setting is ignored, the instrument uses arming in Sample implicitly).

See [Arming](#) for details on this Totalize mode.

5.6 Voltage

The instrument measures the voltage by searching the minimum and maximum signal levels. See [Voltage measurement principles](#) for details.

Vmin, Vmax and Vpp functions allow measuring voltage on 4 input signals in parallel for CNT-104S, CNT-104R, CNT-104B, 2 – for CNT-102, CNT-102B, 1 – for FTR-210R with Option 230. Vminmax allows only one input but provides both – min and max – at the same time. Resolution is 1 mV, up to 16 million samples can be acquired in one measurement session.

Chapter 6

Measurement cheat-sheet

6.1 Generic hints

- Whenever you find yourself in trouble while setting up the measurement – use Autoset:
 - Connect the signals, choose measurement function/inputs, choose Sample Count and Sample Interval,
 - Press Autoset button.

And it will find proper settings for most cases when measuring continuous signals.

- Use Auto choice for settings items unless you understand the implications of selecting other option.
- Settings → User Option → Recall Defaults will reset measurement settings to Defaults.
- Save complex measurement configurations as Presets (Settings → Measurement Presets or dedicated icon on measurement screen). In this case you can easily recreate the same measurement setup if you need it later.
- Make sure input circuits are setup appropriately:
 - Use Auto-trigger for signals above 100 Hz, otherwise make sure Absolute trigger level is set. appropriately (prefer using Autoset for low frequency signal – it will set trigger levels for you). Make sure input impedance is set correctly. Use only DC coupling for low frequency signals and rely on Autoset to setup proper trigger levels. Keep Preamp OFF, except for extremely low input signal levels (below 50 mVrms). Keep Attenuation 1x, except for signals with amplitudes above exceeding +/- 5V.
 - Keep Filter Off, except for low frequency sine wave signals (below 100 kHz).
- Settings → Advanced → Voltage Mode should be set to Normal, except for signals below 100 Hz. For signals below 100 Hz please use Autoset to let the counter select best voltage mode for you. Set Voltage mode explicitly only if Autoset fails to find appropriate instrument setup (e.g. for not continuous signals)

6.2 Measuring 1 PPS

Hints:

- Set DC on inputs 1 PPS signals are connected to,
- Select measurement function and inputs,
- Set Sample Interval to 0 (or 1 μ s for base CNT-102, CNT-102B, CNT-104B, FTR-210R),
- Use Autoset or set Trigger Mode to Manual and set Trigger Level to the middle of 1 PPS signal voltage range.

Same is most of the time true for signals below 100 Hz.

6.3 Measuring single cycles or pulses

Hints:

- Set DC on the inputs, which the signals are connected to,
- Select:
 - Period Single for measuring single cycle frequency period, or
 - Time Interval Single for measuring intervals between events, or
 - Totalize for counting events, or
 - Any function from Pulse group for measuring pulse characteristics.

Please note: using other functions will not give reliable results for single cycles/pulses.

- Set Trigger Mode to Manual and set Trigger Level to the middle of signal voltage range.

Please note: auto-trigger won't work for single cycles/pulses.

6.4 Measuring Frequency/Period

See *Measuring 1 PPS* if signal is below 100 Hz.

Hints:

- The basic setting Sample Interval in the Measurement menu is central to all Frequency related measurement. This setting means the same as Measuring time, or Gate time, used by other counter manufacturers.

A long Sample Interval (Gate time) increases resolution (counting during a longer time) but decreases measurement speed. The Sample Interval is always a compromise between how many digits you want to read, and how fast you want to take your frequency samples. For normal bench use – 200 ms is a good choice, because it is hard for the eye to follow faster changes in the displayed value.

The instrument will give 12-13 digits resolution with 1 s Sample Interval, 9 digits with 1 ms Sample interval, and 6 digits with 1 μ s Sample Interval

- Use AC Coupling because possible DC offset is normally undesirable.
- Use Trigger Mode Auto and/or Autoset.
- Use Preamplifier ON for signals with amplitudes below 200 mVpp.

Please note: amplifying the signal also amplifies the noise.

- Sample Interval of 200 ms is a reasonable tradeoff between measurement speed and resolution on the bench.

6.5 Jitter measurements

Statistics provides an easy method of determining the short term timing instability, (jitter) of pulse parameters.

Note: that the measured pulse parameter should be a single cycle value, whether it is period, or pulse width.

6.5.1 Single cycle jitter

Single cycle jitter made on random samples of single periods, is usually specified with its rms value, which is equal to the standard deviation based on single measurements. The instrument can then directly measure and display the rms jitter. Jitter can also be expressed as peak-to-peak value, which is also displayed in the Statistics screen.

6.5.2 Cycle-to-cycle jitter

Cycle- to-cycle jitter demands zero dead-time measurements without gaps and can be made on input signals with a jitter frequency of up to 20 MHz for CNT-104S, CNT-104R, CNT-104B and FTR-210R with Options 230, 122F. There is currently no dedicated measurement function, but the raw data of a Period Average measurement, with Sample Interval of 0 or down to 50 ns or 1 μ s (depending on particular model and corresponding license installed), could be exported to e.g. Matlab or Excel for “number crunching” and analysis.

6.5.3 Wander measurements

Wander measurements, which is a “slow jitter” measurement with jitter frequencies <10 Hz is made by using the TIE function, which compares the accumulated period phase drift, with the ideal phase from an ideal clock.

6.5.4 Deterministic jitter

Deterministic jitter is revealed in the Distribution graph, which will show underlying noise sources in a clear way. For example a sine modulated noise source would give a bathtub shape, a pulse modulated noise source would give a twin peak shape, and a measurement of a source containing not one, but two, fundamental frequencies will be displayed as “double hump”.

6.6 Frequency Modulated Signals

A frequency modulated signal is a carrier wave signal (CW frequency = f_0) that changes in frequency to values higher and lower than the frequency f_0 . It is the modulation signal that changes the frequency of the carrier wave.

The instrument can accurately measure:

- f_0 = Carrier frequency.
- f_{dev} = Frequency deviation = $(f_{max} - f_{min})/2$. And via the timeline graph, you will also get a good indication of the modulation frequency f_{mod}

6.6.1 Initial capture settings

The optimum settings is to find a balance between large enough sample intervals to achieve high resolution per individual frequency sample, max. 10% of the Frequency deviation.

And small enough Sample intervals to capture enough frequency samples per modulation cycle for good graph visibility.

A rule of thumb is that the number of samples per modulation cycle should be >10, for good graphical view of the modulation signal, and acceptable error of f_{max} and f_{min} .

Example: 10 kHz modulation frequency (100 μ s modulation cycle) of a 200 MHz carrier with 200 kHz deviation (0.1% modulation).

Set Sample interval to 10 μ s (10% of the modulation cycle). Set Sample Count (N) to 100 (to cover 10 modulation cycles).

Now every frequency sample will have a resolution of $(10 \text{ ps}/10 \mu\text{s}) \times 200 \text{ MHz} = 200 \text{ Hz}$.

This resolution is 1000 times better than the frequency deviation.

Start measurement and view the Timeline graph, which will show 10 modulation cycles, with 10 samples per modulation cycle.

To improve the graphical experience, lower Sample Interval to 1 μ s (1% of the modulation cycle), and increase Sample Count to 1000.

Now each frequency sample has a resolution of $(10 \text{ ps}/1 \mu\text{s}) \times 200 \text{ MHz} = 2 \text{ kHz}$. Still with a lot of margin to deviation.

You may want to play around with the Sample Interval and Sample Count setting until you have found your optimum view of the FM signal (no of displayed mod. cycles).

6.6.2 Carrier Wave Frequency f_0

To determine the carrier wave frequency, just look at f_{mean} which is best approximation of f_0 .

Ideally the sum of all Sample Intervals should be selected to cover an integer number of modulation periods. This way the positive frequency deviations will compensate the negative deviations during the measurement.

Example: If the modulation frequency is 1 kHz, the Sample Interval $10\ \mu\text{s}$ and $N = 1000$ will make the instrument measure exactly 10 complete modulation cycles. A bad combination of Sample Interval and N would worst case mean that exactly half a modulation cycle is uncompensated for, giving a max. error for a sine modulation of:

$$f_0 - f_{\text{mean}} = \Delta f_{\text{max}} / (\text{sample int.}) \times N \times f_{\text{mod}} \times \pi$$

For very accurate measurements of the carrier wave frequency f_0 , make an extra measurement session and set Sample Interval as close as possible to an integer number of modulation cycles, and increase the number of samples substantially. A worst case error of half a modulation cycle means far less in a million cycles compared to 10 cycles.

6.6.3 Frequency deviation $f_{\text{max}} - f_0$

Read the max, min, and mean frequency values from statistics screen or beneath the graph and calculate f_{dev} as either:

- $f_{\text{max}} - f_{\text{mean}}$
- $f_{\text{mean}} - f_{\text{min}}$
- $f_{\text{p-p}}/2$

These three values should be exactly the same for an ideal sine wave or square wave modulation.

6.6.4 Modulation frequency f_{mod}

The modulation frequency is easiest found by visual estimate in the graph on screen by using Cursors. Place one cursor on the beginning of the first modulation cycle and the other – on the end of the last modulation cycle. If the end point time difference between cursors is T seconds and the exact integer number of modulation cycles between cursors is M , the modulation frequency is:

$$f_{\text{mod}} = M/T$$

6.6.5 Errors in f_{max} , f_{min} , and $f_{\text{p-p}}$

A too large Sample Interval compared to the modulation cycle time leads to an averaging error that will underestimate the true deviation. A Sample interval corresponding to 10% of the modulation cycle, or 36° of the modulation signal, leads to an error of approx. 1.5%.

If that error is not acceptable, decrease the Sample Interval to make more samples than 10 during the modulation cycle.

6.7 Frequency profiling

Profiling means measuring and plotting frequency variation versus time. Examples are measuring warm-up drift in signal sources over hours, measuring the linearity of a frequency sweep during seconds, VCO switching characteristics during milliseconds, or the frequency changes inside a “chirp radar” pulse during sub-microseconds.

The instrument can handle many profiling measurement situations with some limitations. In profiling applications, the instrument acts as a fast, high-resolution sampling front end, storing results in its internal memory. These results are later displayed on screen and/or transferred to the controller for analysis and graphical presentation.

You must distinguish between two different types of measurements called free-running and repetitive sampling.

6.7.1 Free-Running Measurements

Free- running measurements are performed over periods down to the sub-microseconds range, e.g., to measure initial drift of a signal generator or oscillator, to plot linearity of a sweep signal ramp, or to measure short-term stability down to microsecond averaging times. In these cases, measurements are performed at user-selected Sample Intervals, and performed as gap-free measurements in the range 50 ns or 1 μ s (depending on particular model and corresponding license installed) to 1000 s.

Just start the block measurement and view the profile in the graph presentation mode.

6.7.2 Repetitive Sampling Profiling

The measurement setup just described will not work when the profiling demands less than 50 ns or 1 μ s (depending on particular model and corresponding license installed) intervals between samples.

How to do a VCO step response profiling with 50 samples during a time of 1 μ s.

This measurement scenario means that you need to come to 20 ns between samples (50 points * 20 ns = 1 ms observation time).

You will need a repetitive input step signal, and you have to repeat your measurement 50 times, taking one new sample per cycle. And every new sample should be delayed 20 ns with respect to the previous one.

Profiling can theoretically be done manually, but the best would be to perform this series of measurements with a dedicated program on PC, controlling the instrument and collecting data from it remotely.

The following are required to setup a measurement:

A repetitive input signal (e.g., frequency output of VCO). An external SYNC signal (e.g., step voltage input to VCO). Use of start arming delay (20, 40, 60 ns, etc). See Fig. 6.1 for a test setup diagram.

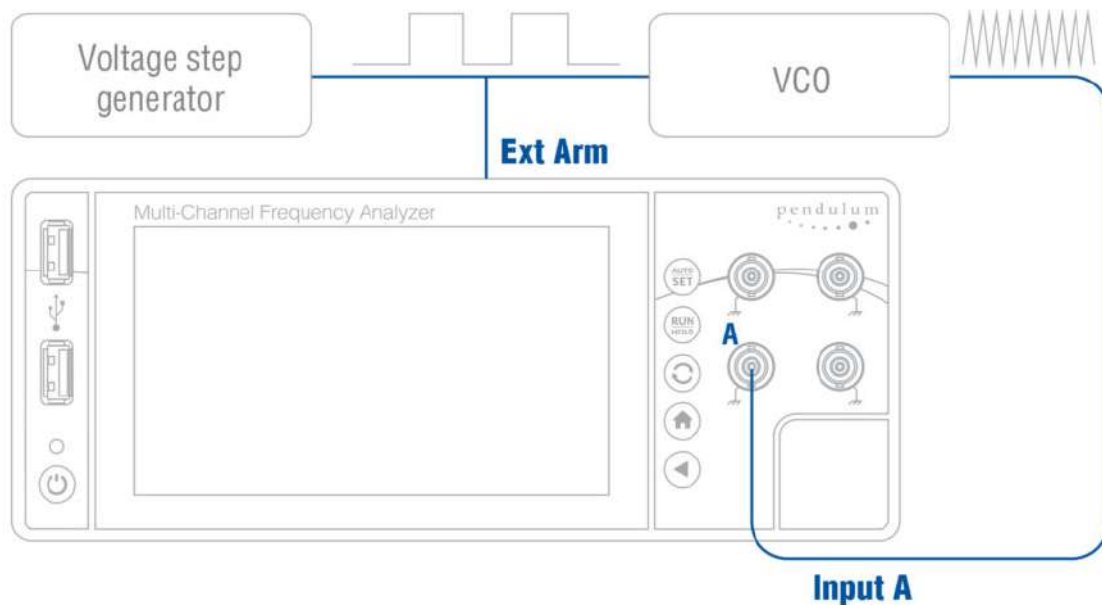


Fig. 6.1: Setup for transient profiling of a VCO.

6.7.3 V_{rms}

When the waveform (e.g. sinusoidal, triangular, square) of the input signal is known, its crest factor, defined as the quotient (Q_{CF}) of the peak (V_p) and RMS (V_{rms}) values, can be used to set the constant K in the mathematical function $K \cdot X + L$. The display will then show the actual V_{rms} value of the input signal, assuming that V_{pp} is the main parameter.

$$V_{\text{RMS}} = \frac{1}{2 \times Q_{\text{CF}}} \times V_{\text{pp}}$$

Example: A sine wave has a crest factor of 1.414 ($\sqrt{2}$), so the constant in the formula above will be 0.354.

Chapter 7

Other Features

7.1 CNT-104R, FTR-210R specific features

7.1.1 Disciplining Settings

Note

Only available for CNT-104R, FTR-210R

For CNT-104R, FTR-210R disciplining is set to “Always” by default and disciplining source is set to “GNSS” if Option 55 is present or “External PPS IN” otherwise. This can be reconfigured via “Oscillator Disciplining” and “Disciplining Source” parameters in menu Settings → Timebase

CNT-104R, FTR-210R can be put to Manual Holdover by setting Oscillator Disciplining to Manual Hold-Over.

