ELETTRONICA MONTI

AT10 USER'S MANUAL

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Basic Safety Instructions

The manufacturers of AT10 make all efforts to keep the safety standards up to date and to offer customers the highest safety. The product and the auxiliary equipment are designed, built and tested in accordance with the safety standards that apply in each case. To maintain this condition and to ensure safe operation, please observe all instructions and warnings provided in this manual.

It is user's responsibility to use the product in a proper manner. This product is designed for use solely in industrial and laboratory environments. It must not be used in any way that may cause personal injury or property damage. The user is responsible if the product is used for any purpose other than its designated purpose. The manufacturer shall assume no responsibility for an improper use of the product.

The product must be used for its designated purpose and in accordance with its performance limits (see data sheet, documentation, the following safety instructions). Using the product requires technical and theoretical skills. Specialised and trained staff should handle the product.

Observing the safety instructions may help prevent personal injury or damage.

This instrument contains voltage hazardous to human life and safety, and is capable of inflicting personal injury.

This instrument is provided with a IEC-60320-C14 AC 110V/220V receptacle. Use direct mains only if allowed by local regulations.

If this instrument is powered from the mains through an autotransformer, ensure the common connector is connected to the neutral of the power supply.

⚠ Do not use a two-conductor extension cord or a three-prong/two-prong adapter.

⚠ Use only the provided AC/DC adaptor.

⚠ This instrument may be opened only by authorised personnel.

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Product Disposal

This symbol means that the product cannot be disposed of with municipal waste. It is the user's responsibility to protect human health and the environment by disposing of discarded equipment by delivering it to the recycling station of electrical or electronic waste. For more information, contact the urban waste disposal service.
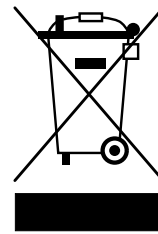
3

General Information

The AT10 is both a programmable frequency reference and a frequency/phase counter; a two-in-one instrument that finds applications in virtually any calibration and R&D laboratory where high-precision time and frequency measurements are performed, as well as all facilities requiring an accurate frequency standard. Indeed, thanks to the on-board atomic rubidium oscillator, the AT10 guarantees frequency reference outputs and frequency measurements with an accuracy better than ±5E-11, a short-term stability better than 3E-12, and a frequency drifting less than 5E-11 per month.

The AT10 can achieve a frequency accuracy better than 10E-12 when disciplined via an external 1PPS signal (normally a GPS signal without S.A.). Indeed, the AT10 has an auto-calibration/disciplining mechanism which, based upon an externally-provided 1PPS signal, zeroes phase and frequency changes as well as other long-term effects such as ageing. The averaging mechanism guarantees an excellent long-term stability. The AT10 autodetects a 1PPS reference, if any, and starts auto-calibrating; after 14 hours GDO accuracy is guaranteed to be within 10E-12. Auto-calibration is permanent and remains effective also after power cycling.

The AT10 makes clock calibration an easy, fail-safe and quick process. Indeed, the AT10 guarantees an almost instantaneous feedback about the frequency error of the clock signal under test. Three measurements per second are always available, even for low-frequency clocks as low as 10 kHz, still maintaining a resolution of 0.1 ppm. Such an extraordinary performance is achieved thanks to an FPGA-based phase comparison between a 2-GHz clock and the clock under test.

The AT10, as an input frequency counter, covers a wide frequency band that spans from 10 kHz up to 6 GHz. Two inputs are available: a high-impedance BNC-input for clocks from 10 kHz up to 125 MHz, and a 50-Ω SMA-input for clocks from 100 MHz up to 6 GHz.

The AT10 provides a fine-programmable frequency reference that covers frequencies from 1 Hz up to 125 MHz with a resolution as low as 0.0776 Hz. At the same time, the AT10 provides an exceptionally-low phase-noise programmable output from 20 MHz up to 1 GHz, with a phase noise as good as –143 dBc/Hz at 10-kHz offset, dropping to less than –150 dBc/Hz at 1 MHz offset. The low-noise reference output includes an automatic frequency correction for outputs below 625 MHz.

The AT10 has three 10-dBm 10-MHz sine outputs, two 0-dBm 10-MHz sine outputs, two 0-dBm 10-MHz square outputs, two differential low phase-noise programmable CW outputs, one fine-programmable CW output, and one 1PPS TTL output. All these outputs, except for low phase CW outputs, have an Allan Variance less than 5E-11 at 1 s and 7E-12 at 100 s.

