CNT-104R

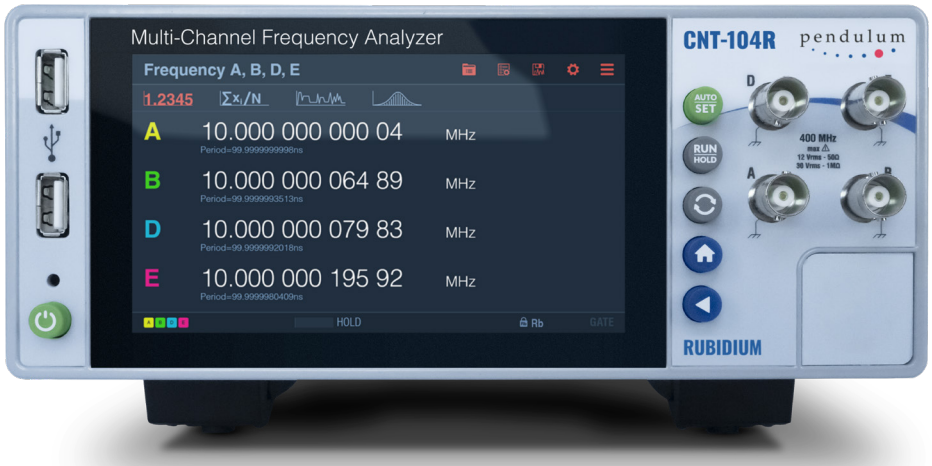
Multi-channel Rubidium Frequency Calibrator / Analyzer

pendulum

DATA SHEET

NEW PRODUCT

- **Combined 400 MHz Multi-channel Frequency Analyzer and 10 MHz Frequency Reference with integrated Rubidium oscillator**
- Ultra-stable 10 MHz **Frequency Reference**, using optional buit-in GNSS-control of the Rubidium oscillator
- Excellent one-box, ultra-accurate **Frequency Calibrator**
- **Time calibration** is accurate to 10 ns rms to UTC (with GNSS option)
- Test 1-4 DUTs in parallel
- Gap-free frequency measurements; 50ns to 1000s gate time
- Ultra-high resolution: Time: 7 ps; Freq.: 12-13 digits/s
- Graphic touch screen display for settings and display of values, statistics (numeric and distribution graph), trend & modulation domain
- The instrument can be controlled locally via touch screen or mouse, or remotely (from anywhere in the world) - via web interface or VNC
- Intelligent and easy-to-use



The Pendulum CNT-104R is a new concept for super-performance ***multi-channel frequency and time-interval calibration*** & analysis, in a bench-top unit. It is a one-box Frequency and Time Interval calibrator combining an ultra-stable 10 MHz Rubidium Frequency Reference with a 4-channel advanced Frequency Analyzer. You can calibrate up to 4 oscillators/clocks in parallel simultaneously on 4 input channels.

The optional ***GNSS control of the Rubidium clock*** eliminates the small ageing drift giving an unprecedented accuracy in a compact one-box solution. On the large graphic screen, you can watch drift over time and frequency distribution, as well as traditional numeric and statistics parameters. CNT-104R has gap-free measurements, <7 ps time resolution, 12-13 digits/s frequency resolution, and variable gate time setting from 50ns to 1000s.

Highest Performance for R&D and metrology

- The ultra-high resolution of 12 to 13 digits for 1s gate time gives faster and more accurate calibration results. Track and compare 4 parallel signals with 7 ps resolution/timestamp, at a settable rate from 1000s down to 50 ns between samples in each channel.
- Gap-free, zero-dead-time counting provides back-to-back measurements without losing any cycle, even for very long measurements.
- The CNT-104R is also a high-performance Modulation Domain Analyzer (MDA) for the advanced user. Thanks to the high speed of up to 20M meas./s for 4 parallel signals, very fast frequency or phase/time changes can be captured in real time.