Disciplining source can be selected between:

- GNSS (only for CNT-104R with Option 55 (GNSS), FTR-210R)
- External 1 PPS IN

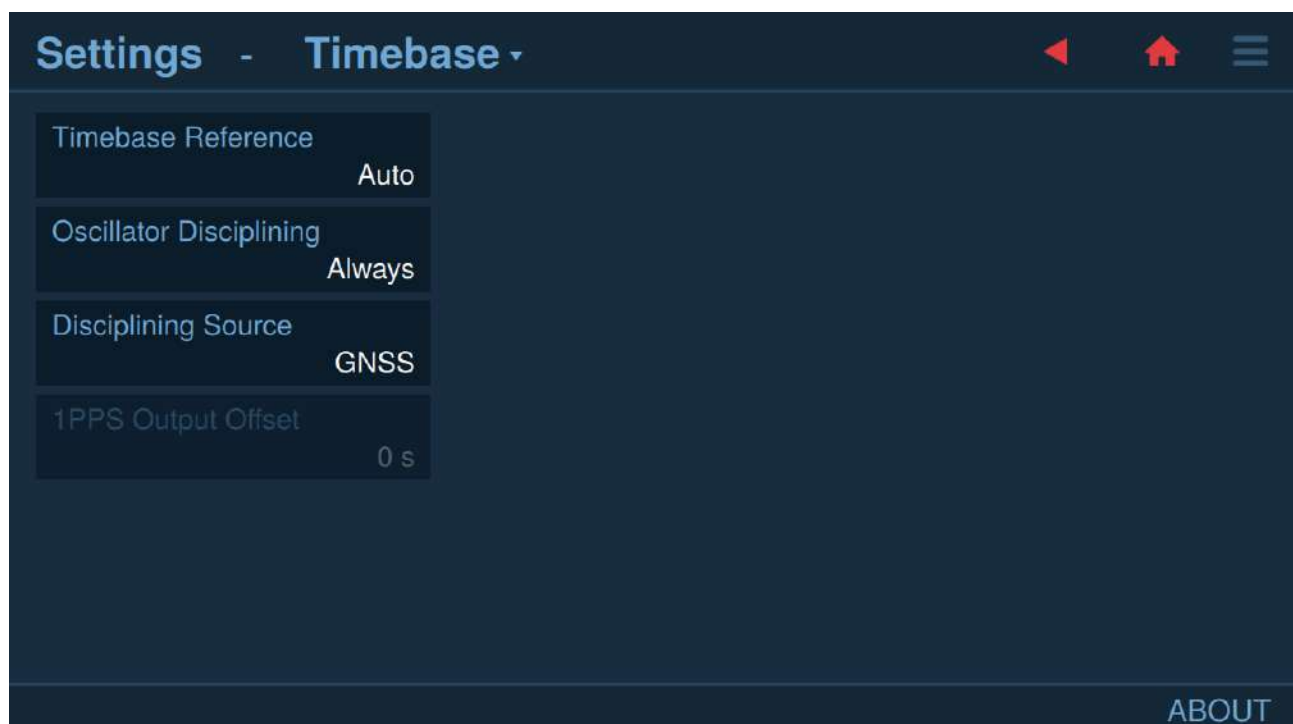


Fig. 7.1: Disciplining Settings

7.1.2 Rubidium & Disciplining Status

Note

Only available for CNT-104R, FTR-210R

Table 7.1: Rubidium Status

Rb Icon	Status	Comment
 flashing	Warming up	Rubidium typically warms up in 10 min at 25°C
	Obtained internal lock, warmed up	Normal operation

Table 7.2: Disciplining Status

Disciplining Icon	Status	Comment
None	Manual Hold-Over	The user explicitly selected Manual Hold-Over mode
 flashing	Hold-over. Set to be disciplining but isn't locked to the disciplining source.	This state is normal when the oscillator is adjusting its PPS phase to the disciplining source and usually changes to "Disciplining" in approximately 30 minutes. However, if this state lasts long time, it makes sense to check antenna, GNSS Status or external 1 PPS IN signal (if Disciplining Source is set to External 1 PPS IN)
	Disciplining	Normal operation

7.1.3 GNSS Settings & Status

Note

Only available for CNT-104R with Option 55 (GNSS), FTR-210R.

GNSS Settings & Status are available via Settings → GNSS

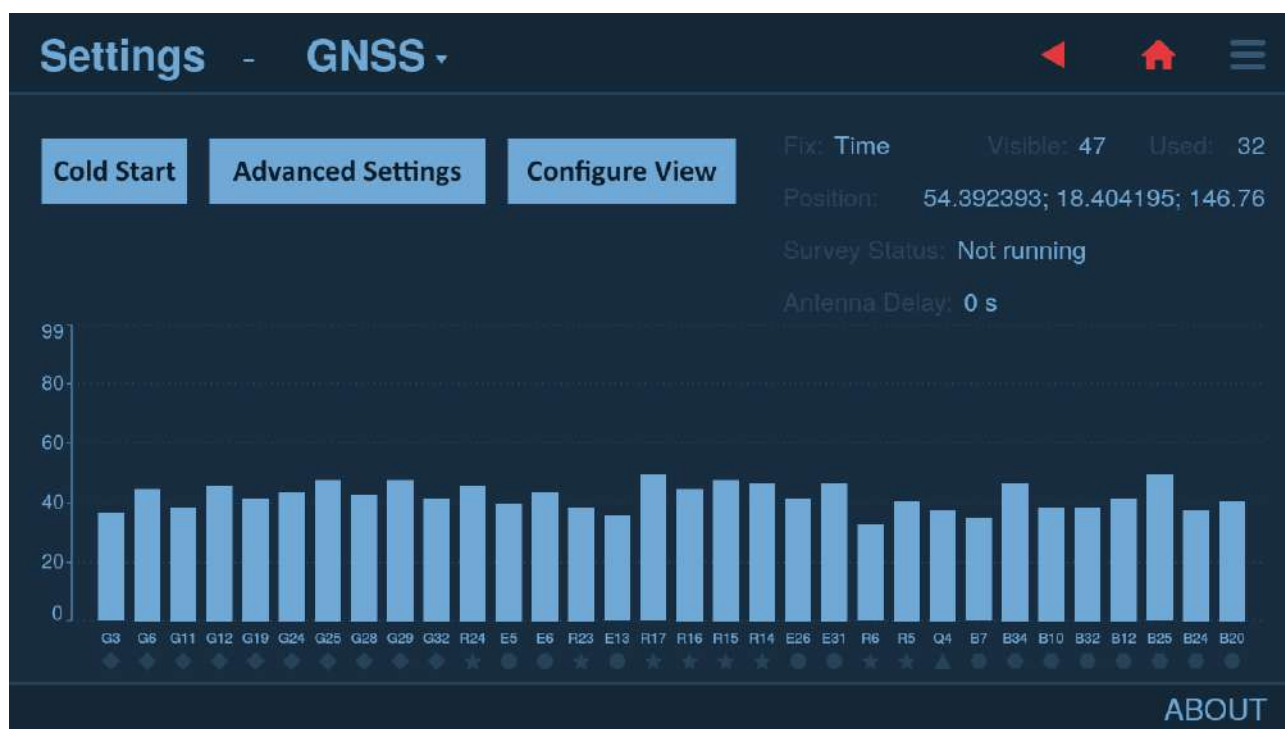


Fig. 7.2: GNSS Settings & Status



Fig. 7.3: GNSS Advanced Settings

7.1.3.1 Cold Start

Cold Start will reset the GNSS receiver and all its cached data including the position and almanac.

Note

It is necessary to do Cold Start of the receiver after moving the instrument/antenna to a new location. Please also do a Cold Start when you first turn the instrument on after receiving it.

7.1.3.2 Antenna delay

Antenna delay setting allows compensating for the signal propagation through the antenna and the cable. Please refer to the specification of particular antenna and cable for the typical propagation delay figures or measure the actual propagation delay of your setup for maximum accuracy.

Please see below a table with typical figures for the optional HW accessories available directly from Pendulum Instruments:

Table 7.3: Typical delay figures for optional Antenna and Cables

Accessory	Delay, ns	Comment
Option 01/200 Multi-GNSS Antenna	<10	Based on group delay variation across the GNSS band
Option 02/20T Antenna Cable, 20 m	78.5	Cable's Velocity of Propagation factor is 85% (corresponds to 3.92 ns/m)
Option 02/25T Antenna Cable, 25 m	98	
Option 02/50T Antenna Cable, 50 m	196	
Option 02/130T Antenna Cable, 130 m	510	

7.1.3.3 Self-survey

Self-survey is a special feature of timing GNSS receivers which allows to first average the position down to required accuracy, then fix it and continue solving GNSS navigation equations for time only, thus maximizing the timing accuracy.

It is controlled by 2 parameters: Survey-in Accuracy and Time. The former specifies the required averaged position accuracy while the latter one will make sure the survey won't finish before specified period even if the required accuracy has been reached.

Note

Self-survey is never run automatically after it has completed at least once. On power up the instrument will use fixed position which is the result of the last successful self-survey. To force self-survey (e.g. after moving the instrument/antenna to a new location) please use Cold Start button under Settings → GNSS. Changing self-survey parameters (Settings → GNSS → Advanced) will also force self-survey to be restarted.

Note

Depending on the antenna location, possible interferences and other factors which have impact on the GNSS signal reception, it might be not possible to reach desired position accuracy. In this case it is necessary to relax the survey accuracy and survey time parameters.

7.1.3.4 Used Signals

This parameter allows to select particular GNSS signals to be used. Normally it shouldn't be modified unless there are known issues with particular signal or some restrictions apply.

7.1.3.5 Status

The GNSS Status screen displays the following information about the current GNSS receiver state:

- **Fix.** Can be of the following values:
 - No fix. This means the GNSS receiver cannot determine positional and timing information yet. Under normal conditions and good sky view GNSS receiver will typically obtain the first fix in less than 5 min. If this status continues longer than 5 minutes this may indicate poor GNSS reception.
 - 3D fix (minimum 4 satellites available). The receiver is successfully solving for position and time, but self-survey has not completed yet.
 - 2D fix (minimum 3 satellites available). Last known altitude is kept constant and the receiver is solving for latitude/longitude and time only.
 - Time. Self-survey has been completed. The receiver fixes the position averaged during the self-survey and keeps solving for time only. Time solution can be calculated with 1-2 satellites. Time fix allows for maximum timing accuracy.
- **Visible.** Number of satellites in view
- **Used.** Number of satellites used for the solution.
- **Position** (latitude; longitude; altitude)
- **Survey Status.** Shows overall the self survey progress relative to minimum survey time (set by Survey-in Time setting).

Note

If minimum survey time has passed but required position accuracy (set by Survey-in Accuracy setting) has not been reached yet, the progress will be indicating 99%.

- **Antenna delay** currently set
- **Satellites chart** shows the following information about satellites currently in view:
 - Satellite ID - under the bar.
 - Constellation symbol under the ID. For the legend - see Configure View drop-down selection
 - Signal to noise ratio (SNR) - bar height.
 - If particular satellites is used for solution (filled SNR bar) or not (empty SNR bar)

Configure View drop-down menu can be used to remove information regarding certain constellations from the satellite chart.

Note

Configure View selection has impact only on the Satellite Chart, it doesn't exclude the unselected constellations from the solution. To exclude certain constellations or signals from GNSS solution please use Settings → GNSS → Advanced → Used Signals.

7.2 Hold-off

Hold-off function allows to insert dead-time into input trigger circuit which effectively acts as a digital lowpass filter. Hold-off can be set to 0 (Hold-off OFF) or in the range [20 ns .. 2.683 s] which correspond to low-pass filter frequency from 100 MHz down to 0.5 Hz.

Setting Hold-off to approx. 75% of the cycle time of the signal allows to inhibit erroneous triggering for noisy signals.

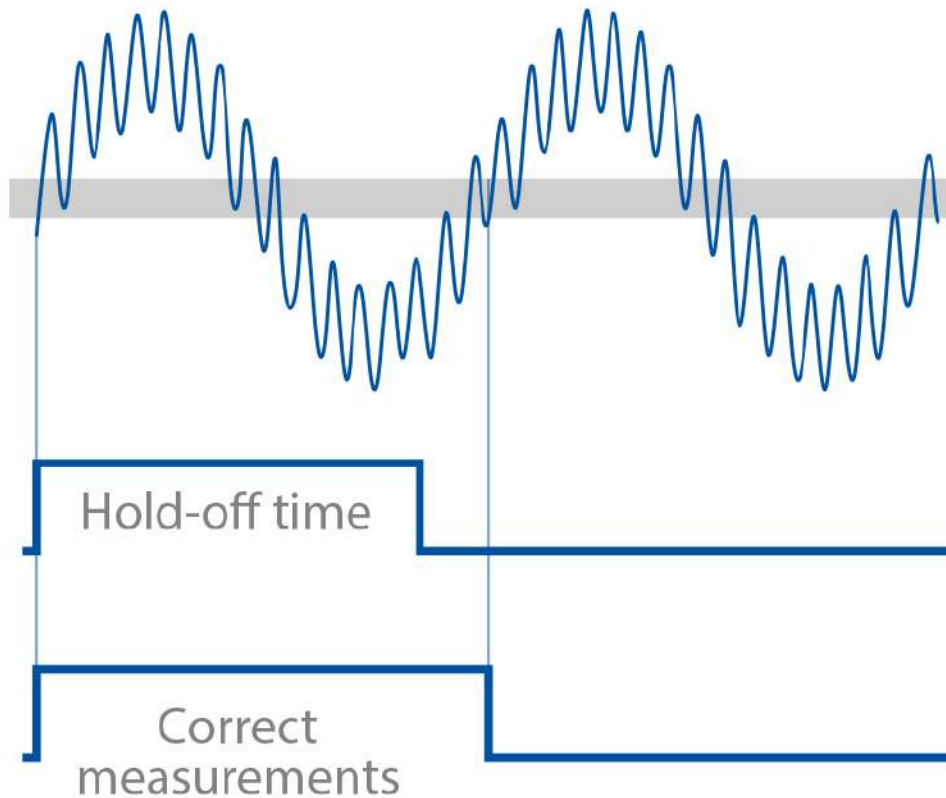


Fig. 7.4: Using hold-off as a Digital LP filter to cope with erroneous triggering on noisy signal

Hold-off is also an effective measure to cope with contact bouncing on the front of the signal under test.

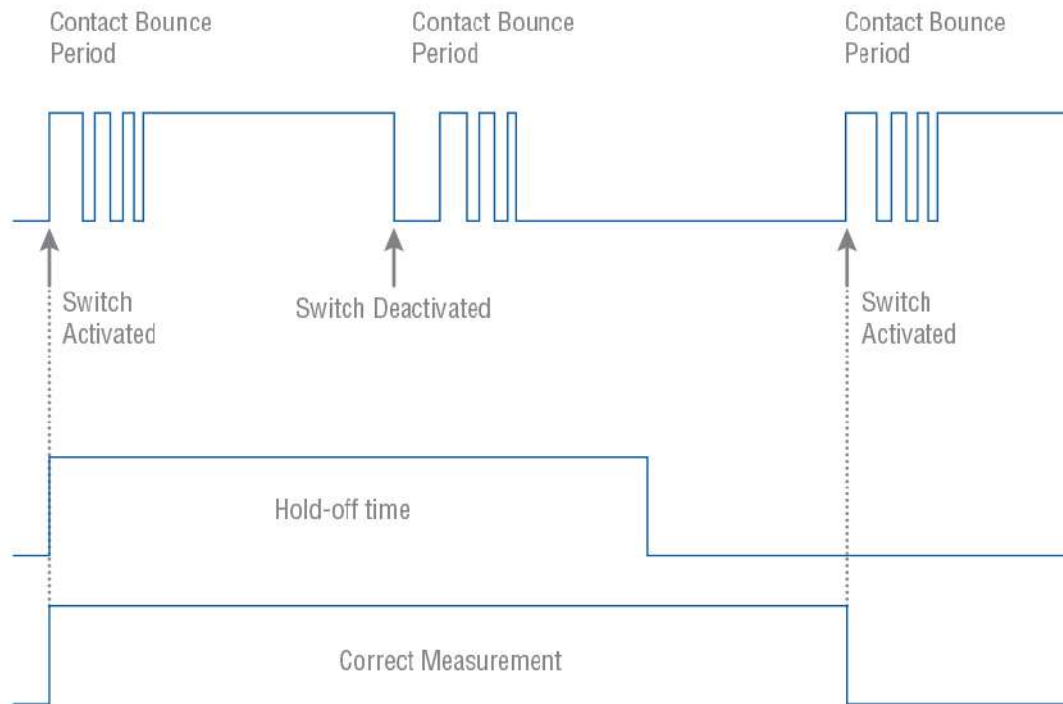


Fig. 7.5: Using Hold-off to cope with switch bounce effect

You should be aware of a few limitations to be able to use the Hold-off feature effectively and unambiguously. First you must have a rough idea of the frequency to be measured. A cutoff frequency that is too low might give a perfectly stable reading that is too low. In such a case, triggering occurs only on every 2nd, 3rd or 4th cycle. A cutoff frequency that is too high (>2 times the input frequency) also leads to a stable reading. Here one noise pulse is counted for each half-cycle.

7.3 Timeout

The instrument ends measurement when all requested samples have been collected. However, if signal is absent (or lost) on one of the inputs used for the measurement – timestamps from this channel will never come and instrument will wait forever unless measurement is stopped explicitly.

However, in many cases this is undesirable behavior. For example in an automated test system when absence of signal can be a result of a wrong test setup or device under test malfunction, it would be a waste of time to wait until the expected end of a long measurement to discover that one of the signals is just missing.

This is where Timeout function comes to help. If Timeout is ON, the measurement will end in case there are no samples from one of measurement inputs for the time duration set by Timeout Time.

7.4 Calibration

7.4.1 Internal Calibration

The instrument has a possibility to compensate for some internal sources of error by the means of internal calibration. This procedure doesn't require any external signal, the instrument can perform it automatically.

Performing internal calibration before the start of measurement helps getting maximum accuracy and best resolution. However, because internal calibration takes up to 2 s it has impact on measurement speed which might be important in automated test systems. Hence, the instrument allows to choose the schedule of internal calibration. Summarizes available options.

Mode	Description
Every 30 minutes	The instrument performs internal calibration every 30 minutes between successive measurements or when it is idle. This is the default option which provides the best trade-off between accuracy, resolution and average measurement speed.
Before every measurement	The instrument performs internal calibration before each timing measurement to ensure best resolution and accuracy. This results in additional time overhead of around 2 s per measurement session. If such overhead is not critical – this is the recommended choice.
Once (after warm-up)	The instrument performs internal calibration only once – after the instrument has warmed up. This guarantees no calibration overhead, but resolution will deteriorate over time.