The AT10 can display frequency deviation figures as well as two user-configurable graphical representations to get more insights quickly. A histogram provides at runtime a representation of the numerical data distribution, thus providing a quick statistical view of the ongoing measurement. A time-series chart represents frequency deviations in time, thus giving a quick glance of the measurement trend, namely the short-term stability of the device under test.

A Micro-USB interface allows for direct communication with the AT10. This interface can be used for both fail-safe firmware updating and laboratory system integration.

3.1 Specifications

TABLE 3.1: **Generic AT10 Oscillator Specifications**

Frequency Accuracy at Shipment	better than ±5E-11 @ + 25°C
GDO Accuracy after 24h-GPS-Locked	better than ±1E-11 @ + 25°C
Lock time	≤7 minutes typical @ +25 °C ≤15 minutes @ -5 °C
Frequency - Temperature Coefficient (ambient temperature)	≤ 8E-10 [-5 °C – 60 °C] ≤ 2E-10 [20 °C – 40 °C]
Short-term Stability	1 s: ≤ 5E-11 10 s: ≤ 1.8E-11 100 s: ≤ 7E-12 1000 s: ≤ 3E-12
Long-term Stability	≤ 5E-12 per day ≤ 5E-11 per month (design guarantee)
Ground Magnetic Effect	≤ 1E-11
MTBF	≥ 100.000 hours

TABLE 3.2: **Input Specifications**

Measurement Resolution	0.333 s 1 s 50 s 500 s	0.1E-6 1E-9 0.1E-9 1E-12
Low Frequency		
Frequency Range	10 kHz – 150 MHz	
Maximum Input Level	25 dBm	
Sensitivity Sine Wave	100 kHz 500 kHz 1 MHz 10 MHz 100 MHz 150 MHz	250 mVpp 50 mVpp 50 mVpp 50 mVpp 250 mVpp 500 mVpp
Sensitivity Square Wave	10 kHz 100 kHz 500 kHz 10 MHz	50 mVpp 50 mVpp 50 mVpp 50 mVpp
High Frequency		
Frequency Range	100 MHz – 6 GHz	
Maximum Input Level	20 dBm	
Sensitivity	100 MHz 250 MHz 500 MHz 1 GHz 4 GHz 6 GHz	-15 dBm -21 dBm -25 dBm -31 dBm -33 dBm -30 dBm

TABLE 3.3: **Output Specifications**

Fixed-Frequency 10 MHz

5 x Sinusoidal Output	3 x 10 dBm ±1 dB	(1 on front and 2 on rear panel)
	2 x 0 dBm ±1 dB	(2 on rear panel)
2 x Square Output	2 x >0 dBm	(2 on rear panel)
10 MHz Phase to Noise (SSB)	10–Hz offset	-95 dBc/Hz
	100–Hz offset	-125 dBc/Hz
	1–kHz offset	-135 dBc/Hz
	10–kHz offset	-140 dBc/Hz
Harmonic spurs (Front)	<-80 dBc	
Termination	50 Ohm	

Pulse Per Second (PPS)

Period	1 s	
PPS Output Level	3 Vpp ±0.5 V	(1 on rear panel, autoswitched)
PPS Output Duty Cycle	0.16 %	
PPS Input Level	2 Vpp ±1.5 V	(1 on rear panel, autoswitched)
PPS Input Duty Cycle	1-99 %	

Arbitrary Frequency

DDS Output	square wave > 1 Vpp (50 Ω)	(1 on rear panel)
Frequency Range	1 Hz – 125 MHz	
Frequency Resolution	0.0776 Hz	
10 MHz Phase to Noise (SSB)	1–kHz offset	-105 dBc/Hz
	10–kHz offset	-106 dBc/Hz
	100–kHz offset	-103 dBc/Hz
	1–MHz offset	-114 dBc/Hz
Termination	50 Ohm	