Save money in production test

- The 4-channel design enables 4 parallel frequency measurements. One CNT-104R can replace 4 existing frequency counters in a test system at a lower cost/counter, ***plus*** provide an ultra-stable reference frequency to the test stand. 5 instruments-in-one-box.
- Choose between Ethernet, or WLAN as a communication interface to a PC/Laptop/Tablet, or to the test system controller.
- High bus speed reduces test time in ATE test systems. Perform fast block measurements up to 170k meas/s. Test time is reduced compared to existing solutions, and time is money.

Optional GNSS control for ultimate calibration performance

- Using the optional GNSS control, the 10 MHz frequency reference accuracy is 1E-12 averaged over 24h, day after day, forever. The intrinsic ageing of the Rubidium clock is totally eliminated.
- You can use the GNSS control either for continuous disciplining of the Rubidium timebase, or as a one-shot reset of the accumulated ageing drift, e.g. when you work mostly in a GNSS-denied environment.
- Calibrate 1-4 frequency sources in a short time to 11 digits uncertainty
- The GNSS receiver also provides an *internal Phase/Time Reference* with an outstanding accuracy
- Calibrate 1-3 external sync signals, with an uncertainty of 10 ns rms to UTC
- The portable format, short warm-up time, and the GNSS option, makes CNT-104R an excellent "Travelling clock" for field testing of sync clocks outside the normal lab.
- Calibration results can be saved in internal memory, on a USB stick, or on a connected PC

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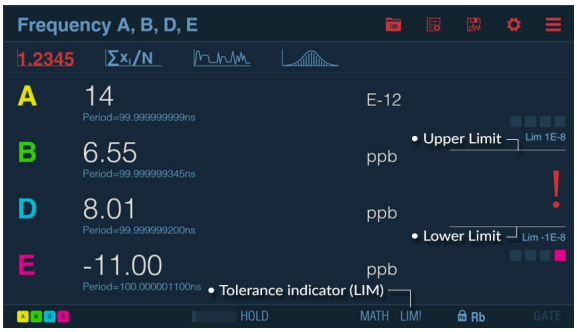
Easy-to-understand Graphical Presentation

One of the great features of the CNT-104R is the graphic display with its menu oriented settings. The non-expert can easily make correct settings, thanks to the guided instruction on most setting pages.

Valuable signal information, given in multi-parameter displays, removes the need for other instruments like DVM's and Scopes for quick signal verification.

Measured values are presented as both numerics and graphics. Graphical presentation of results (distribution, trends etc.) gives a better understanding of the nature of jitter. It also provides a much better view of changes vs time, e.g. drift. The same data set can be viewed in Numerical, Statistics, Distribution and Time-line views. It is very easy to capture and toggle between views of the same data set.

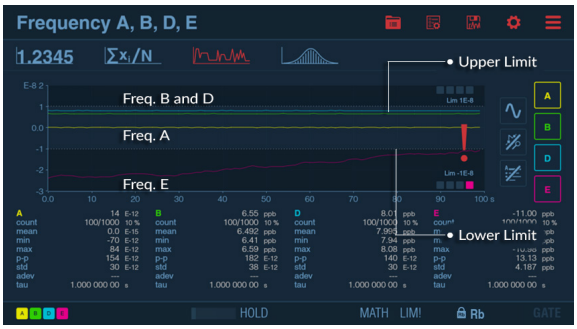


View 4 signals simultaneously on screen. 4 instruments in one!

Tolerance limits for calibration

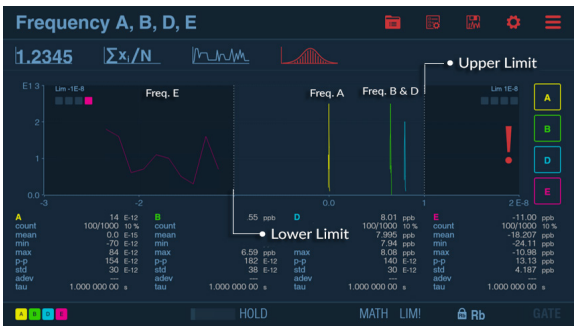
When selected, tolerance limits are displayed and give direct graphical feedback whether limits are exceeded (FAIL - a big exclamation mark) or not (PASS - no exclamation mark).