Table 4. Internal Calibration Modes

To provide maximum flexibility, the instrument also provides the possibility to perform internal calibration explicitly. This is especially useful when Interpolator Calibration Mode is set to Once.

All above can be configured under Settings → Advanced section (see Fig. 7.6).



Fig. 7.6: Internal Calibration configuration

7.4.2 Timebase Calibration

Note

For CNT-104R with Option 55 (GNSS), FTR-210R timebase calibration is not required unless the instrument is used in Hold-over or Manual Hold-over modes

For increasing measurement accuracy, a good reference source can be used for timebase calibration. Connect the source to Input A, select Settings→Timebase Calibration, choose reference frequency and start the procedure. It is possible to interrupt the process midway, re-apply result from previous calibration or reset to factory calibration setting.

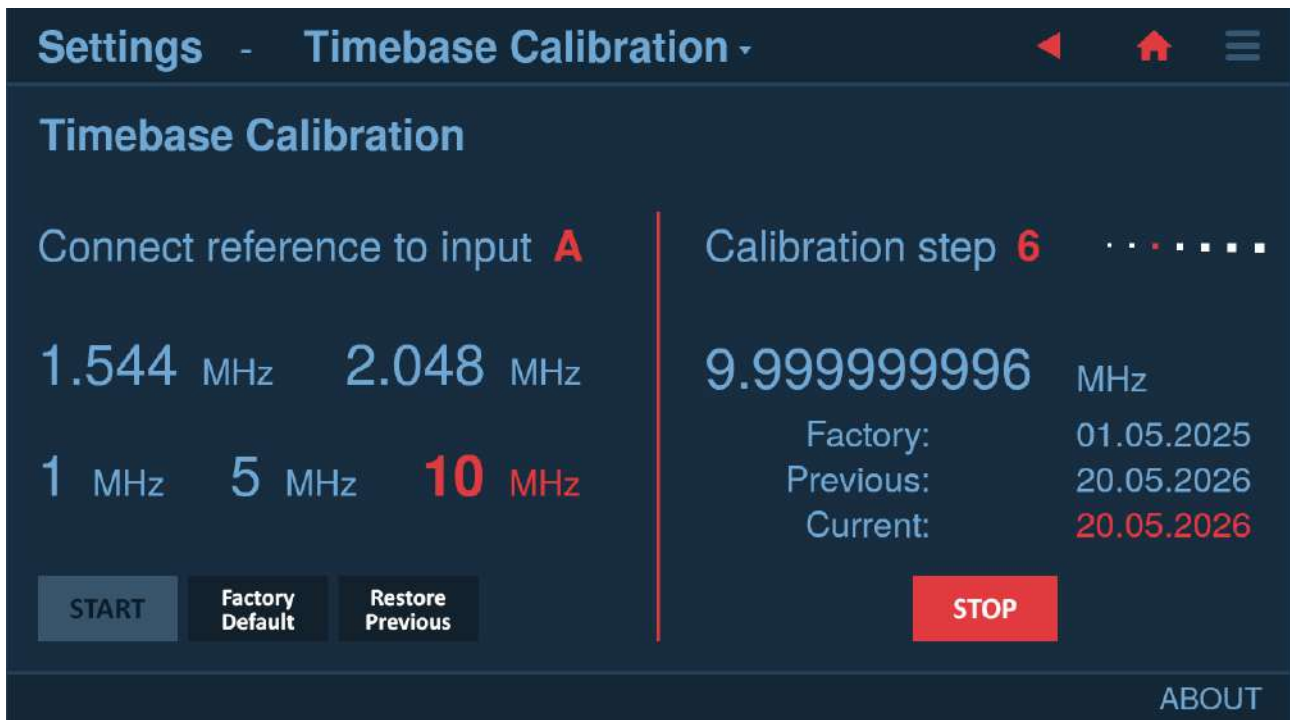


Fig. 7.7: Timebase Calibration menu

7.4.3 Voltage Calibration

For increasing accuracy of voltage measurements and manual trigger level setting accuracy, a good source of DC voltage can be used for voltage calibration. Open Settings → Voltage menu, select the input to be calibrated and follow the instructions.

Note

Pictures below illustrate display of CNT-104S model.

For CNT-102, CNT-102B, channels D, E are not available and areas, fields and graphical objects for corresponding to these channel are not present. Up to 2 signals can be measured in parallel.

For FTR-210R with Option 230, channels B, D, E, C are not available and areas, fields and graphical objects for corresponding to these channel are not present. Only one signal can be measured in parallel.

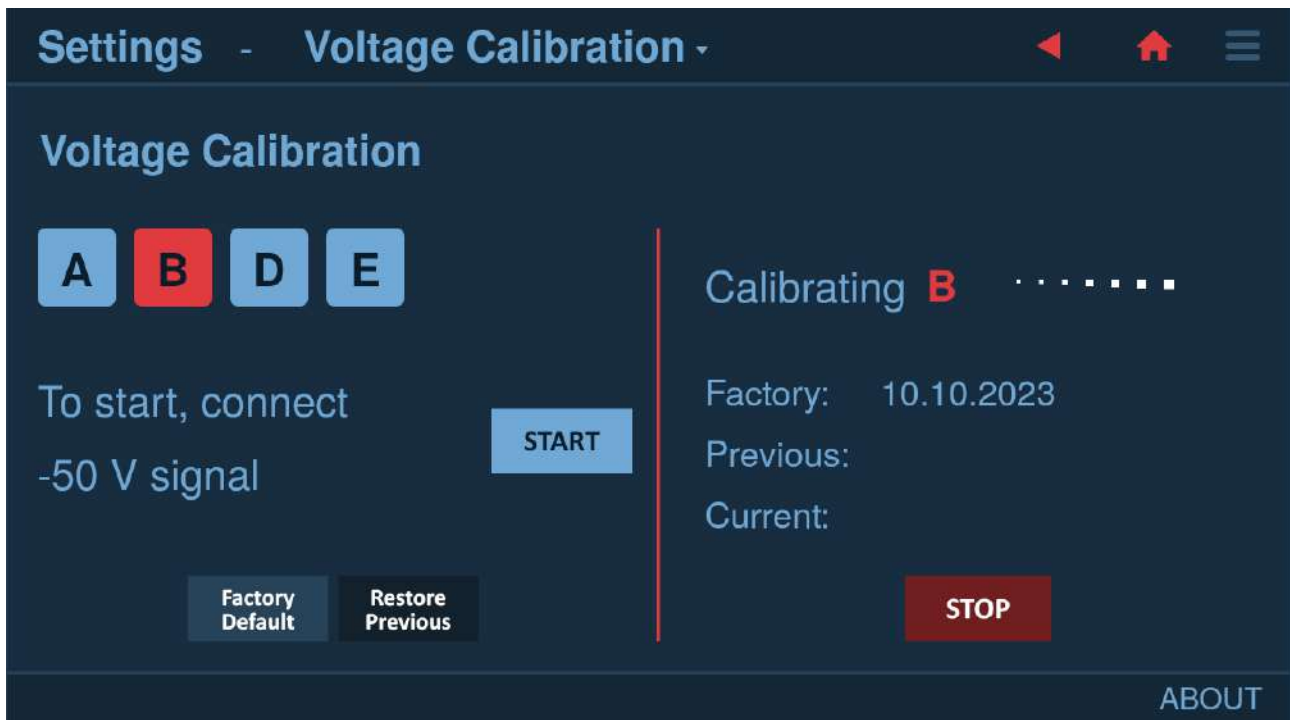


Fig. 7.8: Voltage Calibration menu

Note

Voltage calibration sets inputs to 1 MOhm impedance.

7.5 Mathematics

The instrument can use five mathematical expressions to process the measurement result before it is displayed:

- $K \times X + L$
- $K / X + L$
- $(K \times X + L) / M$
- $(K / X + L) / M$
- $X / M - 1$

Select Settings → Math / Limits to enter the Math / Limits submenu.

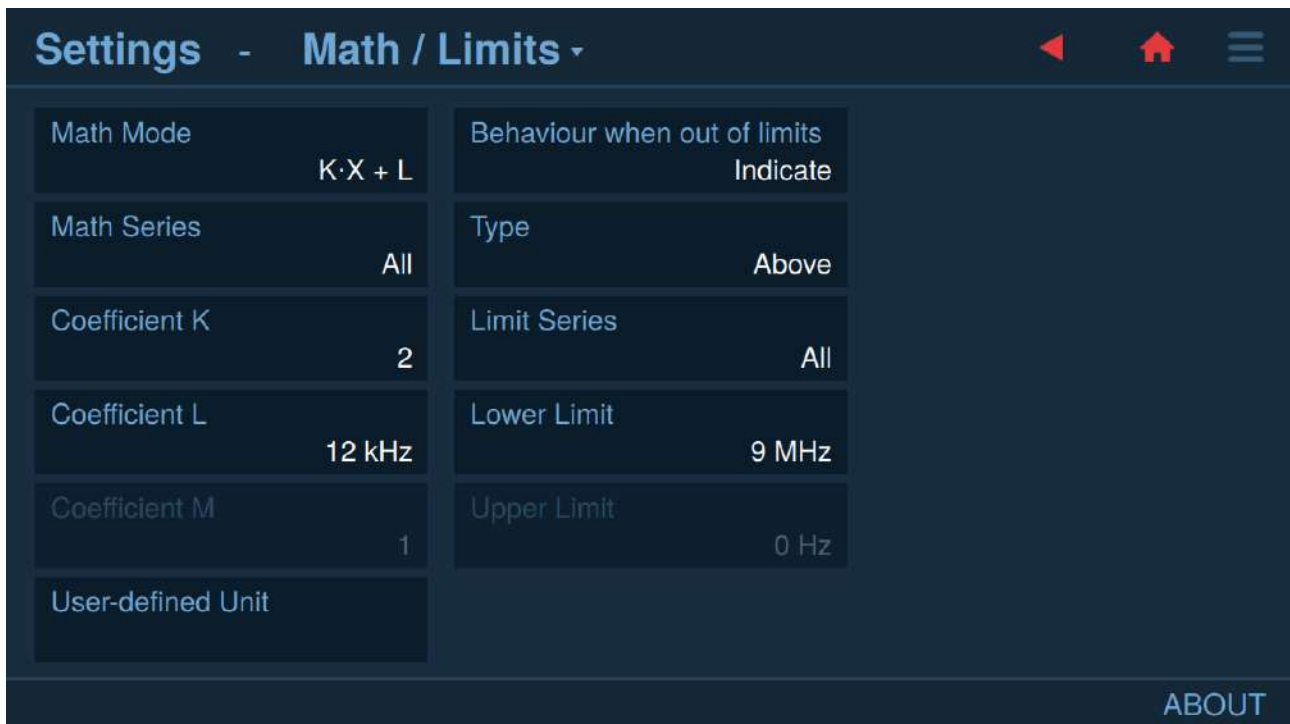


Fig. 7.9: Math / Limits configuration

The default values of K (Scale factor), L (Offset) and M (Reference value) are chosen to 1, 0 and 1 respectively, so that the measurement result is not affected directly after activating Math. Recalling the default setting will restore these values as well.

It is possible to apply Mathematics function to all measurement series or to selected one.

When Mathematics is turned on, the instrument status bar shows MATH indicator.

7.5.1 Example use cases

If you want to observe the deviation from a nominal frequency, for example 10 MHz, instead of the absolute frequency itself, you can do like this:

- Select Math
- Select the expression $K \times X + L$
- Select $K = 1$ (if not already set)
- Select $L = -10 \text{ MHz}$
- Now the display will show the deviation from the value you have just entered.

By changing the constant K you can scale the result instead. Set for example $K = 60$ to convert Frequency in Hz to RPM (revolutions per minute) from rotation transducers.

Use the expression $X/M-1$ if you want the result to be displayed as a relative deviation. The result will be displayed as

%, ‰ (per mille or one-thousandth), ppm, ppb, or as a dimensionless number like $+1.2345\text{E}-12$.

7.6 Limits and Alarms operation overview

The block diagram on Fig. 7.10 describes the logic of Limits and Alarms features and how they interoperate with each other. The upper part describes Limits in details and the lower part – the way to configure Alarms, including Limits as a source for an alarm.

Alarms control block (bottom half of the diagram) monitors events from various sources and outputs information about them in various forms (see [Alarms](#) for details).

The sources of events are:

- Limits control block
- Rubidium oscillator (only CNT-104R)
- GNSS control block (only CNT-104R with Option 55 (GNSS))

The limits control block checks samples during a measurement and signals “Limit exceeded condition” event when a sample exceeds defined limits (see [Limits](#) for details). Rubidium oscillator notifies about hold-over condition. GNSS control block notifies about GNSS fix loss.

The events from the the mentioned event sources (alarms, Rb oscillator status, GNSS) can be routed to various “outputs”:

- Display
- Pulse output connector
- Ethernet interface

Display output is not configurable and always indicates limits excess (when limits are configured) and Rb oscillator status (on units with Rb oscillator).

Pulse output connector is multiplexed between multiple features, so in order to route an alarm to pulse output, corresponding setting needs to be activated to configure pulse output for alarms indication. A license option may be required to use pulse output. Refer also to [Pulse Output \(option\)](#) for details.

Network notifications are implemented in a form of SNMP protocol.

This diagram describes the maximum set of options. It is shared between CNT/FTR devices. Some settings or functions may be unavailable on particular models, including measurement function, Pulse Output, IRIG-B code generator, Rubidium oscillator, GNSS receiver etc.

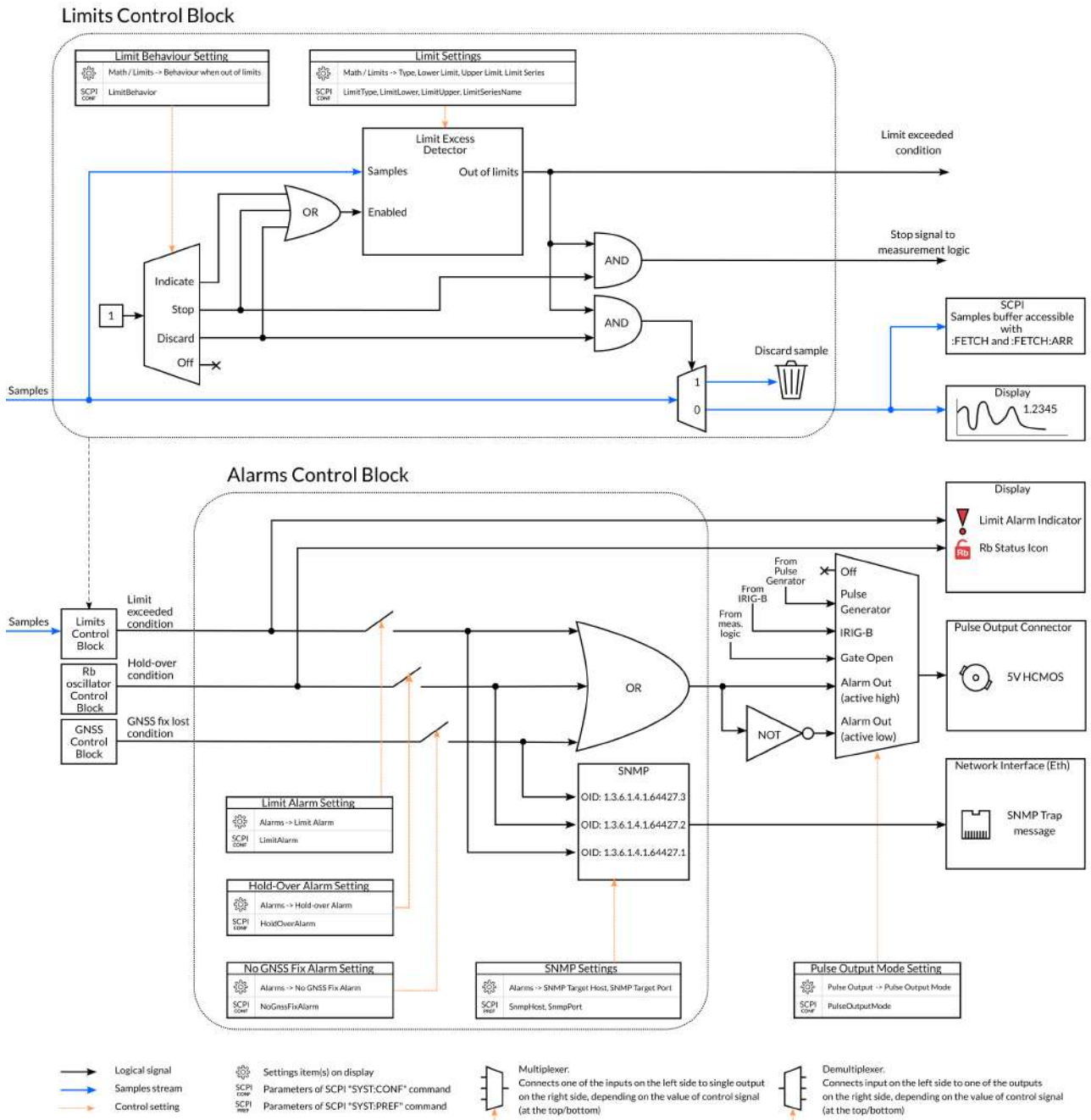


Fig. 7.10: Limits and alarms logical diagram

7.6.1 Example use case

In this example we will trigger an alarm on Frequency A measurement in every possible way: screen notification, SNMP messages or Pulse Output voltage levels.