RF Frequency

2 x Differential RF Output	P and N	(2 on rear panel)
Frequency Range	20 MHz-625 MHz	(with freq. accuracy info & correction)
	625 MHz-1 GHz	(without freq. accuracy info)
Frequency Tolerance ($\leq$ 625 MHz)	<0.5 ppm	(after LOCK)
Frequency Resolution	output frequency tuned as $f = (round(5e^3/f_{MHz})) * 5e^6$	
Non-harmonic Spurs	<-90 dBc	
156.25 MHz Phase to Noise (SSB)	10-kHz offset	−143 dBc/Hz
	20-kHz offset	−143 dBc/Hz
	100-kHz offset	−144 dBc/Hz
	200-kHz offset	−145 dBc/Hz
	1-MHz offset	−150 dBc/Hz
	2-MHz offset	−154 dBc/Hz
	10-MHz offset	−162 dBc/Hz
	20-MHz offset	−162 dBc/Hz
Amplitude Response	20 MHz	>-5.0 dBm
	50 MHz	>-5.0 dBm
	156.25 MHz	>-7.0 dBm
	500 MHz	>-10.0 dBm
	1 GHz	>-13.0 dBm
Termination	50 Ohm	

Table 3.4: **General**

Power DC	12 V DC (AC-DC adaptor included)
Power Mains	110 V-220 V AC (Check local regulation)
Typical Power Consumption	Static (@ 25 °C) < 10 W Peak Consumption < 30 W
Front Panel	HW Button (3-colour LEDs) 2 BNC (In, Out) 1 SMA (In)
Rear Panel	10 BNC 1 Micro (B) USB 1 IEC-60320-C14 AC 110V/220V 1 DC-12V 5.5 x 2.1 mm Jack 1 Banana Jack (GND)
Dimensions (W x L x H)	22 cm x 29 cm x 10 cm
Weight	2.1 kg

3.2   *Front and rear panel*
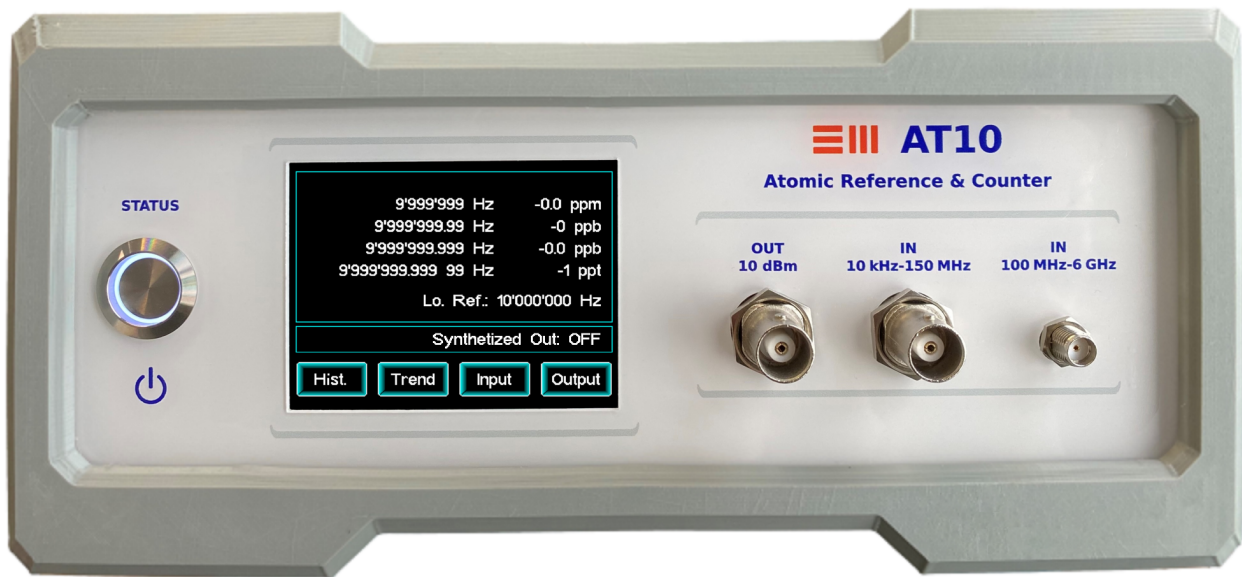
Figure 3.1: AT10 front panel

Legend front panel from left to right:

- Power button: to switch the AT10 On and Off

- Touch screen display: to show the instrument status and select available functions
  Upper box: input data
  Lower box: output data
  "Buttons" to select available functions

- BNC fixed-frequency sinusoidal output (10 MHz, 10 dBm)

- BNC low frequency input (10 kHz -150 MHz)

- SMA high frequency input (100 MHz - 6 GHz)

Figure 3.2: AT10 rear panel

Legend rear panel from left to right:

- two BNCs fixed-frequency sinusoidal output (10 MHz, 10 dBm)
- two BNCs fixed-frequency sinusoidal output (10 MHz, 0 dBm)
- two BNCs fixed-frequency square output (10 MHz, 0 dBm)
- two BNCs differential RF Output (P and N)
- one BNC PPS output/input
- one BNC DDS output
- one micro (B) USB
- one DC-12V jack
- one banana Jack (GND)
- one IEC-60320-C14 AC 110V/220V

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Operating Instructions

4.1   Setup

There are two ways to power the AT10. Either through the 12 V DC using the included AC-DC adaptor or, only if allowed by local regulations, through direct mains using the IEC-60320-C14 AC 110V/220V receptacle. When the AT10 is connected to power, the power button will appear yellow; the AT10 is in a stand-by low power mode. When the AT10 is turned on, the power button will appear red. Then it turns blue while the internal rubidium oscillator is warming up (the display shows "Rubidium Unlock"). As soon as the internal temperature is stable, the AT10 is ready and the power button will appear white. It is not possible to use the instrument during the unlocking-time, which depends on the external temperature (see Tab. 3.1). After unlocking the stability of the rubidium oscillator improves over time until it reaches its long-term stability of $\leq$ 5E-11 per month (design guarantee).

Figure 4.1: Main menu

The display is composed of three sections. The upper box shows input details and values. The lower box shows output details. The touch-screen "buttons" on the bottom are to navigate the menu and select specific functions (see Fig. 4.1).
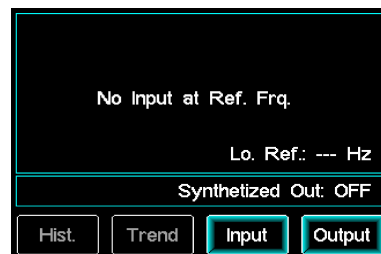
4.2   *Frequency Reference Measurement*

The AT10 is designed to measure the quality of a frequency reference. The input module of the AT10 covers two frequency spans: the low frequency span ranges from 10 kHz to 150 MHz (BNC connector) and the high frequency span ranges from 100 MHz to 6 GHz (SMA connector). Once the reference source is connected to the AT10, the power button appears green. Per default, the instrument is in low frequency mode and automatically detects the frequency reference, rounding up to the nearest common value.

Figure 4.2: Initial input screen; measurements are still loading

The display shows the reference frequency and the selected input frequency span, the measured frequency and the related errors with different resolutions (Tab. 3.2). Three measurements per second with a resolution of 0.1 ppm are almost immediately available. This is the reading in the first row of the input screen. The 1-ppb error reading is updated every second, and available 10 s after the beginning of the measurement (second row reading). For this reason the writing initially appears grey and turns white as soon as the measurement is stable. The third and fourth reading with a resolution of 0.1 ppb and 1 ppt are available after 50 s and 500 s respectively; blue horizontal bars are shown while loading. These measurements are moving average measurements that, once ready, are updated every second. In Fig. 4.2 only the measurement with a resolution of 0.1 ppm is already available; the other measurements are still loading. Fig. 4.3 shows a completely loaded input screen. If the error exceeds 1000 ppm, the AT10 does not show any results. If the measurement is not sufficiently stable or the absolute error value exceeds the measurement resolution by a factor of 10E3, the related reading is not shown and "- - -" will appear.

Figure 4.3: Input screen

While the AT10 remains in automatic mode, it automatically detects the frequency of the reference input. Moreover, the AT10 allows to either set the reference frequency manually to a desired value or block the automatic frequency detection process. This is preferred (i) when the automatically detected reference frequency value does not correspond to the frequency of the source under test or (ii) when the reference input varies greatly and its frequency gets closer to another common reference value, and hence the AT10 may change the reference frequency during the measurement. To block the frequency reference, the frequency can either be set manually, navigating from "Input" to the "Freq." menu, or the automatically detected frequency reference can be blocked by selecting "Man." in the "Input" menu. In either case the frequency reference is blocked and the writing appears grey ("Lo. Ref.: f Hz", see Fig. 4.2, where f is the reference frequency value).

The above indications are valid for both input frequency spans. To switch from low frequency to high frequency mode the reference source must be connected to the high frequency AT10 input (SMA connector)
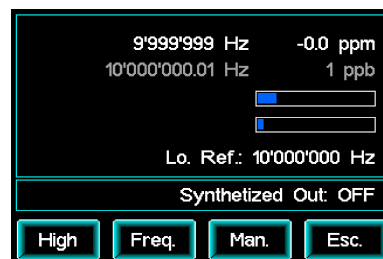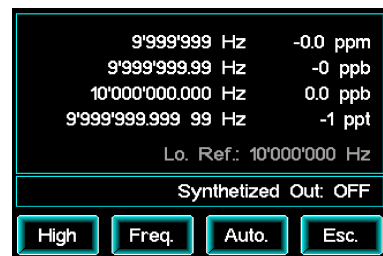
and the option "High" must be selected in the input menu.