In the example below, three 10 MHz and one 5 MHz oscillators are tested in parallel, with tolerance limit ±0.1 Hz or $1x10^{-8}$. Oscillator A, B, D are inside limit range. Oscillator E is just outside range.



The time-line view reveals drift during the calibration

The limits can also be viewed in the frequency distribution display mode. The basic information is the same but this graph gives additional info.



The Frequency distribution view reveals the spread (stability) of the oscillators

CNT-104R as in-house reference

The CNT-104R comes as standard with one 10MHz reference output with ultimate frequency accuracy to $1x10^{-12}$, 24h average, using the optional integrated GNSS disciplining of the Rubidium clock. The addition of an FDA-301A Frequency Distribution Amplifier multiplies the number of outputs that can be distributed to 4, 8, or 12, depending on the number of rear-panel installed output modules (1, 2, or 3).

The FDA-301A distribution amplifier extends the number of 10 MHz outputs, up to 12

Full flexibility for remote control

The CNT-104R comes as standard with a Gbit Ethernet interface for remote control and data transfer.

Using an external WiFi dongle in the front panel USB port, enables you to connect CNT-104R to your local wireless network.

You can access and control the instrument from your lab bench, or from anywhere in the world, using the integrated web interface.

Outstanding ease-of-use

The big color touch screen with its intuitive menus lets you make your settings via a simple finger touch. Alternatively you can connect a wireless mouse to the front USB host port, and make your settings via mouse clicks on screen instead. Or you can use the web-server interface to control CNT-104R from a large PC-screen.

The intelligent AUTO SET will help you to make best settings for each measurement function.

You do not even need to be close to your instrument. The web server functionality lets you connect to the CNT-104R over Ethernet, view the front panel, and control the measurements and read and save results via a few mouse clicks.

You can pan and zoom in graphs to view individual samples with cursor read-outs. And any measured signal can be smoothed, to reveal underlying trends in the presence of excessive noise.

The CNT-104R combines an ultra-stable 10 MHz Frequency Reference, with an accurate, fast, advanced, yet easy-to-use Multi-channel Frequency Analyzer.

The super-high-performance CNT-104R is the optimal tool for accurate, fast, and easy Frequency and Phase/Time calibration.

Display modes

Values & Statistics

Numeric display of Measurement values or Statistics parameters. Values mode also display auxiliary parameters.

Time-line & Distribution

Multi-channel graphs are color-coded. Up to 4 input signal graphs can individually be hidden/displayed,

Measuring Functions

Resolution

Measure up to 4 input signals in parallel with down to 7 ps resolution per timestamp (Period single, Time Interval, Pulse width, Rise/Fall time, Duty cycle, TIE), or 12 digits/s (frequency and period average).

Smart Frequency/Period avg. calculation mode

All measurements are made ***gap-free*** (back-to-back). Statistics resolution enhancement algorithm (*smart mode*) gives up to one extra result digit depending on input signal and measurement setting.

Frequency A, B, D, E

Mode: ***Parallel measurements*** on up to 4 inputs.
Range: 0.001 Hz to 400 MHz
Aux. Parameter: Vmax, Vmin, Vp-p

Frequency C (option)

Range: See input C
Aux. Parameter: Period C

Frequency Ratio (A,B,C,D, or E) / (A,B,C,D, or E)

Mode: ***Parallel measurements*** on 2 or 4 inputs.
Range: (10^{-9}) to 10^{11}
Aux Parameters: Freq 1, Freq 2

Period A, B, C, D, E average

Mode: ***Parallel measurements*** on up to 4 inputs.
Range: See the inverse of Frequency specifications
Aux. Parameter:

- Ch. A, B, D, E: Vmax, Vmin, Vp-p
- Ch. C: Frequency C

TIE A, B, C, D, E (Option 151)