After measurement itself is configured, please set also these settings (adjust example values to your own use-case):

- Math/Limits → Behaviour when out of limits = Indicate
- Math/Limits → Type = Range
- Math/Limits → Lower Limit = 5 MHz
- Math/Limits → Lower Limit = 50 MHz

- Pulse Output → Pulse Output Mode = Alarm Out (active high)
- Alarms → SNMP Target Host = 192.168.100.19
- Alarms → Limit Alarm = On

7.7 Limits

The Limits feature is used to set numerical limits and define how the instrument reports measurement results relative to those limits.

Please see also [Limits and Alarms operation overview](#) if you wish to configure Alarms for user-defined limits.

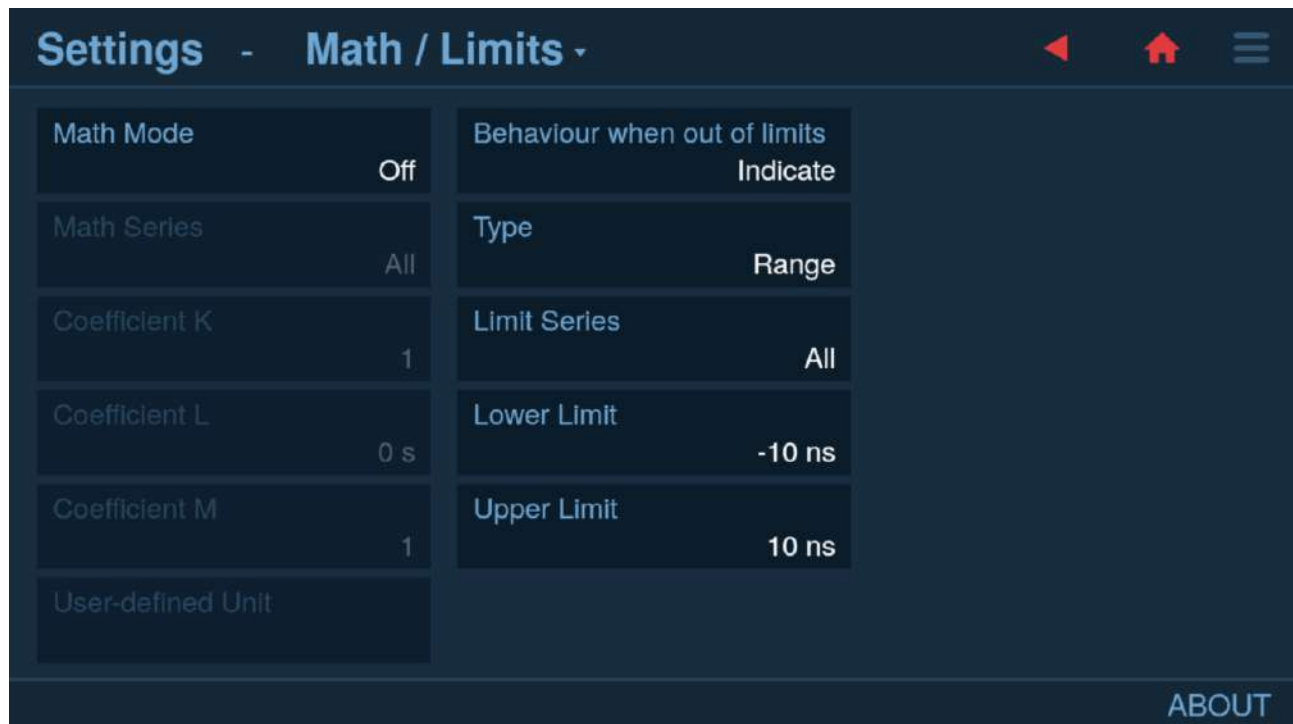


Fig. 7.11: Math / Limits configuration

Behavior when out of limits setting defines how the device will react:

- Off – limits are not checked.
- Discard Samples – only samples meeting the limit criterion are captured, the rest are discarded. Limit status is displayed.
- Indicate – all samples are captured; limit status is displayed.
- Stop Measurement – measurement session stops if measured value doesn't meet the limit criterion.

There are deprecated values that can be selected by SCPI: Capture, Alarm, Alarm Stop. They replaced the Discard Samples, Indicate, Stop Measurement correspondingly. Please, do not use them, they are only for backward compatibility.

Note

Additionally, for all deprecated values Limit Alarm setting will be set to On and disabled.

Limit Type:

- Above – results above set Lower Limit will pass.
- Below – results below set Upper Limit will pass.

- Range – results within the set limits will pass.

Limits can be applied to all measurement series or to selected one, depending on user's choice.

When Limit Behavior is not Off, the instrument status bar shows LIM. It will change to LIM! if at least one sample didn't meet set Limit criterion during measurement session.

Numeric, Graph and Distribution screens will also have additional Limit indicators displayed.

Note

Pictures below illustrate display of CNT-104S model.

For CNT-102, CNT-102B, channels D, E are not available and areas, fields and graphical objects for corresponding to these channel are not present. Up to 2 signals can be measured in parallel.

For FTR-210R with Option 230, channels B, D, E, C are not available and areas, fields and graphical objects for corresponding to these channel are not present. Only one signal can be measured in parallel.

Exclamation mark means at least one of series is currently not in Limits



Series Limits current state (upper and lower):
each element represents particular series
state – it has color of the series if series
Limit failed, dark color otherwise.

Status Bar Limits indicator

Fig. 7.12: Math / Limits menu

7.7.1 Limits Pass/Fail indication for Frequency Offset function

For *Frequency Offset measurements (Calibrator Use-case)* there is an additional **P / F** indicator that is displayed on the right side of the plot after measurement completes.

P indicator stands for “Pass”. Pass criteria is that **average measured offset falls within current tolerance limit**. Please note that even when individual samples fall out of the tolerance limit, the measurement can still finish with a “pass”. Tolerance limit is set in Settings → Measurement → Frequency Tolerance.

F indicator stands for “Fail”.



Fig. 7.13: Example of a Frequency Offset measurement finishing with a “pass” result



Fig. 7.14: Example of a Frequency Offset measurement finishing with a failure

7.8 Pulse Output (option)

Note

License is needed to unlock Pulse Output functionality in the instrument.

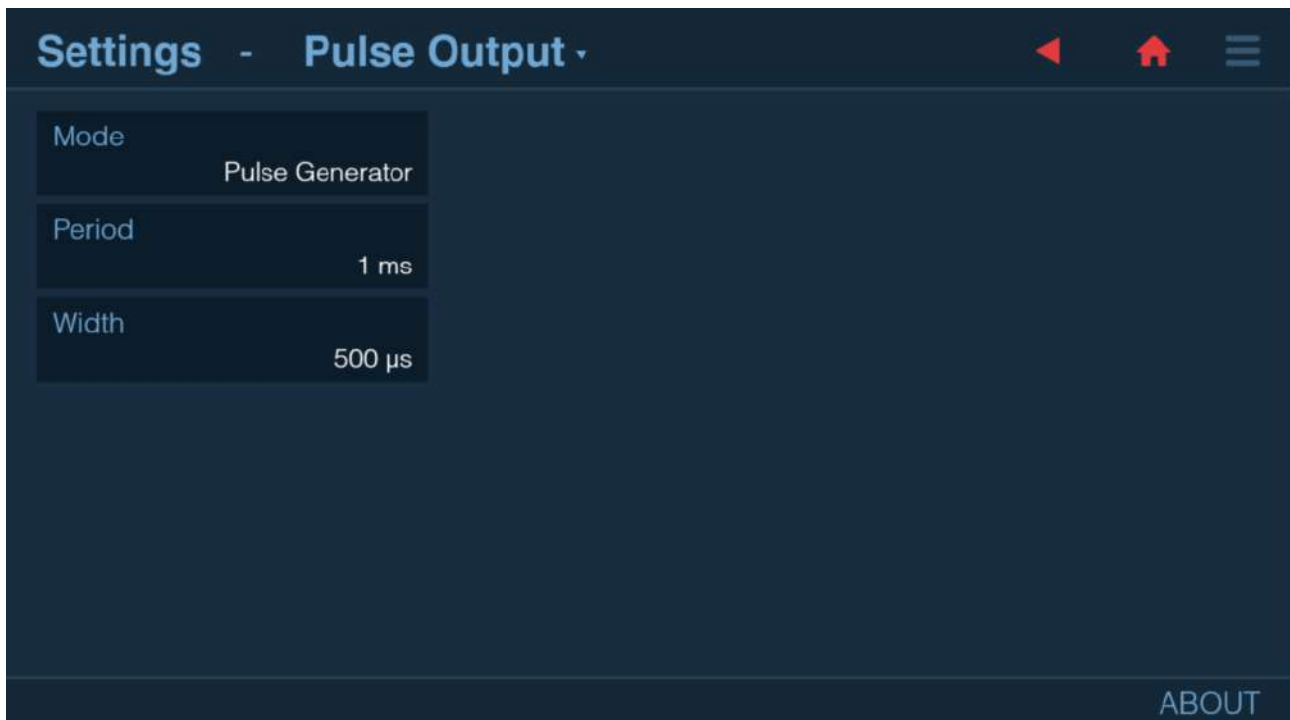


Fig. 7.15: Pulse Output configuration

Pulse Output is located on rear panel of the instrument and can be used for one of the following purposes:

- Pulse Generator. Pulse period can be selected in [10 ns .. 2.147 s] range in 2 ns steps, pulse width – from 6 ns in 2 ns steps. Pulse width must be at least 4 ns lower than period.
- Gate Open. High level indicates that measurement is in progress.
- Alarm Out. Indicates when Limits Alarm is active. Can be selected between Active High and Active Low

Irrespective to the selected mode, the amplitude of Pulse Output signal is set to TTL levels into 50 Ohm termination

7.9 Alarms



Fig. 7.16: Alarms configuration

Alarms can be used for notifications of several events using SNMP and Pulse Output Alarm Out.

Please see also [Limits and Alarms operation overview](#) if you wish to indicate user-defined limits with Alarms.

These are the settings for configuring SNMP:

- SNMP Target Host. Hostname or IP address for receiving notifications (traps) from the instrument.
- SNMP Target Port. Port for receiving notifications (traps) from the instrument.

Besides that, there are several conditions under which a notification can occur:

- Limit Alarm. Send a notification if samples do not meet the limit criteria. The limits are configured in Settings → Math / Limits → Behaviour.
- Hold-Over Alarm. Send a notification if Rubidium oscillator is in the Hold-Over state. Manual Hold-Over is also taken into account.
- No GNSS Fix Alarm. Send a notification if GNSS is in NoFix state.

When the reason for notification disappears, another notification is sent to signal this event.

Pulse Output enters active state if at least one of these conditions is met and *Pulse Output Mode* is set to *Alarm Out*. The logic level on Pulse Output becomes inactive when there are no active alarms. After setting the SNMP host the device starts sending notifications according to the following OIDs (object identifiers):

- *iso.3.6.1.4.1.64427.1* - Limit Alarm notification
- *iso.3.6.1.4.1.64427.2* - Hold-Over Alarm notification
- *iso.3.6.1.4.1.64427.3* - No GNSS Fix Alarm notification

These messages carry an alarm state flag: active and inactive (1 or 0 correspondingly).

Example:

iso.3.6.1.4.1.64427.2 = INTEGER: 1 — Hold-Over Alarm has been triggered

7.10 ADEV Graph (option)

Note

A license (option 161) is required to unlock ADEV graph in the instrument.

Allan deviation (ADEV) is a commonly used way to analyze noise and estimate signal stability. ADEV Graph option enables calculation of ADEV values for a range of intervals, displays results in graphical and textual form, with possibility to save them into a file. The instrument uses 'overlapped ADEV' as a method of calculation. For detailed specifications, including ADEV floor, please check instrument's datasheet.



Fig. 7.17: ADEV graph tab

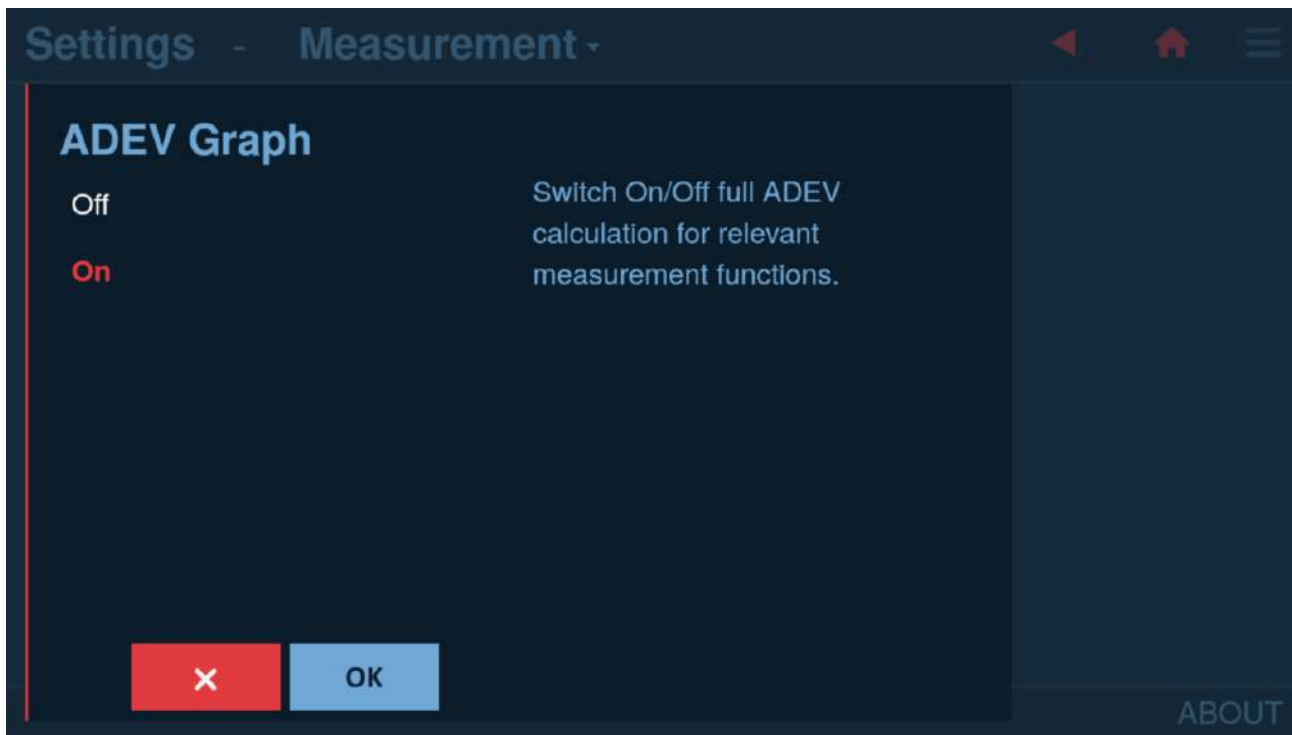


Fig. 7.18: ADEV graph setting

ADEV Graph is turned Off by default (to avoid performance penalties on fast measurements) and can be enabled via the settings menu: “Settings->Measurement->ADEV Graph->On” (see Fig. 7.18)

The data are displayed on the graph in logarithmic horizontal and vertical axes. The vertical axis represents ADEV values and horizontal values - observation intervals (τ). The graph is constantly updated during measurement.

ADEV values for most typical observation intervals (only powers of ten), are displayed under the graph. Touching that area (clicking with mouse pointer) will open a window with more detailed table of ADEV values (Fig. 7.19)



Fig. 7.19: ADEV(τ) detailed list

There is a possibility to save results to a file using “Save measurement” button. The file will be created in user partition and named as “<Date>_<Function>_ADEV.csv”, where <Date> is current date and <Function> is measurement function.

Allan Deviation can be calculated from Frequency data (measurement functions Frequency, Period Average) or phase data (measurement functions TIE, Time Interval, Time Interval Single, Dual Time Interval). Allan Deviation calculation only makes sense for zero dead time back-to-back measurements.

Tip

Please note that calculating Allan Deviation from measurement data which use linear regression techniques (i.e. Smart Frequency and Smart Period Average) is not possible. Attempts of applying ADEV formulas to the data obtained from “smart measurement” will NOT yield correct Allan Deviation.