4.2.1   Graphical Representations

The AT10 can directly display two different graphical representations of the measurement error: a histogram and a time-series chart. The histogram chart (select "Hist.") provides a representation at runtime of the numerical data distribution (see Fig. 4.4). The chart is made of 21 bars, each representing the rate of occurrence of a certain error value, namely the number of times the error value has been measured. The chart is normalized to the maximum rate of occurrence value. This value is represented by a bar of fixed length; other bar lengths are adjusted accordingly at run time. The numerical figure representing the actual experimental probability (the ratio of the value of a certain rate of occurrence to the total number of measurement samples in percent) is in the upper left corner of the display. Per default, the experimental probability of the most frequent error value is shown (related to the highest histogram bar). The experimental probability of other error measurements can be displayed by touching directly on the histogram bar related to the error value of interest. The total number of measurement samples is shown in the lower left corner of the AT10 display. The histogram binning can be customised; the x-axis scale (ppb/div) can be modified manually selecting "Div.", minimum 0.5 ppb/div and maximum 1000 ppm/div are allowed.
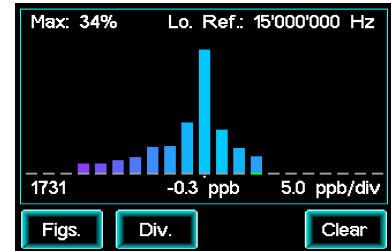
Figure 4.4: Histogram

Additional information are available on the histogram screen. The reference frequency and the input frequency mode ("Lo." for low and "Hi." for high) are indicated in the upper right corner of the display. Moreover, the little green line below the histogram bar indicates in which histogram bin the error measurement falls at runtime. If the error sample falls outside of the graphical span, the line on the bar will become red (either on the far left or the far right of the graph, depending on the error direction).

To reset the histogram view and thus start a new chart press "Clear". To return to the previous display showing the numerical error press "Figs.".

The second graphical representation is a time-series chart that represents frequency deviations in time, thus giving a quick glance of the measurement trend, namely the short-term stability of the device under test (select "Trend", see Fig. 4.5). The reference frequency and the input frequency mode ("Lo." for low and "Hi." for high) are indicated in the upper right corner of the display. The x- and y-axis spans as well

Figure 4.5: Measurement Trend

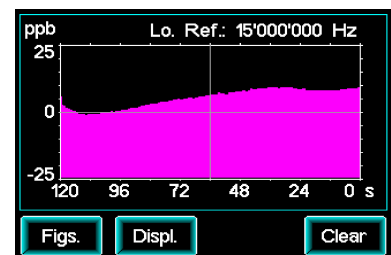as the centring on the y-axis can be modified manually in the menu "Displ.". The selectable x-axis span ranges from 120 s to 32760 s, while the selectable y-axis span ranges from 10 ppb to 19990 ppb. Press "Clear" to start the graphical representation anew and "Figs." to return to the previous display showing the numerical error.

4.3   Output

The AT10 provides two different programmable frequency reference output types: the "Arbitrary Frequency" and the "RF Frequency" output. Fig. 4.6 shows the output screen with the two available options "DDS" for Arbitrary Frequency and "RF" for RF Frequency. In the output box of the screen the selected output functions are shown. Initially, the programmable output is off, as indicated by the writing "Synthetized Out: OFF".
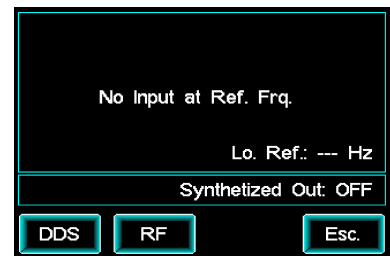
Figure 4.6: Output screen

4.3.1   Arbitrary Frequency Output

The Arbitrary Frequency output is a fine programmable frequency reference that covers frequencies from 1 Hz to 125 MHz, with a resolution of 0.0776 Hz. It is a square wave with a phase to noise ratio (measured at 50 MHz) ranging from roughly -80 dBc/Hz to -100 dBc/Hz (see Tab. 3.3). It has the same frequency characteristics as the internal rubidium oscillator (see Tab. 3.1), displaying an additional fixed (frequency-independent) error of 0.0776 Hz corresponding to the frequency resolution.