TIE = Time Interval Error, calculated as: *Accumulated period - Expected ("ideal") accumulated period*
Mode: ***Parallel measurements*** gap-free on 1 to 4 inputs.
Freq range: See Frequency specifications
Aux. Parameter: Ref Frequency

Period A, B, D or E single

Mode: ***Parallel measurements*** on 1 or 2 inputs
Range: 2.5 ns to 1000 sec.
Aux. Parameter (A, B): Vmax, Vmin, Vp-p

Time Interval A, B, D, E (single or continuous)

Mode: ***Parallel timestamping*** of trigger events on up to 4 channels on continuous or single-shot signals.
Start and stop channel(s): any of A, B, D, E
Note: each input can produce 1 or 2 trigger events with individual trigger level and slope
Accumulated Time Interval: add/subtract 1 start channel period to the Time Interval, when required)
Range: -1000s to +1000s
Repetition rate: up to 300 MHz or single-shot events
Min. Pulse width: 1.5 ns

Positive and Negative Pulse Width A, B, D, E

Mode: ***Parallel measurements*** on 1 or 2 inputs
Range: 1.5 ns to 1000 sec.
Repetition rate: up to 300 MHz or single-shot events

Rise/Fall Time A, B, D, E

Mode 1: ***Parallel measurements*** on 1 or 2 inputs of Rise OR Fall time, or
Mode 2: ***Single*** input measurement of Rise AND Fall time on the same pulse
Range: 1.5 ns to 1000 sec.
Aux. Parameters: Slew rate, Vmax, Vmin

Positive and negative Slew Rate A, B, D, E

Mode: ***Parallel measurements*** on 1 or 2 inputs
Calculation: (80% of Vp-p) / (Rise or Fall Time)
Aux. Parameters: Rise/Fall time, Vmax, Vmin

Positive and Negative Duty Cycle A, B, D, E

Mode: ***Single*** input meaurement; rep. rate <300 MHz
Range: 0.000001 to 0.999999
Aux. parameters: Period, Pulse width

Phase A Relative B, B Relative A

Mode: Intended for phase shift or delay measurements of two signals with identical frequency
Accumulated Phase: add/subtracting 360° to the Phase, when required.
Range: -180° to +180° (Acc. Phase is OFF)
Resolution: 0.00003° to 100 kHz, decreasing to 0.03° >100 MHz. (10k sample statistics averaging)
Freq. Range: up to 300 MHz
Aux. Parameters: Freq (A), Va/Vb (in dB)

Totalize A, B, D, E

Inputs: up to 4 inputs (A, B, D, E)
Mode: Tot A, B, D, E; A+B, D+E; A-B, D-E: A/B, D/E
Range: 1 to 10^{10} counts
Freq range: up to 400 MHz
Start control: Manual, start arming
Stop control: Manual, stop arming, timed

Vmax, Vmin, Vp-p A, B, D, E

Range: -5 V to +5 V, -50V to +50V
Freq. Range: DC, 1Hz to 200 MHz
Coupling: Sine (AC or DC), Square (DC only)
Resolution: 1 mV (5V range), 10 mV (50V range)
Uncertainty (5V range):

- DC, 1Hz to 1kHz: <1% +15 mV
- 1kHz to 20 MHz sine: 3% +15 mV (typ.)
- 20 to 100 MHz sine: 10% +15 mV (typ.)
- 100 to 200 MHz sine: 30% +15 mV (typ.)

(For square waves add 10% to Vmax,/min & 20% to Vp-p)
(For 50V range, add 2% + 150 mV)
Aux parameters: Vmin, Vmax, Vp-p

Input Specifications

Inputs A, B, D, E (BNC connector)

Frequency Range:

- DC-Coupled: DC to 400 MHz
- AC-Coupled: 10 Hz to 400 MHz

Impedance: 1MΩ // 40 pF or 50 Ω (VSWR ≤2:1 typ.)
Trigger Slope: Positive or negative
Channel-channel skew: <30 ps (after calibration)
Sensitivity (typical):