7.10.1 Time Interval measurements and Allan Deviation

In case of measurement functions “Time Interval X,Y,Z,U” or Time Interval Single “X,Y,Z,U” (where X, Y, Z, U represent selected measurement inputs, for example A, B, D, E) the reference/etalon signal is to be connected to the input X, and DUTs (devices to tests, for example oscillators), are to be connected to Y,Z,U. Signals on all inputs must have same nominal frequency. Depending on exact model of the instrument, some of the inputs referred as X, Y, Z, U may be not available.

In case of Dual Time Interval X,Y,Z,U the reference/etalon signals are to be connected to inputs X and Z and DUTs - to Y and U. The signals on inputs X and Y must have same nominal frequency, and also signals on Z and U must have same nominal frequency. Dual Time Interval function is available only on instruments with 4 measurement channels.

This way, resulting Time Interval series are essentially absolute differential TIE (or phase error) of DUTs relative to the reference/etalon signal(s).

7.10.2 Down-converted signals and Allan Deviation

For the case when input signals are result of signal down-conversion (e.g. to bring high frequency signal to the acceptable range or to improve the Allan Deviation floor) it is convenient to use Math function (Settings -> Math/Limits) to account for down-conversion and get ADEV results for the original signal.

The Math function should be configured the following way (under Settings -> Math/Limits):

- Math Mode = $K * X + L$
- Coefficient L = 0
- Coefficient K depends on which measurement function is used:
 - $K = F_{\text{nom_orig}} / F_{\text{nom_downconverted}}$ for Frequency measurement function
 - $K = F_{\text{nom_downconverted}} / F_{\text{nom_orig}}$ for Time Interval, Time Interval Single, Dual Time Interval, Period Average,

where $F_{\text{nom_orig}}$ - nominal frequency of the signal before the down-conversion, $F_{\text{nom_downconverted}}$ - nominal frequency of the signal after the down-conversion.

For TIE measurement function, using Math in this case is not needed. Just set Settings -> TIE Reference Frequency to $F_{\text{nom_downconverted}}$.

For Math Modes other than $K * X + L$, Allan Deviation calculation is not performed.

7.11 Network configuration

The instrument supports wired 10/100/1000 Mbps connection as well as wireless (via external USB Wi-Fi adapter).

Additionally, Ethernet-over-USB connection is also supported, via back panel USB port (see below for details).

If network configuration of a blind panel instrument ((CNT-104B, CNT-102B)) is unknown, you can verify (and correct if needed) it by accessing the instrument via USB interface using web browser or VNC client.

The instrument has IPv4 support and can be configured in either Static or Dynamic (DHCP) mode. If Static mode is selected, user is expected to manually enter IP address, Network mask and Gateway. For Dynamic mode, these fields are read-only and display IP address, network mask and gateway that are currently in use.

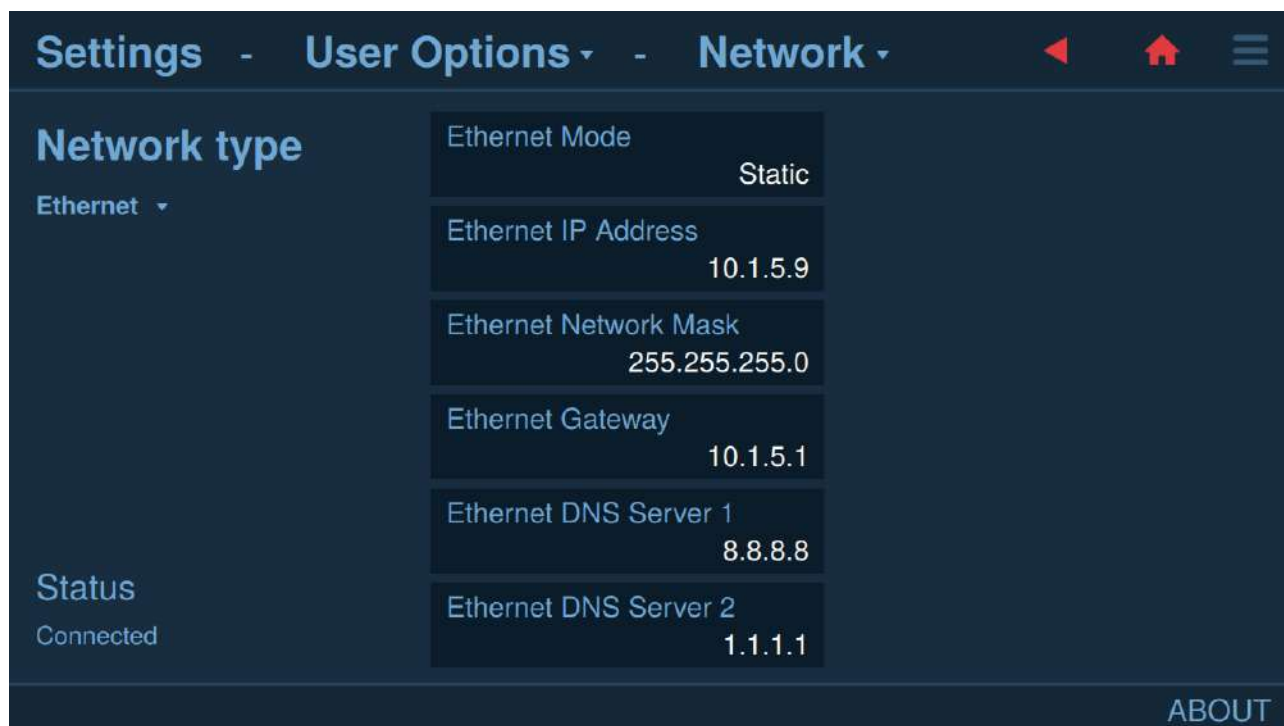


Fig. 7.20: Network configuration

One common task is the way to find the device on the network, when it has a dynamic address assigned. Several ways are possible:

- For devices that have a screen, you can look up currently assigned IP address on the *Settings* → *Network* page shown above. Please also ensure that the current status is shown as Connected, otherwise displayed information may be not up-to-date.
- All devices can be discovered on the network by their name. [See below](#)
- All devices support Ethernet-over-USB connection. In order to use it, please attach a USB cable to device's back panel and USB port on the PC. The PC will get a new virtual Ethernet controller installed. Access the device using **169.254.77.201** address, the same way as with physical Ethernet port. Please read [below](#) for details:

7.12 Network discovery

In order to establish a connection to a device that does not have a screen for checking its current IP address, network name discovery is essential. However, it can also be useful for devices equipped with a screen.

Network name discovery mechanism provides a way to translate device's own name into an IP address, for connecting to it via Ethernet (or wireless) interface.

Note that discovery does not work over USB. If you wish to connect via USB cable, use **169.254.77.201** address instead.

The discovery can be done using LLMNR and mDNS protocols, supported by many operating systems.

As a first step, find out your device's name. The name has the following format:

pendulum-<model>-<serial>

For example: **pendulum-cnt104s-123456**.

All letters are lower case. Model name includes only letters and digits, without hyphen (**cnt104s**, not **cnt-104s**). Device's serial number can be found on the rear panel or in Settings → About in the user interface.

You can then use this name directly (for VNC clients, web browsers, SCPI connections) or discover the IP address first and use the IP address. However, IP addresses are subject to change, whereas using the symbolic name is a more stable solution.

If you wish to discover the IP address, please run `ping -4 <name>[.local]` command, for instance `ping -4 pendulum-cnt104s-123456.local` or `ping -4 pendulum-cnt104s-123456` (the `.local` part is optional).

Other commands can also be used, but they are OS-dependent and we do not describe them in this manual. `ping` command is the most universal tool, present in all systems.

When you access the device from a web browser, compose an URL in this form: `http://pendulum-cnt104s-123456.local/` or just `http://pendulum-cnt104s-123456/` (adjust according to your device model and serial number). For the latter, **note the trailing slash**, it can be helpful to avoid running a web search instead of treating user input as a network host name.

Below you can see an example of using Firefox to access a CNT-104R device:

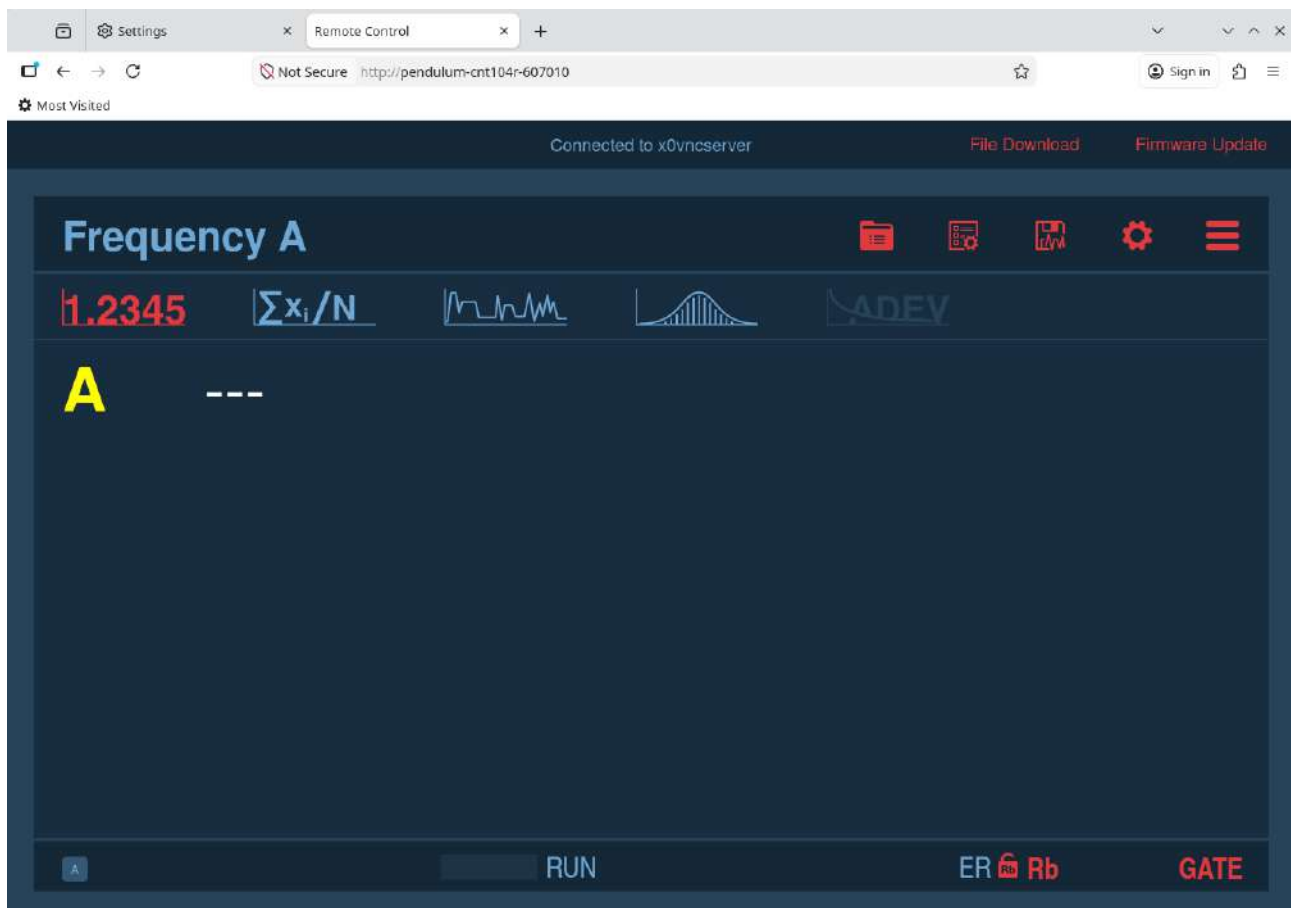


Fig. 7.21: Accessing a CNT-104R by hostname in Firefox

For SCPI connections this format of resource string can be used: `TCPIP::pendulum-cnt104s-123456::hislip0::INSTR`. Adjust this resource string for your instrument's model and serial number.

7.12.1 Using LXI Discovery Tool for network discovery

Alternatively, instead of checking device's rear panel for serial number and using `ping` command, one can also find all CNT-100 series Multi-Channel Frequency Analyzers and FTR-210R GNSS disciplined Frequency and Time References on the network that are currently online using software called **LXI Discovery Tool** (only for Windows).

In this tool it is important to enter Advanced View because the default is to use VXI-11 discovery algorithm that is not supported by our instruments. Enter Advanced View via Settings → Advanced View. Choose **_hislip._tcp** as **mDNS Service Type**.

Click Search button. After a few seconds you should see a table filled with IP addresses on the left and text descriptions on the right of all found units (and possibly other equipment as well).

In the example below a CNT-104S unit with IP address 192.168.22.12 and serial number 607016 and a CNT-104R unit with IP address 192.168.22.11 and serial number 607010 were found.

In this example LXI Discovery Tool version 1.10 was used.

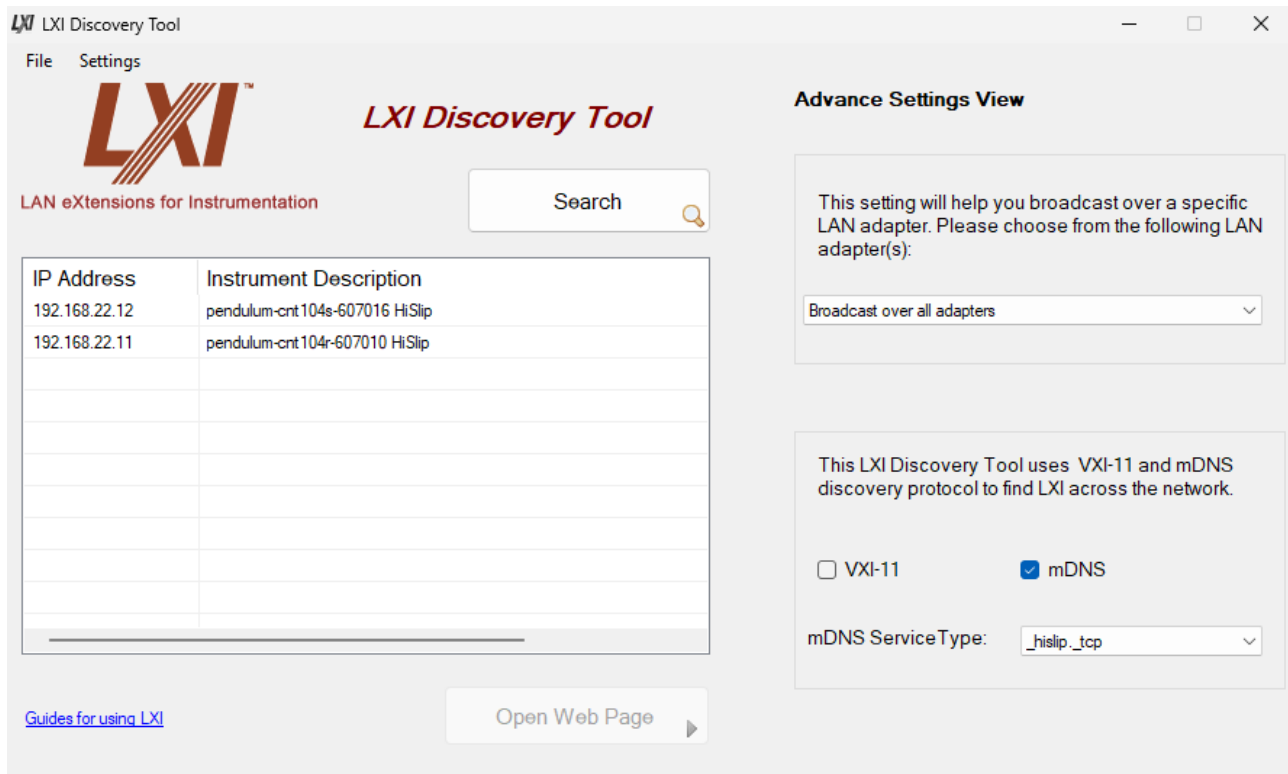


Fig. 7.22: Example of using LXI Discovery tool.

7.13 Back panel USB interface

Back panel USB interface can be used as a replacement for Ethernet.

When you connect the device to a PC with a USB cable, a virtual Ethernet adapter appears on the PC. The adapter uses RNDIS protocol for Ethernet-over-USB connection.

USB cable is not included in the package. Please use any standard-compliant USB 2.0 cable with type A and type B connectors.

This type of connection is supported in all major operating systems, including Windows and Linux distributions. In most cases no additional configuration is required. If you have a non-standard system configuration or otherwise require help with this type of connection, please contact our technical support.

The PC automatically gets a DHCP-assigned IP address from the device after a few seconds.

You can access the device at **169.254.77.201** with a browser, VNC client or VISA client (HiSlip connection).

Please note that communication with several devices over USB is not supported.

If you need to access several CNT-100 series Multi-Channel Frequency Analyzers or FTR-210R GNSS disciplined Frequency and Time References, prefer pure Ethernet connections for them.

