NOVATECH

INSTRUMENTS, INC.

Models 2960AR and 2965AR
Disciplined Rubidium Frequency Standards

2960AR

2965AR

1.0 DESCRIPTION

1.1 The Models 2960AR and 2965AR are rubidium frequency standards which can be disciplined to an external 1pps (one pulse per second) reference signal. This 1pps is commonly derived from primary, or other standards, such as GPS (global positioning satellite). When disciplined to 1pps, the 2960AR and the 2965AR provide primary standard accuracy and stability.

1.2 The 2960AR provides three fixed frequency outputs of 10MHz, 10MHz and 5MHz, while the 2965AR replaces one of the 10MHz outputs with a programmable 50MHz synthesized output. The 2965AR is particularly useful in applications which require non-standard or customer specified frequencies. The synthesized output is locked to the internal rubidium oscillator and has the same accuracy as the 10MHz and 5MHz outputs. All outputs have a nominal amplitude of 1Vrms into 50Ω.

1.3 The most recent version of this manual can be found on Novatech Instruments, Inc. web site.

2.0 SPECIFICATIONS

2.1 **FREQUENCY STABILITY (Δf/f)**

Short Term:	t=1s	$<3x10^{-11}$
	t=10s	$<1x10^{-11}$
	t=100s	$<3x10^{-12}$
Aging:	Monthly	$<\pm5x10^{-11}$ after 1 month
	Yearly	$<\pm5x10^{-10}$ after 3 months

Holdover (24Hours, ±2°C): $<\pm1x10^{-11}$ (<±1μs after >10x 1pps tracking time constant)

Temperature: +5 to +45°C $<\pm1x10^{-10}$

Line Voltage: ±10% $<\pm5x10^{-12}$

2.2 **FREQUENCY ACCURACY**

At shipment: $<=\pm5x10^{-11}$ at 20°C.

Retrace: $<=\pm5x10^{-11}$ from last frequency after 1hour ON and 24hours OFF (constant environment).

2.3 **FIXED SINEWAVE OUTPUTS**

10MHz and 5MHz, $1V_{RMS}$ $\pm0.25V_{RMS}$ into 50Ω. (10MHz, 10MHz and 5MHz for 2960AR)

2.4 **SYNTHESIZED SINEWAVE OUTPUT** (2965AR only, typical)

Frequency programmable from 100Hz to 50MHz in 1μHz steps.

Amplitude: $1V_{RMS}\pm0.25V_{RMS}$ at 5MHz into 50Ω (±3dB from 100Hz to 50MHz, referenced to 10MHz).

Phase Noise:<-140dBc, 10kHz offset, 1MHz output.

Harmonics: <-45dBc, spurious: <-55dBc.

2.5 **SPECTRAL PURITY** (10MHz outputs)

Harmonic <-25dBc.

Spurious/Non-Harmonic/Sub-Harmonic: <-45dBc.

2.6 **PHASE NOISE** (Typical, 10MHz output, 50Ω)

Frequency Offset	dBc
1Hz	-70
10Hz	-90
100Hz	-120
1kHz	-140
10kHz	-140

2.7 **1pps IN and OUT**

1pps IN: DC-coupled, accepts TTL or CMOS. 1pps OUT: TTL, 133μs negative pulse width. Typical output jitter: 20ns peak-peak (1 minute measurement time). (differential RS422 output optional)

2.8 **ENVIRONMENTAL**

Temperature: +0°C to +50°C operating.

Humidity: 80% to 31°C, decreasing linearly to 50% at 40°C.

2.9 **SIZE**

6.4cm H, 18.5cm W, 24.1cm L, excluding bail and feet.

2.10 **CONNECTORS**

BNCs on front panel for sine outputs. BNCs on rear panel for 1pps I/O. DE9 on rear panel for synthesizer RS232 serial interface (2965AR only, no connect for 2960AR). A serial cable is provided with the 2965AR.

2.11 **LINE POWER**

120/240VAC ±10%, 50/60Hz. 30VA (50VA max during warm up <20minutes).

2.12 **FRONT PANEL INDICATORS**
POWER OK: AC power is applied and on.
RUBIDIUM LOCK: Green: Oscillator is locked. Red: Warm-up.
1 PPS LOCK: Locked to and tracking a 1pps input.

2.13 **ACCESSORY**
GPS1: Matching GPS smart antenna system.

3.0 INSTALLATION

WARNING:

The 2960AR and 2965AR line power input connection is provided with a 3-wire cord. Do not defeat the grounded conductor.

3.1 **Power Connection.** Verify that the rear panel indicates your line power (120VAC or 240VAC 50Hz/60Hz). Connect the provided 3-wire line cord to your power source. The power switch is built-in to the input module on the rear panel.

3.2 **2960AR Installation.** The 2960AR requires no user setup beyond the application of line power and connection to your application. Connect your 50Ω coaxial cables to the appropriate front panel BNC. See below for 1pps connections and use.

NOTE:

If you plan to use your 2960AR or 2965AR as part of a calibration system or house standard, it is suggested that it be powered from an uninterruptable power supply (UPS) (along with your 1pps source, if used).