- DC-400 MHz: <70 mVrms (PreAmp=OFF)
- DC-100 MHz: 15 mVrms (PreAmp=ON)
- 100-200 MHz: 25 mVrms (PreAmp=ON)
- 200-350 MHz: 35 mVrms (PreAmp=ON)
- 350-400 MHz: 50 mVrms (PreAmp=ON)

Hysteresis window: approx. 20 mV (PreAmp=OFF)
Attenuation: x1, x10
Dynamic Range (x1):
PreAmp = OFF: 0.2 to 10 Vp-p within ±5V window
PreAmp = ON: 0.01 to 3 V p-p within ±1.5V window
Trigger Level: Read-out in menu

- Resolution: 1mV
- Uncertainty (x1): ±(15 mV + 1% of trigger level)

Trigger Level modes: Manual, Relative (to Vp-p), Auto
Auto Trigger Level is set to:

- 50% point of input signal's Vp-p, combined with a wide hysteresis between the 40% and 60% points, for frequency, period average, TIE
- 10% and 90% points, for Rise/Fall Time, Slew rate
- 50% point with minimum hysteresis for all other functions
- Min. voltage 200 mVp-p

Analog LP Filter: Nominal 10 or 100kHz selectable
Max Voltage Without Damage:

- 1MΩ: 350 V (DC + AC pk) to 440 Hz, falling to 12 Vrms at 1MHz.
- 50 Ω: 12 Vrms

Input C (Option 10)

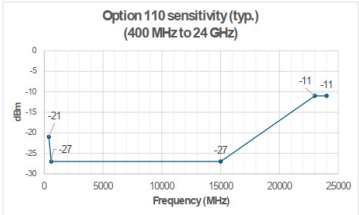
Operating Input Power Range opt. 10:

- 100 to 300 MHz: -21 dBm to +35 dBm
- 0.3 to 2.5 GHz: -27 dBm to +35 dBm
- 2.5 to 2.7 GHz: -21 dBm to +35 dBm
- 2.7 to 3.0 GHz: -15 dBm to +35 dBm

Prescaler Factor: 16
Impedance: 50 Ω nominal, VSWR <2.5:1 typ.
Max Power without Damage: +35 dBm
Connector: Type N Female

Input C (Option 110)

Freq. Range: 0.4 to 24 GHz; As standard SW limited by 10 GHz. Upgradable by SW license to 15, 20 or 24 GHz



Max Operating Input Power Level: +20 dBm
Prescaler Factor: 64
Impedance: 50 Ω nominal, VSWR <2.0:1 typ.
AM tolerance: > 90% within sensitivity range
Max Power Without Damage: +27 dBm
Connector: 2.92 mm, SMA compatible Female

Rear Panel Inputs and Outputs

Reference Frequency Input (BNC)

Frequency: 1, 5, or 10 MHz; 0.1 to 5Vrms sine
Impedance: 50Ω (nom.)

Reference Frequency Output (BNC)

Source: External input if used, otherwise internal
Frequency: External ref freq., or 10 MHz (internal)
Output impedance: 50 Ω
Amplitude: 1Vrms sine into 50 Ω (nom.)

External Disciplining Input (SMA)

Frequency: 1 pps (from external source)
Input levels: TTL levels in 50Ω

Arming Input (BNC)

Arming of all measuring functions

- Impedance: Approx. 1kΩ
- Freq. Range: DC to 160 MHz
- Trigger level: approx. 1.5V fixed
- Trigger slope: Pos. or neg. selectable

Programmable Pulse Output (Option 132)

Pulse mode: Pulse generator, Gate open, Alarm
Period range: 10ns-2s in 2ns steps
Pos. Pulse width range: 4ns-2s in 2ns steps
Rise time: 2.5 ns (nom.)
Output impedance: 50 Ω (nom.)
Output level: Low <0.4V; High: 4.5-5.25V (open output); 2.0-2.5V (50 ohm load)

Multi-GNSS antenna input (SMA) - Option 55

Supported Systems and Frequencies:

- GPS: L1 C/A, L5
- Gallileo: E1 B/C, E5a
- GLONASS: L1OF
- BeiDou: B1I, B1C, B2A
- NavIC: SPS-L5
- QZSS: L1 C/A, L5

System/frequency bands can be individually enabled/disabled

Supported active antenna parameters:
Gain: 17 to 50 dB, <+10 dBm at receiver input
DC feed on center pin: +5V, 100 mA max.