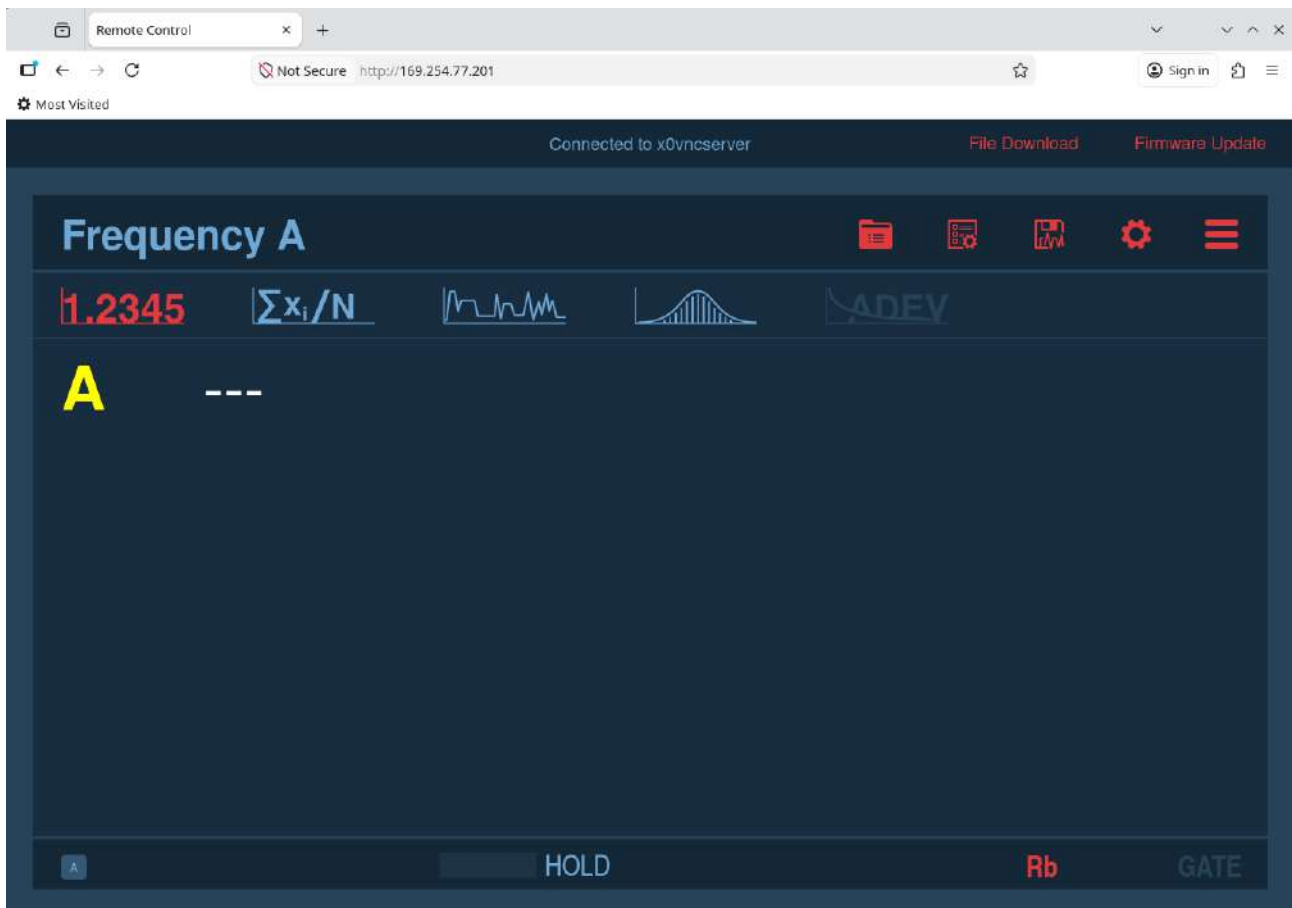


Fig. 7.23: Accessing the device from Firefox using USB interface

7.13.1 Web Interface

The instrument has built in web server that provides Web Interface allowing to see the instrument screen and control it remotely, download files and upgrade firmware.



Fig. 7.24: Web Interface

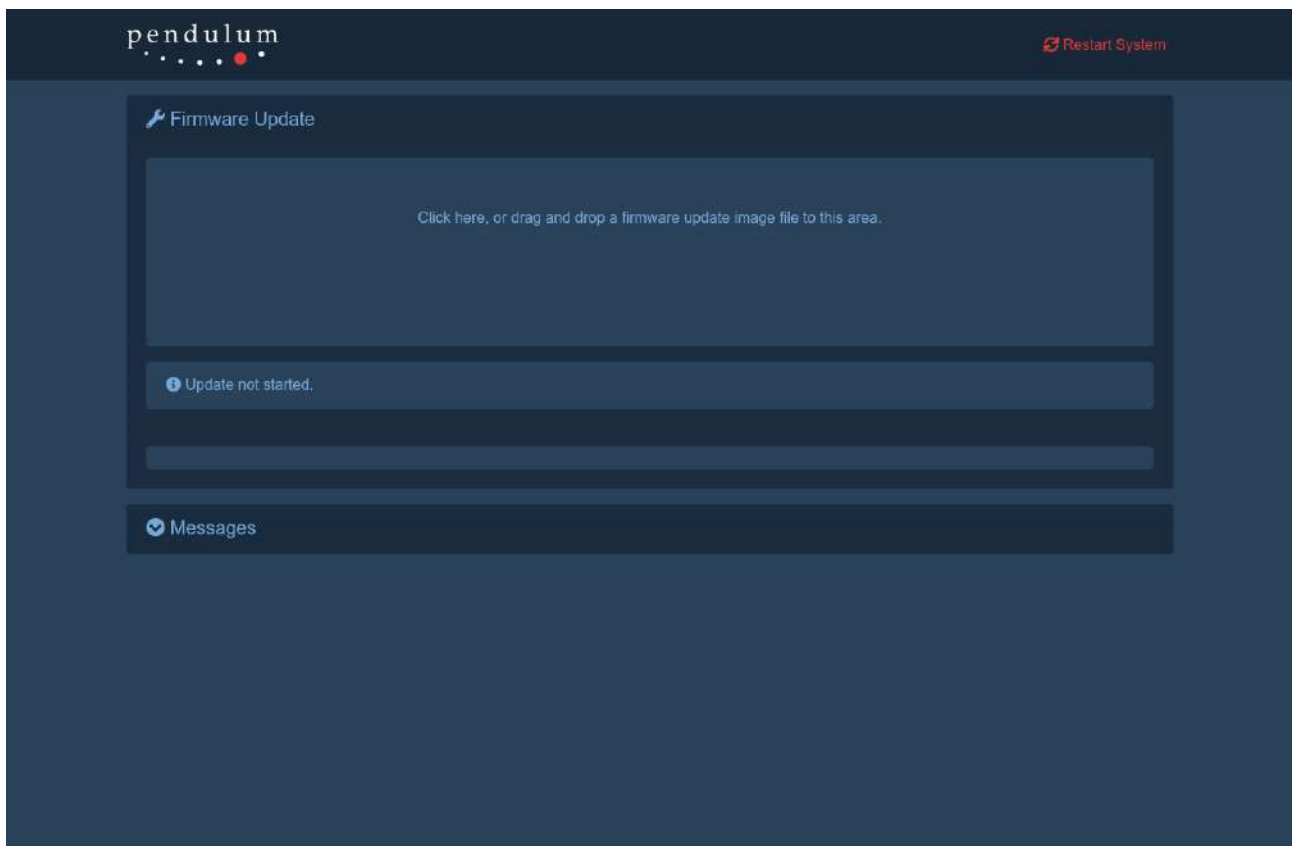


Fig. 7.25: Firmware Update page of the Web Interface

Directory listing for /

- [2023-01-25_14-04-08_Time_Interval_A B D E_A-B.csv](#)
- [2023-01-25_14-04-08_Time_Interval_A B D E_A-D.csv](#)
- [2023-01-25_14-04-08_Time_Interval_A B D E_A-E.csv](#)
- [2023-01-25_14-04-08_Vn-p_A B D E_A.csv](#)
- [2023-01-25_14-04-08_Vn-p_A B D E_B.csv](#)
- [2023-01-25_14-04-08_Vn-p_A B D E_D.csv](#)
- [2023-01-25_14-04-08_Vn-p_A B D E_E.csv](#)
- [lost+found/](#)

Fig. 7.26: File Download page of the Web Interface

7.13.2 VNC

The instrument also exposes VNC server on port 5901 which allows remote access and control. One can use any VNC client software on PC, mobile phone or tablet.

7.14 GPIB (IEEE 488.2)

When Option 26 is present GPIB address can be configured in Settings → User Options → GPIB section.

Connect the device to a bus controller via GPIB port on the back panel. Please pay attention to *possible cables overlapping*. The device should now be accessible by the controller. The chosen address must not coincide with addresses of other devices on the bus.

7.15 Front USB ports

Front panel USB ports can be used for connecting:

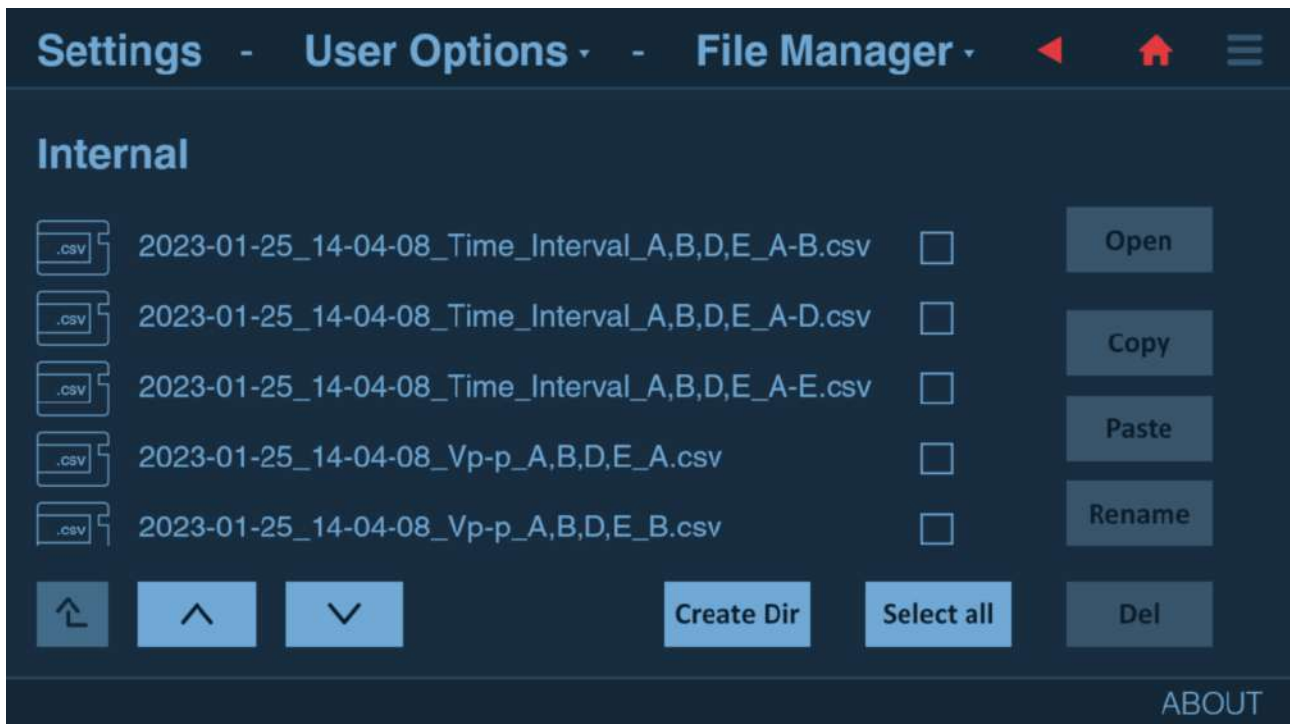
- Peripherals (PC keyboard and mouse) which complement the touch screen interface.
- USB storage for saving measurement results, presets or upgrading firmware.
- Wi-Fi adapter for enabling wireless networking. Please check the datasheet for the list of supported dongles that were tested for compatibility. Other models may be missing a driver and not work out-of-the-box.

Note

Only FAT32 and exFAT filesystems are supported for USB sticks. NTFS is not supported.

7.16 File Manager

The instrument has built-in File Manager accessible via Settings → User Options → File Manager or dedicated icon on measurement screen.



7.17 Firmware Update

There are 2 ways of updating firmware of the instrument:

Update via Web Interface (preferred):

- Download SW update file (it has .swu extension) to your PC
- Connect the instrument to LAN: either via Ethernet cable or use supported Wi-Fi dongle to connect via Wi-Fi
- On the instrument open Settings → User Options → Network to check or set current IP address
- On PC open web browser and type the instrument address to address field. The instrument's Web Interface will open
- Click Software Update link on top right and follow the instructions

Update via USB stick:

Note

Only FAT32 and exFAT filesystems are supported for USB sticks. NTFS is not supported.

- Copy SW update file to the USB stick. The file has .swu extension
- Insert the USB stick to one of the instrument's front panel USB ports
- Navigate to Settings → User Options → Firmware Update
- On Firmware Update screen tap/click on SW update file. SW update will start. No progress indication will be displayed – wait until the instrument reboots

7.18 Installing license

Note

Only FAT32 and exFAT filesystems are supported for USB sticks. NTFS is not supported.

- Put License File on USB stick
- Insert the USB stick to one of the instrument's front panel USB ports
- Navigate to Settings → User Options → Import License
- Select License to be imported. After confirmation the user interface will-reload to activate the new license.

Chapter 8

Measurement Uncertainties

8.1 General

The uncertainty of a measurement is defined according to GUM, "Guide to the Expression of Uncertainty in Measurement", an international standard that provides rules for evaluating and expressing measurement uncertainty. GUM is supported by several international organizations, like BIPM, ISO and IEC.

Key principles include characterizing the uncertainty factors in Type A or B

Type A: Evaluation of uncertainty by statistical analysis of a series of observations, e.g. repeatability, resolution, noise factors.

Type B: Evaluation of uncertainty by means other than statistical analysis, e.g. with the use of estimates from previous measurements, specifications from the manufacturer, calibration certificates etc.

Although not strictly identical, we will use the terms Random and Systematic Uncertainty for type A and type B

- Random uncertainties that can be reduced by averaging - u_{rnd}
- Systematic uncertainties that can NOT be reduced by averaging - u_{syst}

The uncertainties in each type shall be expressed as a "Standard uncertainty", typically the standard deviation, or "1- σ " rms uncertainty.

Assuming that all contributing uncertainty factors are independent of each other and not correlated, the combined uncertainty u_c (1- σ) is:

$$u_c = \sqrt{u_{rnd}^2 + u_{syst}^2}$$

Assuming a normal (gaussian) distribution, this combined uncertainty has a confidence interval of 68%, meaning that the probability is 68% that the "true" measurement value fits in the uncertainty interval and 32% that it is outside.

8.2 Expanded Uncertainty (All functions)

In normal metrology practice, you want to have a higher confidence interval of typically. 95% (σ), which calls for an Expanded Uncertainty U_{95} with a coverage factor (k) of 2.

$$U_{95} = 2 * u_c = 2 * \sqrt{U_{rnd}^2 + U_{syst}^2}$$

For even higher demands, a coverage factor $k=3$ can be used, giving a confidence interval of 99.7% for a normal distribution.

8.3 Random Uncertainties (1- σ)

8.3.1 Quantization Error (E_q)

Caused by the digital measurement kernel

For base CNT-102, CNT-102B, CNT-104B, FTR-210R:

$$E_q = 14 \text{ ps rms (per timestamp)}$$

For CNT-104S, CNT-104R, or instruments with Option 121 or 121F:

$$E_q = 7 \text{ ps rms (per timestamp)}$$

8.3.2 Start/Stop Trigger Error (E_{ss})

Caused by noise/jitter in the analog input and/or the Device under test. It can be expressed as either:

$$E_{noise} = \frac{\sqrt{V_{input-noise}^2 + V_{signal-noise}^2}}{\left| \frac{dV}{dT} \right|_{trg}} (s)$$

for non-pulse signals (e.g. sine), or:

Or:

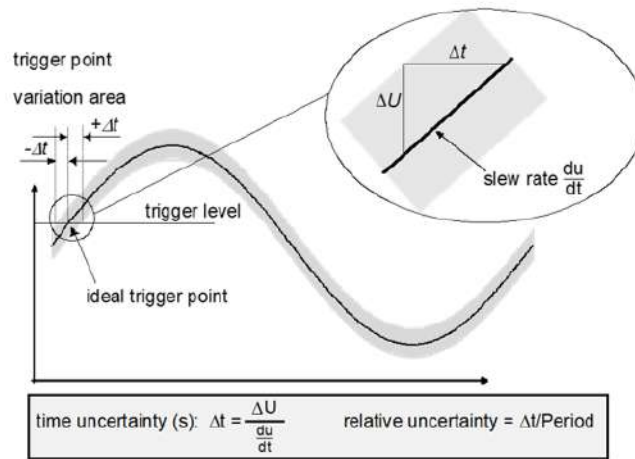
$$E_{noise} = \sqrt{\frac{V_{input-noise}^2}{\left| \frac{dV}{dT} \right|_{trg}} + E_{jitter}^2} (s)$$

for pulse signals.