Figure 4.7: DDS menu screen

To use the Arbitrary Frequency output, select "DDS" in the "Output" menu and turn it on. Select "Freq." to set the frequency to the desired value (see Fig. 4.7). Per default the output is set to 10 MHz. The AT10 input and the AT10 Arbitrary Frequency output are completely independent, thus, AT10 arbitrary frequency reference and frequency counter can be used simultaneously.
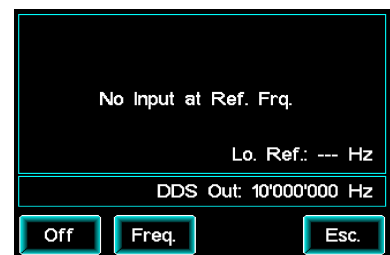
4.3.2   RF Frequency Output

The RF Frequency differential output is a programmable frequency reference that covers frequencies from 20 MHz up to 1 GHz, with an exceptionally-low phase noise as good as –143 dBc/Hz at 10-kHz offset, dropping to less than –150 dBc/Hz at 1 MHz offset. To achieve these extraordinary performances, the hardware limits available output frequencies, which are given by the following equation: $f_{out} = (round(5e^3/f_{setting})) * 5e^6$ where frequency values are expressed in MHz and where $f_{setting}$ is the frequency set by the user and f_{out} is the actual frequency generated by the RF oscillator.
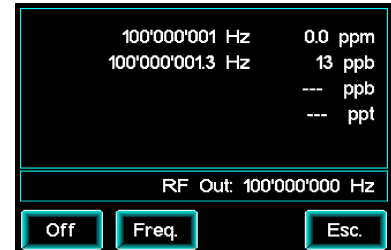

Figure 4.8: RF menu screen

As, by nature, RF low-phase noise reference cannot be accurate in frequency, the actual RF tone is affected by a frequency error. However, AT10 offers an automatic frequency error measurement. Basically, the frequency counter function is used to internally measure the actually generated frequency. This means the system inhibits the frequency counter (unlike the Arbitrary Frequency output, the RF Frequency output and the AT10 input cannot be used simultaneously). The power button appears green as the automatic frequency error measurement is active.

For outputs below 625 MHz, the AT10 RF Frequency output includes an automatic frequency correction that guarantees a frequency accuracy better than 0.5 ppm. The AT10 implements a novel control mechanism to adjust the frequency which is inspired by chemical reaction dynamics. In practice, the algorithm adjusts always with the finest resolution the RF PLL but with variable timing dependent on the measured error. The higher the error, the faster the algorithm modifies PLL registers. The result is a robust and self-healing control mechanism that guarantees exceptional phase-noise. Above 625 MHz the automatic frequency correction is not available any more (the chemical algorithm is deactivated), but the internal error measuring function still remains. The last-performed automatic frequency correction remains still active even when the frequency is changed to a value above 625 MHz. It is thus advised to first minimize the error of the oscillator by selecting a frequency still in the automatic frequency correction range (below 625 MHz) and wait for the oscillator to adjust. Subsequently select the desired high frequency.

To use the RF Frequency output, select "RF" in the "Output" menu and turn it on. Select "Freq." to set the frequency to the desired value (see Fig. 4.8). Per default the output is set to 100 MHz. The internally measured error is displayed in the input box of the screen.

4.3.3   Fixed Frequency Outputs

The AT10 is equipped with various additional fixed frequency outputs. There are three 10-MHz 10-dBm sinusoidal outputs. Two on the rear and one on the front panel. The 10-dBm output on the front panel has an additional RF filter that guarantees a harmonic distortion below -80 dBc. Further, there are two 10-MHz 0-dBm sinusoidal outputs, two 10-MHz square wave outputs and a standard 1PPS output, see Tab. 3.3 for additional details.