Auxiliary Functions

Trigger Hold-Off
Time Delay Range: 20 ns to 2 s in 10 ns steps

External Start and Stop Arming
Modes:
- Start Arming
- Stop Arming
- Ext. Gate (combined Start and Stop Arming)

Arming channels: A, B, D, E or rear panel ARM
Arming delay to first trigger ready: <5 ns (typ.)
Start/Stop Time Delay Range: 20 ns to 2 sec.

Statistics
Functions: Maximum, Minimum, Mean, Δmax-min, Standard Deviation and Allan Deviation
Display: Numeric or frequency distribution graph
Sample Size: 2 to $16x10^6$ samples

Limit alarm
Graphical indication of limits with Pass/Fail message on front panel,
Limit Qualifier: OFF or Capture values above, below, inside or outside limits

Sample Interval (Gate time)
The Sample Interval sets the measuring time (gate) in Frequency/Period and Totalize modes, and the time between measurements/samples in all other modes
Range: OFF or 50 ns to 1000 sec.

Mathematics
Functions: OFF, (K*X-L)/M, (K/X-L)/M, X/M-1
X is current reading, and K (Scale factor), L (Nulling value) and M (Reference value) are constants

Other Functions
Timebase Reference: Internal, External or Auto-selected
Restart: Aborts current measurement and starts a new
Run/Hold: Switch between RUN (continuous measurements) and HOLD (Freezes result, until a new measurement is initiated via Restart)

Save and Recall Settings and Measurements
Instrument Set-ups can be saved/recalled. Setups saved to internal memory can be user protected.
Measurement results (RAM) can be accessed by connected PC, and/or saved in internal non-volatile memory, and moved to USB stick.
Max. Measurement Speed and Storage size (RAM):
20 MSa/s (1 to 4 inputs): 16k samples
12.5 to 3.125 MSa/s (1 to 4 inputs): 32M samples

Display
Display: Graphic screen for menu control, numerical read-out, status information, plus distribution, trend and time-line graphs
Resolution: 1280*720 pixels
Type: Color Touch 5" TFT LCD display with backlight
Front panel accessible tools: Graph smoothing, pan and zoom, cursor read-out

Remote interfaces

Remote operation
Programmable Functions: All front panel accessible functions
Max. measurement rate (depending on measurement settings):

Block mode:	up to 170k readings/s
Individual results:	up to 425 readings/s
To Internal Memory:	up to 20M readings/s

Data Output format: ASCII, IEEE double precision floating point, or packed

USB interface
USB version: 2.0
Front panel connectors:
2x Type A; (Host) 5V (nom.) max. 0.5A. For FW updates, SW licenses, external mouse, result storage, WiFi dongle.

LAN & WLAN interface
Speed: 10/100/1000 Mbps
Capabilities:
- Web server
- SCPI over HiSLIP protocol, compatibility with VISA

Supported WiFi USB-dongles:
TP-Link TL-WN321G, TP-LINK Archer T4U v.2, TP-LINK Archer T4U v.3

General Specifications

Environmental Data
Class: MIL-PRF-28800F, Class 3
Installation category: II
Operating Temp:
0°C to +50°C / 5 to 75% RH, bench-top,
0°C to +40°C / 5 to 75% RH, rack-mount
Storage Temp: -40°C to +71°C
Max altitude: 4600 meters
Vibration: Random and sinusoidal according to MIL-PRF-28800F, Class 3
Shock: Half-sine 30G per MIL-PRF-28800F; Bench handling
Transit drop test: According to MIL-PRF-28800F
Safety: EN 61010-1:2011, pollution degree 2, installation/over voltage category II, measurement category I, CE, indoor use only
CSA C22.2 No 61010-1-12
EMC: EN 61326-1:2013-06, increased test levels according to EN 61000-6-2:2008, Group 1, Class B, CE