Where

- E_{jitter} - signal period jitter (rms) in seconds of the test object. It is a property of the signal being measured.
- $V_{input-noise}$ - the internal noise voltage of the instrument's input: 500 uVrms (typ.).
- $V_{signal-noise}$ - the rms noise voltage of the signal being measured ($\frac{V_{rms}}{SNR}$).
- $\left| \frac{dV}{dT} \right|_{trg}$ - input signal slew rate at trigger level (V/s); The trigger level is either specified by the user in the settings (when using Absolute or Relative trigger modes) or selected by the instrument automatically (when using Automatic trigger mode).

Noise uncertainty



8.4 Systematic Uncertainties ($1-\sigma$)

8.4.1 Timebase Error (TBE)

TBE is the relative frequency error of the timebase oscillator (dimensionless) and depends on the actual oscillator used. Please, see Timebase section in the datasheet for estimating TBE of internal oscillator, or specification of particular clock reference if External Reference is used.

8.4.2 Trigger Level Timing Error (E_{tl})

Caused by uncertainty in the set trigger levels

Relevant for Rise/Fall Time, Pulse Width, Slew rate, Time Interval, Time offset (*attenuator setting x1*).

$$E_{tl} = \sqrt{E_{tl-start}^2 + E_{tl-stop}^2}$$

where

$$E_{tl-start} = \left(TLU_{start} + \frac{Hyst}{2} \right) \cdot \frac{1}{S_x}$$

$$E_{tl-stop} = \left(TLU_{stop} + \frac{Hyst}{2} \right) \cdot \frac{1}{S_y}$$

where

- S_x - slew rate at start trigger point (V/s)
- S_y - slew rate at stop trigger point (V/s)
- TLU - Trigger Level Uncertainty (V). $TLU = 0.015 + 0.01 \cdot TriggerLevel$ (V)
- Hyst - residual hysteresis window (V). $Hyst = 10 \text{ mV}$

8.4.3 Channel-to-channel skew (E_{ch-ch})

Maximum residual channel-to-channel skew after internal calibration

$$E_{ch-ch} = 44 \text{ ps}$$

8.5 Time Interval, Time Offset, Pulse Width, Rise/Fall Time

8.5.1 Random Uncertainty (rms)

$$u_{rnd} = \sqrt{2 \cdot E_q^2 + E_{ss}^2} \text{ (s)}$$

8.5.2 Systematic Uncertainty

$$u_{syst} = \sqrt{\frac{1}{3} \cdot (E_{tl}^2 + E_{ch-ch}^2 + (TBE \cdot MeasuredValue)^2)} \text{ (s)}$$

8.6 Frequency, Period, TIE

8.6.1 Random Uncertainty (rms)

Normal Frequency, Period or TIE Mode

$$u_{rnd} = \frac{\sqrt{2 \cdot (E_q^2 + E_{ss}^2)}}{T_E} \cdot MeasuredValue \text{ (Hz or s)}$$

Smart Frequency, or Smart Period

$$u_{rnd-smart} = \frac{2.5 \cdot u_{rnd}}{\sqrt{N}} \text{ (Hz or s)}$$

where

T_E - effective sample interval, determined as maximum of Sample Interval configured in instrument settings, and nominal period of measured signal.

$N = 1000$ (fixed number of sub-gates for Smart mode).

8.6.2 Systematic Uncertainty (1- σ)

Both Normal and Smart modes

$$u_{syst} = \frac{TBE \cdot MeasuredValue}{\sqrt{3}} \text{ (Hz or s)}$$

8.7 Note about uncertainties in regard to phase comparison of 1 PPS signals

Assuming well-shaped input pulse signals with fast rise times – trigger errors become negligible.

If the phases of 1 PPS signals being compared are close to each other – TBE becomes negligible for Time Interval/Time Offset measurement.

In such case uncertainty formulas can be simplified in the following way.

8.7.1 Time Interval between 2 x 1 PPS signals or Time Offset

For base CNT-102, CNT-102B, CNT-104B, FTR-210R:

$$u_{rnd} \approx 19.8 \text{ ps}$$

For CNT-104S, CNT-104R, or instruments with Option 121 or 121F:

$$u_{rnd} \approx 9.9 \text{ ps}$$

$$u_{syst} = \frac{E_{ch-ch}}{\sqrt{3}} \approx 25 \text{ ps}$$

Chapter 9

Performance Check

9.1 General Information

Warning

Before turning on the instrument, ensure that it has been installed in accordance with the Installation Instructions outlined in Chapter 1 of the User's Manual.

This performance procedure is intended for:

- Getting confidence that the instrument's specifications are met.
- Incoming inspection to determine the acceptability of newly purchased instruments and recently calibrated instruments.
- Checking the necessity of recalibration after the specified calibration intervals.

It should not be used directly as a ready procedure for accredited calibrations.

Note

- The procedure does not check every facet of the instrument's calibration; rather, it is concerned primarily with those parts of the instrument which are essential for determining the function of the instrument.
- When a test specifies particular external signal parameters - these are parameters at the instrument measurement inputs. Hence, particular signal source settings should consider factors like particular generators systematic uncertainties, cable attenuations, etc.
- Tolerances (where specified) assume ideal test signal. It is up to operator to calculate full total uncertainty depending on actual setup and particular equipment used.
- When tolerances are not specified, expected value should be treated as approximate. The guidelines are:
 - For Nominal values, e.g. Input impedance, assume a tolerance of 10%
 - For Typical values, e.g. AC Voltage uncertainty, assume a tolerance of 20%
- The procedure below is based upon a common frequency reference being used for all equipment in the setup, except for the reference oscillator test.

It is not necessary to remove the instrument cover to perform this procedure.

9.2 Preparations

Power up your instrument at least 30 minutes before checking to let it reach normal operating temperature. Failure to do so may result in certain test steps not meeting equipment specifications.

9.3 Test Equipment

Table 9.1: Recommended equipment for calibration and performance check.

Type of Equipment	Required Specifications
Reference Oscillator	• 10 MHz, 1×10^{-8} (e.g. 6688) for calibrating the standard TCXO oscillator • 10 MHz, 1×10^{-9} (e.g. 6689) for calibrating Option 30 and Option 40 (OCXO) • 10 MHz, 1×10^{-11} (e.g. FTR-210R GNSS disciplined Frequency & Time Reference) for calibrating CNT-104R
Voltage Calibrator	DC -50 V to +50 V (e.g. Fluke 5530A) for calibrating the built-in voltage reference, alternatively corresponding DC power supply + DVM with uncertainty <0.1 %
LF Synthesizer	Square/ Sine up to 10 MHz, 10 V _{RMS}
Pulse Generator	2 ns rise time, 5 V peak, >10 MHz, continuous & one-shot trigger
Oscilloscope	1 GHz, <3% voltage uncertainty
RF Signal Generator	0.1 to 3, 10, 15, 20, or 24 GHz dep. on RF input, <1dBm level uncertainty, 10 MHz ext.ref.
Power Splitter	50 Ω 6dB BNC
T-piece	BNC
Termination	50 Ω feed through BNC
Low-pass Filter	50 kHz (for 1 M Ω load)
BNC Cables	Approx. 10 pcs of suitable lengths

9.4 Internal Self-Tests

Internal self-tests are run on every instrument power up. In case of a failure information message box appears describing the type of the error.

Note

The full self-test procedure is not run when the instrument is turned on after being in stand-by (via stand-by button on the front) to allow for fast booting. You need to unplug the power cord and then plug it back to force self-tests to run.

The self-testing procedure includes:

- Measurement memory tests,
- Analog input circuits tests,
- Trigger level control test,
- Timestamping resolution quick test,
- Selected measurement modes tests,

- Software licenses integrity check,
- Non-volatile storage configuration check,
- RTC battery check.

Self-tests completed (Y/N)	Error messages (Y/N)	Pass/Fail

9.5 Front Panel Controls

Note

This test is not relevant for (CNT-104B, CNT-102B)

Procedure:

- Press SETTINGS icon  on top right.
- Select User Options → RecallDefaults. Confirmation dialog will appear.
- Press Yes.
- Press BACK hard button . Main Settings screen will appear.
- Press Advanced, then press Signal Source and select Test.
- Press ABOUT in bottom right corner. About box will appear.
- Press OK.
- Press HOME hard button . Measurement screen will appear. Frequency around 1 MHz will be measured.
- Press RUN/HOLD hard button . Measurement will be put in SINGLE and then to HOLD after current one finishes.
- Press RESTART hard button . Instrument will perform single measurement.
- Press Measurement Function name in top left corner. Function selection dialog will appear.
- Select Period → Period Single → A, B.
- Press OK. Measurement screen will appear.
- Press AUTOSET hard button . Autoset progress dialog will appear followed by “Autoset finished” notification.

Table 9.2: Front Panel Controls checklist

Control	Pass/Fail
Touch panel	
Hard keys	
 AUTOSET	
 RUN/HOLD	
 RESTART	
 HOME	
 BACK	

9.6 Measuring Functions

Note

Particular measurement function availability depends on particular model and licenses combination.

Procedure:

- Select Settings → User Options → Recall Defaults. Confirm by pressing YES.
- Select Settings → Advanced → Signal Source = Test
- Select Settings → Measurement → Sample Interval = 200 ms, Sample Count = 10
- Select Settings → Inputs → A → Coupling = DC, Impedance = 50 Ω, Trigger Mode = Auto
- Press BACK , press Copy next to A and then press Fill All to copy settings to other inputs.
- Go through Measurement Functions from the table below and verify the results.

Note

The results in the table are rounded off and very approximate. The test signal is not synchronized to instrument timebase and can generate Frequencies far from nominal.

Table 9.3: Measurement functions verification

Measurement Function	Display	Pass/Fail
Frequency A,B, {D,E}	1 MHz ± 100 kHz	
Smart Frequency A,B,{D,E}	1 MHz ± 100 kHz	
Frequency Ratio A,B,{D,E}	1 ± 0.01	
Frequency Diff. A,B,{D,E}	0 Hz ± 0.01 Hz	
Period Average A,B,{D,E}	1 us ± 100 ns	
Smart Period Avg A,B,{D,E}	1 us ± 100 ns	
Period Single A,B ({D,E})	1 us ± 100 ns	
Time Interval A,B,{D,E}	0 s ± 100 ps	
TI Single A,B,{D,E}	0 s ± 100 ps	
Accumulated TI A,B,{D,E}	0 s ± 100 ps	
Phase A,B ({D,E})	0° (360°) ± 1°	
Acc. Phase A,B ({D,E})	0° (360°) ± 1°	
TIE (requires license)	0 s ± 1 ms	
Pos. Duty Cycle A (B,{D,E})	0.5 ± 0.1	
Neg. Duty Cycle A (B,{D,E})	0.5 ± 0.1	
Pos. Pulse Width A,B ({D,E})	500 ns ± 50 ns	
Neg. Pulse Width A,B ({D,E})	500 ns ± 50 ns	
Totalize A,B,{D,E}	increments	
Totalize X+Y A,B,D,E	increments	
Totalize X-Y A,B,{D,E}	0 ± 1	
Totalize X/Y A,B,{D,E}	1 ± 0.1	

9.7 Timebase Oscillator Specification Test

X- tal oscillators are affected by a number of external conditions like ambient temperature and supply voltage. Aging is also an important factor. Therefore, it is hard to give limits for the allowed frequency deviation. The user himself must decide the limits depending on his application and recalibrate the oscillator accordingly.

To check the accuracy of the oscillator you must have a calibrated reference signal that is at least five times more stable than the oscillator that you are testing. See [Table 9.4](#) for acceptance criteria and [Table 9.1](#) for the list of test equipment.

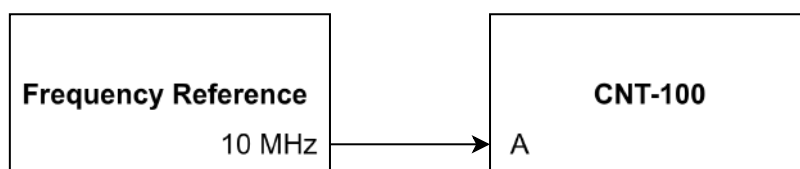


Fig. 9.1: Timebase Oscillator Test Setup

Procedure:

- Connect the frequency reference to input A.
- Select Settings → User Options → Recall Defaults. Confirm by pressing YES.
- Select Settings → Measurement → Sample Interval = 1 s, Sample Count = 100
- Select Settings → Inputs → A → Impedance = 50 Ω
- Press HOME 
- Press $\Sigma x_i/N$ to open measurement statistics view
- Check the Mean Value readout against the accuracy requirements of your application.

Table 9.4 can serve as an acceptance test and gives a worst case figure after 30 minutes warm-up time. All deviations that can occur in a year are added together.

Note

The following figures assume temperature range 20 to 26°C and 95% confidence interval (2-σ)

Table 9.4: Acceptance test for oscillators

Oscillator	Frequency Readout	Suitable Reference	Pass/Fail
Standard (TCXO)	10.00000000 MHz ± 20 Hz	6688	
Option 30 (OCXO)	10.00000000 MHz ± 1 Hz	6689	
Option 40 (OCXO)	10.00000000 MHz ± 0.25 Hz	6689	
Rubidium (CNT-104R)	10.00000000 MHz ± 0.02 Hz	FTR-210R, GNSS disciplined	

9.8 Sensitivity and Frequency Range for 400 MHz measurement inputs

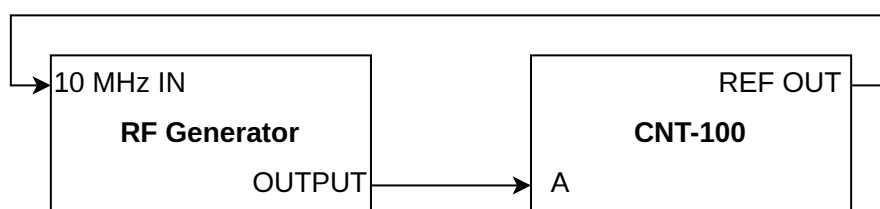


Fig. 9.2: Sensitivity and Frequency Range for 400 MHz measurement inputs test setup

Procedure:

- Select Settings → User Options → Recall Defaults. Confirm by pressing YES.
- Select Settings → Measurement → Sample Interval = 10 ms, Sample Count = 100
- Select Settings → Inputs → A → Impedance = 50 Ω, Trigger Mode = Manual, Preamplifier=On
- Connect a signal from the RF generator to a BNC power splitter.

- Connect the power splitter to Input A of the counter and to an oscilloscope. Set the input impedance to 50 Ω on the oscilloscope.
- Adjust the amplitude according to the following table, using amplitude readout on the oscilloscope.
- Check the Mean Value readout against the limit requirements in the table.