4.4   Auto-calibration

The PPS connector can be used as an auto-calibration input. In auto-calibration mode the frequency of the oscillator of the rubidium can be aligned to a desired value of an accurate input reference. To enter auto-calibration mode, a 1PPS reference signal has to be connected to the PPS connector. When the AT10 is turned on, the AT10 automatically detects if there is a sufficiently stable and accurate input signal to enter auto-calibration mode; a flashing grey satellite appears in the upper left corner of the display. The flashing frequency normally coincides with the PPS reference frequency. During the initial Rubidium unlock phase the satellite blinks faster. When the satellite starts flashing red/grey the actual process of auto-calibration has started without modifying yet the output frequency of the rubidium oscillator. After approximately 14 hours (256 x 198 =50'688 s) the frequency of the rubidium oscillator is aligned in accordance to the PPS input reference and the satellite now flashes green/grey. This calibration is not permanent. After switching off the AT10 the calibration is lost and when the instrument is switched on again, it restarts with its default oscillator frequency alignment. There is a serial command to render the calibration permanent (see Chap. 4.5).

Figure 4.9: Auto-calibration - verifying input signal

Figure 4.10: Auto-calibration - processing

4.5   Serial Communication

The communication protocol is implemented in RS232 environment as follows:

- Baud Rate 115200

- 1 Start Bit

- 1 Stop Bit

- No Parity
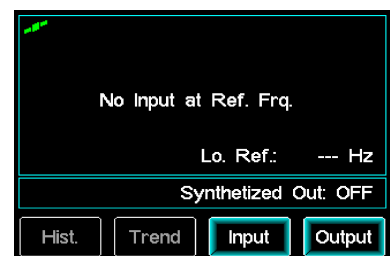
Figure 4.11: Auto-calibration - terminated

Serial commands are made of an ASCII string delimited by the character "#" (0x23) and the character "∗" (0x2A). Replies are terminated with <CR><LF> (\r\n). The command header must be AT. Available commands are query commands "?", that ask the instrument about a specific status, and setting commands "S", that set the instrument with certain parameters (see Tab. 4.1 and Tab. 4.2). All commands produce a reply which contains the command itself.

- Example query command: #AT?IDN∗
  Reply: IDN=AT10; S/N:1913001; FW:A 1.3 05/22.

- Example setting command: #ATSCWF 100∗
  Reply: CWF=OK.

- In the case of an unrecognized command (wrong header), AT10 does not reply.
  Example: #PP?IDN∗ no reply.

- In the case of an unrecognized command type (available commands are ? and S), AT10 replies with the string "Command ERROR".
  Example: #ATPCWF 100∗ Reply: Command ERROR.

- In the case of a wrong command field, AT10 replies with the received command character followed by ERR string.
  Example: #ATSCWF 500∗ Reply: AT=SERR.

When the power button is blue (during the rubidium unlock time and as long as the internal temperature is not stable) the AT10 constantly replies the internal temperature and is not ready yet to receive serial commands. During auto-calibration the AT10 continuously communicates in RS232 environment as follows: ("..." are omitted lines)

TMP:64.4
TMP:65.0
TMP:65.6
Starting calibration procedure (256 s sampling)
id:1; val:21846;
id:2; val:21846;
...
id:197; val:21855;
id:198; val:21851;

Oscillator cal.;@;21846.646484;-15.403748E-12
OK

id:1; val:21844;
id:2; val:21846;
...

TABLE 4.1: **Query Commands (?)**

Command	Description
?IDN	shows instrument name, serial number and firmware version and date example: #AT?IDN∗ reply: IDN=AT10; S/N:1913112; FW:A 1.6 05/22
?TMP	shows internal temperature in °C example: #AT?TMP∗ reply: TMP=75.2
?S/N	shows serial number example: #AT?S/N∗ reply: S/N=1913112
?FPGA	shows FPGA release example: #AT?FPGA∗ reply: FPGA=0x 111
?GDO	shows PPS status (ON or OFF) example: #AT?GDO∗ reply when PPS is OFF: GDO=OFF (PPS OUT) reply in initial calibration phase: GDO=ON (PPS IN) ...not ready yet reply in fully operational calibration phase: GDO=ON (PPS IN); Stage: 85 where stage value represents the number of samples acquired (1 sample every 256 s, 198 samples in total)
?CAL	shows Rubidium calibration value example: #AT?CAL∗ reply: CAL=0.000000E-12
?CWF	shows frequency in MHz of DDS generated reference if DDS is OFF, "CWF = - - -" is returned example: #AT?CWF∗ reply: CWF=10.000000
?CWS	shows DDS status (ON or OFF) example: #AT?CWS∗ reply: CWS=ON
?GRB	gives back RGB image of the display (binary file) example: #AT?GRB∗ reply: see Appendix 5
?INR	shows input impedance status: high impedance (0), 600 Ohm (1) example: #AT?INR∗ reply: INR=0
?GRF	shows RF reference generator status (ON or OFF) example: #AT?GRF∗ reply: GRF=OFF
?RFF	shows RF reference generator frequency in MHz the value represents the actual output frequency (see formula in Tab.) if RF reference generator is OFF, "RFF = - - -" is returned example: #AT?RFF∗ reply: RFF=100.000000
?PUO	shows frequency measurement infos in semicolon-separated csv format example: #AT?PUO∗ reply: ppb:; -0; -0.0; 0.018; Aut. Lo Ref.;10'000'000; Hz; Id.;82 which are as follows: error measurement unit; 1-ppb resolution error; 0.1-ppb resolution error; 0.001-ppb resolution error; reference frequency infos (automatic or manual, high or low); reference frequency value; reference frequency unit; last two fields are reserved for internal use