Power Requirements
Max. Version: 100 to 240 V_{AC} ± 10%, 47 to 63 Hz, <70 W

Dimensions and Weight
Width x Height x Depth: 210 x 90 x 395 mm (8.25 x 3.6 x 15.6 in)
Weight: Net 3 kg (6.6 lb)

Ordering Information

Basic model
CNT-104R: 4-channel 400 MHz Frequency Analyzer, 7 ps resolution, Rubidium timebase

Input C Frequency Options
Option 10: 3 GHz Input C (HW-Factory installed)
Option 110: 10 GHz Input C (HW-Factory installed)
Option 110/15: SW upgrade from 10 to 15 GHz
Option 110/20: SW upgrade from 15 to 20 GHz
Option 110/24 SW upgrade from 20 to 24 GHz

Other HW options (factory installed)
Option 55: GNSS control of Rubidium oscillator
Option 11A: Rear panel inputs for inputs A,B,D,E
Option 11C: Rear panel inputs for input C

Options (SW license enabled)
Option 132: Programmable pulse output
Option 151: TIE measurement function

Included with Instrument:
- 2 year product warranty[2]
- Line cord (*dependent on destination country*)
- Link to User documentation (PDF)
- Certificate of Calibration
- Important information document

2: Warranty period is extended to 3 years, at no cost, by registering the product within 1 year from delivery.

Optional Accessories
- **Option 01/200;** Multi-GNSS L1&L5 antenna, 40 dB gain, N-female connector, incl. mounting kit
- **Option 02/A:** Antenna cable adapter SMA to TNC
- **Option 02/20T:** Antenna cable, N to TNC, 20m
- **Option 02/50T;** Antenna cable , N to TNC, 50m
- **Option 22/90:** Rack-Mount Kit- 1 unit
- **Option 22/05:** Rack-Mount Kit -2 units
- **Option 27:** Carrying Case - soft
- **Option 27H:** Heavy-duty Hard Transport Case
- **Option 90/07:** Calibration Certificate with Protocol; Rubidium oscillator
- **Option 90/07A:** Accredited ISO 17025 calibration; Rubidium oscillator
- **Option 95/05:** Extended warranty 2 extra years
- **OM-100:** User's Manual English (printed)[3]
- **PM-100:** Programmer's Manual English (printed)[3]
- **GS-100-EN:** Getting Started English (printed)[2]

3: Always available as download from the Pendulum website

Time Base Options

Option model	Rubidium	Rubidium
Time base type:	Free run	GNSS-controlled
Uncertainty due to: -Aging per 24h per month per year -Temperature variations: 0˚C to 50˚C 20˚C to 26˚C (typ. value)	 $<5x10^{-12}$ (1) $<5x10^{-11}$ (1) $<5x10^{-10}$ $<3x10^{-10}$ $<3x10^{-11}$	 $<1x10^{-12}$ (1) $<1x10^{-12}$ $<1x10^{-12}$
Short-term stability: τ =1s (Allan Deviation) τ =10s τ =24h	$<5x10^{-11}$ $<2x10^{-11}$	$<5x10^{-11}$ $<2x10^{-11}$ $<2x10^{-12}$
Phase noise stability (typ.) at - 10 Hz / 100 Hz / 1kHz /10 kHz offset from carrier:	<-95/-125/ -135/-140 dBc	<-95/-125/ -135/-140 dBc
Frequency retrace after 1h cont. operation (24h off)	$<3x10^{-11}$	$<3x10^{-11}$
Typ. total uncertainty, averaged over 24h, at 20˚C to 26˚C, after 1yr, at 2σ (95%) confidence interval:	$<6x10^{-10}$	$<2x10^{-12}$

[1]After 1 month of continuous operation

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Specifications subject to change or improvements without notice.

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