Repeat the measurements and input settings above for inputs B, D, E (on CNT-104S, CNT-104R, CNT-104B) or B (on CNT-102, CNT-102B)

Table 9.5: Input A

Frequency (MHz)	Level (mVrms)	Level (dBm)	Minimum value (MHz)	Measured mean value	Maximum value (MHz)	Pass/Fail
10	15	-23	9.999 999		10.000 001	
50	15	-23	49.999 995		50.000 005	
100	25	-19	99.999 990		100.000 010	
200	35	-16	199.999 980		200.000 020	
300	35	-16	299.999 970		300.000 030	
400	50	-13	399.999 960		400.000 040	

Table 9.6: Input B

Frequency (MHz)	Level (mVrms)	Level (dBm)	Minimum value (MHz)	Measured mean value	Maximum value (MHz)	Pass/Fail
10	15	-23	9.999 999		10.000 001	
50	15	-23	49.999 995		50.000 005	
100	25	-19	99.999 990		100.000 010	
200	35	-16	199.999 980		200.000 020	
300	35	-16	299.999 970		300.000 030	
400	50	-13	399.999 960		400.000 040	

Table 9.7: Input D

Frequency (MHz)	Level (mVrms)	Level (dBm)	Minimum value (MHz)	Measured mean value	Maximum value (MHz)	Pass/Fail
10	15	-23	9.999 999		10.000 001	
50	15	-23	49.999 995		50.000 005	
100	25	-19	99.999 990		100.000 010	
200	35	-16	199.999 980		200.000 020	
300	35	-16	299.999 970		300.000 030	
400	50	-13	399.999 960		400.000 040	

Table 9.8: Input E

Frequency (MHz)	Level (mVrms)	Level (dBm)	Minimum value (MHz)	Measured mean value	Maximum value (MHz)	Pass/Fail
10	15	-23	9.999 999		10.000 001	
50	15	-23	49.999 995		50.000 005	
100	25	-19	99.999 990		100.000 010	
200	35	-16	199.999 980		200.000 020	
300	35	-16	299.999 970		300.000 030	
400	50	-13	399.999 960		400.000 040	

9.9 Sensitivity and Frequency Range for RF Input (Input C)

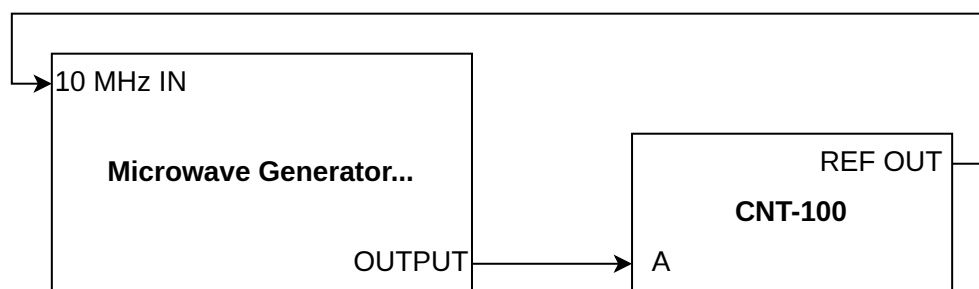


Fig. 9.3: Sensitivity and Frequency Range for RF Input test setup

Procedure:

- Connect the output of the Microwave to input C of the counter.
- Select Settings → User Options → Recall Defaults. Confirm by pressing YES.
- Select Settings → Measurement → Function = Frequency C, Sample Interval = 10 ms, Sample Count = 100
- Adjust the level of the generator, **taking into account the attenuation of the cable** used, preferably by verifying the level at the cable end with a precision power meter.
- Generate a sine wave in accordance with the data in the relevant table (Table 9.9, Table 9.10).
- Check the Mean Value readout against the limit requirements in the table.

Table 9.9: RF input sensitivity, Option 10 (3 GHz)

Frequency (GHz)	Level (dBm)	Minimum (GHz)	value	Measured value	mean	Maximum (GHz)	value	Pass/Fail
0.1	-21	0.099 999 99				0.100 000 01		
0.3	-27	0.299 999 97				0.300 000 03		
2.5	-21	2.499 999 75				2.500 000 25		
2.7	-15	2.699 999 73				2.700 000 27		
3.0	-15	2.999 999 70				3.000 000 3		

Table 9.10: RF input sensitivity, Option 110 (10, 15, 20 or 24 GHz)

Frequency (GHz)	Level (dBm)	Minimum (GHz)	value	Measured value	mean	Maximum (GHz)	value	Pass/Fail
0.4	-21	0.399 999 96				0.400 000 04		
10.0	-27	9.999 999 0				10.000 001 0		
15.0	-27	14.999 998 5				15.000 001 5		
20.0	-17	19.999 998 0				20.000 002 0		
24.0	-11	23.999 997 0				24.000 002 4		

9.10 Resolution Test

Note

This test can't be done on FTR-210R

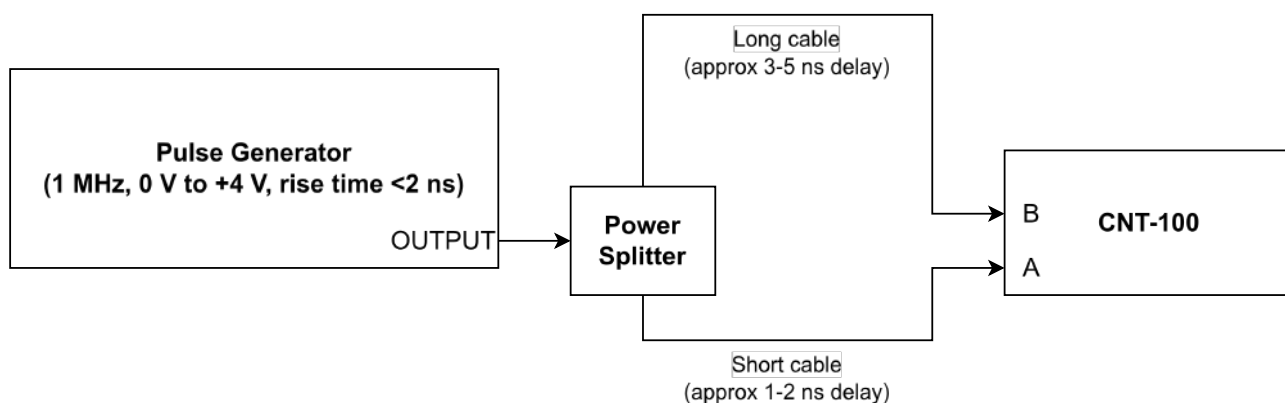


Fig. 9.4: Sensitivity and Frequency Range for RF Input test setup

Procedure:

- Connect the pulse generator to a power splitter.
- Connect one side of the power splitter to Input A on the instrument using a short coaxial cable (< 0.4 m).
- Connect the other side of the power splitter to Input B on the instrument using a longer coaxial cable (0.5 to 1 m).
- Configure the pulse generator:
 - Set Amplitude = 4 V_{pp}, (high level +4 V and low level 0 V), Frequency = 1 MHz,
 - Pulse Width = 500 ns,
 - Rise Time = 2 ns
- Configure the instrument:
 - Select Settings → User Options → Recall Defaults. Confirm by pressing YES.
 - Select Settings → Measurement → Function = TI Single A, B, Sample Interval = 0 s, Sample Count = 10000,
 - Select Settings → Inputs → A → Impedance = 50 Ω, Coupling = DC, Trigger Mode = Manual, Absolute Trigger Level A = +2 V,
 - Press BACK ◀,
 - Press Copy next to input A, then Fill All,
 - Press HOME 🏠 to return to measurement screen.
- Press $\Sigma x_i/N$ to open Statistics View.
- Press HOLD RUN
HOLD and wait while the instrument displays HOLD in the status bar.
- Note the standard deviation value (std)

Table 9.11: Resolution test results

Instrument model	Measured Standard De- viation	Maximum Standard De- viation	Pass/Fail
base CNT-102, CNT-102B, CNT-104B		20 ps	
CNT-104S, CNT-104R, or instruments with Option 121		10 ps	

9.11 Voltage

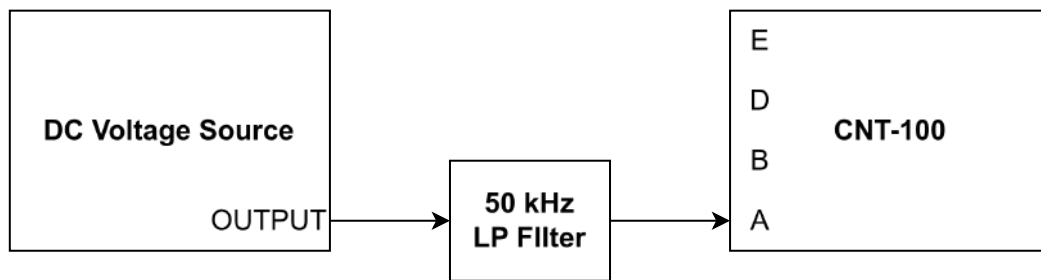


Fig. 9.5: Input A Voltage test setup

Procedure:

- Select Settings → User Options → Recall Defaults. Confirm by pressing YES.
- Select Settings → Measurement → Function = Vminmax A, Sample Count = 10,
- Select Settings → Inputs → A → Coupling = DC. Do not apply an input signal to Input A yet.
- Press BACK ◀,
- Press Copy next to input A, then Fill All,
- The statistics display should now indicate mean values $V_{min} = 0 \pm 0.015 \text{ V}$ and $V_{max} = 0 \pm 0.015 \text{ V}$
- Adjust the current limit of the DC voltage source to $<200 \text{ mA}$.
- Connect $+2.5 \text{ V}_{DC}$ to Input A, using the external 50 kHz low-pass filter on the input.
- The display should now indicate mean values: $V_{min} = 2.500 \pm 0.040 \text{ V}$ and $V_{max} = 2.500 \pm 0.040 \text{ V}$.
- Repeat the measurement with inverted polarity (-2.500 V_{DC})
- Select Settings → Inputs → A → Impedance = $1 \text{ M}\Omega$, Attenuation = 10x.

Caution

Before the next step, make sure the input impedance is still $1 \text{ M}\Omega$. Applying more than 12 V without proper current limiting may cause extensive damage to the main PCB, if the impedance is set to 50Ω .

- Change the DC level to $+25.00 \text{ V}_{DC}$.
- The display should now indicate mean values: $V_{min} = 25.00 \pm 0.92 \text{ V}$ and $V_{max} = 25.00 \pm 0.92 \text{ V}$
- Repeat the measurement with inverted polarity (-25.00 V_{DC}).

Proceed by repeating the measurements for inputs B, D, E (on CNT-104S, CNT-104R, CNT-104B) or B (on CNT-102, CNT-102B), as described above for Input A.

Table 9.12: DC Voltage test results

Input Voltage	Level	Min	Max	A	B	D	E	Pass/Fail
Attenuation=1x, Impedance=1 M Ω , Coupling=DC								
Open input	$V_{\min}$	-15 mV	+15 mV					
Open input	$V_{\max}$	-15 mV	+15 mV					
+2.5 V _{DC}	$V_{\min}$	+2.46 V	+2.54 V					
+2.5 V _{DC}	$V_{\max}$	+2.46 V	+2.54 V					
-2.5 V _{DC}	$V_{\min}$	-2.54 V	-2.46 V					
-2.5 V _{DC}	$V_{\max}$	-2.54 V	-2.46 V					
Attenuation=10x, Impedance=1 M Ω								
Caution								
Before the next step, make sure the input impedance is still 1 M Ω . Applying more than 12 V without proper current limiting may cause extensive damage to the main PCB, if the impedance is set to 50 Ω .								
+25.0 V _{DC}	$V_{\min}$	+24.08 V	+25.92 V					
+25.0 V _{DC}	$V_{\max}$	+24.08 V	+25.92 V					
-25.0 V _{DC}	$V_{\min}$	-25.92 V	-24.08 V					
-25.0 V _{DC}	$V_{\max}$	-25.92 V	-24.08 V					

9.12 Rear Inputs/Outputs

9.12.1 REF OUT

Procedure:

- Connect an oscilloscope to the 10MHz output on the rear of the instrument. Use a coaxial cable and 50 Ω termination.
- The output voltage should be sinusoidal and $>1V_{p-p}$, typically $1V_{rms}$.

Table 9.13: Reference Output test results

Test	Minimum Value	Measured Mean Value	Maximum Value	Pass/Fail
REF OUT amplitude	0.9 V _{RMS}		1.1 V _{RMS}	

9.12.2 EXT REF IN

Note

Not available for FTR-210R GNSS disciplined Frequency & Time Reference

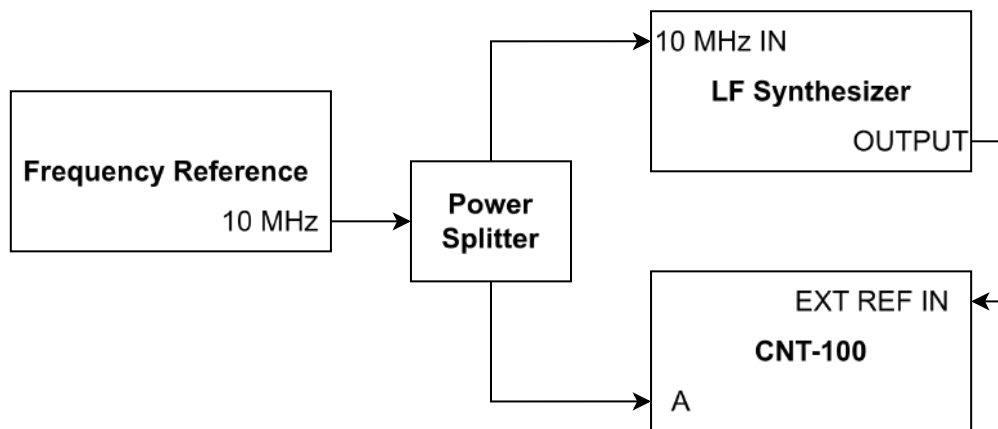


Fig. 9.6: External Reference Input test setup

Procedure:

- Select Settings → User Options → Recall Defaults. Confirm by pressing YES.
- Select Settings → Inputs → A → Impedance = 50 Ω.
- Make connections according to Fig. 9.6.
- Configure LF Synthesizer to generate 10 MHz, 200 mV_{RMS} (0.57 V_{p-p}) signal.
- Select Settings → Timebase → Timebase Reference = External.
- The instrument display should show 10 MHz.
- Change the external reference frequency to 5 and 1 MHz.
- The counting should continue, and the display should still show 10 MHz.

Table 9.14: External Reference test results

External frequency	reference	Fre-	Minimum Value	Mean Value measured by CNT-100	Maximum Value	Pass/Fail
10 MHz to EXT REF IN			N/A	should be 10 MHz	N/A	
5 MHz to EXT REF IN			N/A	should be 10 MHz	N/A	
1 MHz to EXT REF IN			N/A	should be 10 MHz	N/A	

9.12.3 EXT ARM IN

Note

Not available for FTR-210R GNSS disciplined Frequency & Time Reference

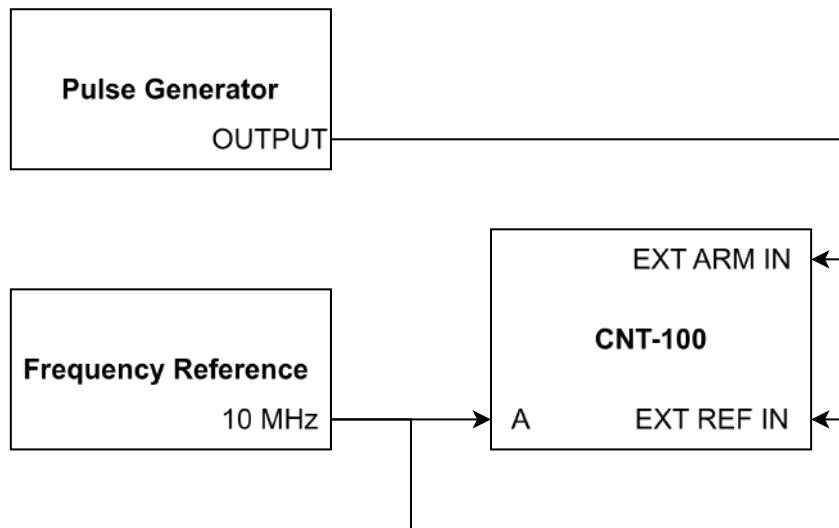


Fig. 9.7: External Arming Input test setup

Procedure:

- Select Settings → User Options → Recall Defaults. Confirm by pressing YES.
- Select Settings → Inputs → A → Impedance = 50 Ω.
- Make connections according to Fig. 9.7.
- Settings for the pulse generator:
 - Single shot pulse,
 - manual trigger,
 - amplitude TTL = 0 - 2 V_{p-p}, and
 - duration = 10 ns.
- Select Settings → Arming → Start Arming Source = EA. The instrument does not measure.
- Apply one single pulse to Ext Arm Input.
- The instrument measures once and shows 10 MHz ± 1 Hz on the display.

Table 9.15: External Arming test results

Test	Minimum Value	Mean Value measured by CNT-100	Maximum Value	Pass/Fail
Frequency A, start arming on Ext Arm In	9.999 999		10.000 001	

9.12.4 PULSE OUT

- Connect an oscilloscope to the pulse output on the rear panel with a 50 Ω coaxial cable terminated at the scope input with 50 Ω (internally or externally).
- Enter Settings → Pulse Output.
- Set Mode to Pulse Generator. Select Pulse Period and set the value to 1000 ns. Select Pulse Width and set the value to 500 ns.
- The output signal should be a pure square wave signal with 1 MHz frequency and 50 % duty cycle. The rise/fall time should be approximately 2.5 ns. The low and the high level should be <0.2 V resp. >2.4 V.
- Connect the Pulse output to input A (50 ohm) of the instrument and measure Frequency.

Table 9.16: Pulse Output test results

Parameter under test	Minimum Value	Measured Value	Mean	Maximum Value	Pass/Fail
PULSE OUT Low Level (as measured by an Oscilloscope)	N/A			+0.2 V	
PULSE OUT High Level (as measured by an Oscilloscope)	+2.4 V			N/A	
PULSE OUT Frequency (as measured by CNT-100)	0.999 999 MHz			1.000 001 MHz	

Chapter 10

Specifications

Up-to-date specifications for CNT-100 series Multi-Channel Frequency Analyzer are available on the Pendulum Instruments web site:

https://pendulum-instruments.com/wp-content/uploads/datasheets/Datasheet_CNT-100_series.pdf

Chapter 11

Sales and Service Contacts

For additional product information, customer support and service, please contact Pendulum Instruments at the following addresses:

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