TABLE 4.2: **Setting Commands (S)**

Command	Description
SCAL	save the rubidium calibration value example: #ATSCAL∗ reply: CAL=OK
SUNCAL	reset the rubidium calibration value to factory settings example: #ATSUNCAL∗ reply: UNCAL=OK
SFRQ	set frequency reference in Hz, 0 sets it back to auto-frequency example: #ATSFRQ 10000∗ reply: FRQ=OK
SPUO	print continuously frequency measurement infos in RS232 environment with semicolon-separated csv format (2), verbose format (1), or stop printing (0) example semicolon-separated csv format: #ATSPUO2∗ reply: ppb:; -0; -0.0; 0.018; Aut. Lo Ref.:;10'000'000; Hz; Id:;82 which are as follows: error measurement unit; 1-ppb resolution error; 0.1-ppb resolution error; 0.001-ppb resolution error; reference frequency infos (automatic or manual, high or low); reference frequency value; reference frequency unit; last two fields are reserved for internal use example verbose format: #ATSPUO1∗ reply: 10'000'000 Hz, -0.0 ppm 10'000'000.00 Hz, -0 ppb 10'000'000.000 Hz, 0.0 ppb 10'000'000.000 03 Hz, 3 ppt Aut. Lo Ref.:10'000'000 Hz [Id.231] which are as follows: 1-Hz resolution measured frequency, 0.1-ppm resolution error 10-mHz resolution measured frequency, 1-ppb resolution error 1-mHz resolution measured frequency, 0.1-ppb resolution error 10-μHz resolution measured frequency, 1-ppt resolution error reference frequency infos (automatic or manual, high or low), reference frequency value, field in brackets is reserved for internal use example stop printing: #ATSPUO0∗ reply: PUO=OK
SIRS	input range selection (0: Low, 1: High) example: #ATSIRS 0∗ reply: IRS=OK
SCWS	set continuous wave generator (DDS) status (1: on / 0: off) example: #ATSCWS 1∗ reply: CWS=OK
SCWF	set continuous wave generator (DDS) frequency in MHz example: #ATSCWF 20∗ reply: CWF=OK
SGRF	set RF generator status (1: on / 0: off) example: #ATSGRF 1∗ reply: GRF=OK
SRFF	set RF generator frequency in MHz example: #ATSRFF 100∗ reply: RFF=OK

SFRZ	freeze display for a given time in s, give any serial command to unfreeze example: #ATSFRZ 1∗ reply: FRZ=OK
SINR	set low input impedence: high impedence (0), 600ohm (1) example: #ATSINR 0∗ reply: INR=OK

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Appendix

A binary file representing the image of the display can be downloaded via the serial command "#AT?GRB∗". The reply to this command is a 236183-bytes long bitstream, which is made of a header and the whole RGB image of the display. The header indicates the display resolution and is always the following 23 bytes: "$H\_RES = 328; V\_RES = 240\backslash r\backslash n$" where "$\backslash r\backslash n$" is carriage return and line feed $(0x13, 0x10)$. The following RGB image is organised as 240 rows of 328 pixels. Each pixel is made of 24 bits, namely three bytes that represent the three hexadecimal integers between $0x00$ and $0xFF$ specifying the intensity of the three colours. The first byte is related to red, the second byte to green and the third byte to blue (see Tab. 5.1).

TABLE 5.1: **Display RGB Image**

	Column 1			Column 2			Column 3			Column ...			Column 326			Column 327			Column 328		
Row 1	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
Row 2	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
Row 3	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
Row ...	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
Row 238	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
Row 239	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
Row 240	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B