3.3 **RS232 Installation (2965AR only).** To use the 2965AR internal synthesizer with the RS232 serial interface, connect your host computer to the 9-pin rear-panel connector with the provided cable. Please note that the data **TO** the 2965AR is on pin 3; the data **FROM** the 2965AR is on pin 2 and the **COMMON** return is on pin 5. Set your host to 19.2 kbaud, 8 bits, 1 stop bit, no parity and no hardware flow control. See Table 2 for RS232 Serial Commands.

NOTE:

The 2965AR is provided with a 2 meter RS232 cable. If you require a different length, please note that a DB9 male-to-female, straight-through connection is required. Only pins 2, 3 and 5 are used.

3.4 The serial commands are not case sensitive. There must be a space after each command except `R`, `C`, `S`, `Qr` and `Qe`. End with any combination of `CR`, `LF` or `CRLF`. Received commands result in a response code being returned per Table 1. Codes beginning with a `'?'` indicate illegal or unrecognized commands.

Table 1: RS232 Response Codes

Repsonse Code	Meaning
`OK`	Good command received (not sent for Reset, C, Qr and Qe)
`?0`	Unrecognized Command
`?1`	Bad Frequency
`?3`	Input line too long

3.5 The command `'Qr'` returns the values in the volatile RAM of the instrument. The values returned reflect the present output and state of the 2965AR synthesizer and are as follows:

```
F 12.345678901234
45 06 03 1B 05 00 00 02
```

3.6 The first line shows the output frequency in MHz to 1μHz resolution. All twelve digits are always sent. The next line has hexadecimal values showing the present state of internal registers. These values will only be the same as those from the `'Qe'` command if the values have been unchanged or a `'S'` command has been executed. They are reserved for factory use.

3.7 The command `'Qe'` returns the stored values in the non-volatile EEPROM of the instrument. The values returned reflect the last saved state of the 2965AR synthesizer and are as follows:

```
F 12.345678901234
45 06 03 1B 05 00 00 02 00 EF FF B7 01
```

3.8 The first line shows the output frequency in MHz to 1μHz resolution. The next line has hexadecimal val-

Table 2: Synthesizer RS232 Serial Commands (2965AR only)

Serial Command	Function
F xx.xxxxxxxxxxx	Set Frequency in MHz to nearest 1μHz. Decimal point required.
E x	Serial Echo Control. x=D for Echo **D**isable, x=E for Echo **E**nable. Default is **E**nabled.
S	Save current state into EEPROM and sets valid flag. State saved is used as default upon next power up or reset.
Reset	Reset. This command resets the instrument. EEPROM data is preserved and, if valid, it is used upon restart. (The command 'R' also performs this function.)
RbR	Reset the Rubidium Oscillator. This sets the internal Rubidium settings to the last internally saved values. Does not affect the synthesizer output. Restarts 1pps tracking time.
C	Clear. This command clears the EEPROM valid flag and restores all factory default values (5MHz output).
Qr	Query the volatile (RAM) memory storage. These are the values currently output by the synthesizer. These will equal the stored values in the EEPROM after a 'Reset' or power up only if no changes have been made in the settings.
Qe	Query the non-volatile memory (EEPROM) storage.

ues showing the saved state of internal registers. These are for factory use.

3.9 **Signal Outputs.** The 2960AR has three front panel outputs of 10MHz, 10MHz and 5MHz. Each has a nominal amplitude of 1Vrms into 50Ω. The 2965AR has three front panel outputs of 10MHz, 5MHz and a 50MHz synthesized output. Each has a nominal amplitude of 1Vrms into 50Ω.

3.10 See section 5.0 for the rear panel 1pps IN and OUT characteristics and use.

4.0 Operation

4.1 **Power on.** After power is applied, the 2960AR/2965AR **POWER OK** LED will illuminate green. This indicates that the applied line power is within tolerance and the unit is functioning.

4.2 **Rubidium Warm-up.** After power is applied, the 2960AR/2965AR will take up to 20 minutes to reach Rubidium Lock. During Rubidium warm-up time, the front panel LED labelled **RUBIDIUM LOCK** will illuminate red. When the lock has been achieved ($\Delta f/f < \pm 1x10^{-8}$), this LED will illuminate green. This function is independent of 1pps tracking.

NOTE:

*During the Rubidium locking process, the front panel **RUBIDIUM LOCK** LED may switch between red and green. A steady green indicates LOCK.*

4.3 Proper operation in stand-alone mode, without a 1pps connection, is indicated by a green **POWER OK** LED and a green **RUBIDIUM LOCK** LED. The 1pps LED will remain off.

NOTE:

The 2960AR and 2965AR will meet their specified accuracy within a few hours after power-up. For applications requiring verification of long-term stability, the periods shown in the specifications will have to be met.

4.4 See the section "1pps Operation," below, for details on 1pps connections and operation.

4.5 **Serial control of Synthesizer (2965AR only).** The user host computer software must properly format the serial commands. Incorrect formatting will result in an error code being returned. See Table 1 for a list of RS232 error codes.

4.6 Depending upon your host, the 2965AR may not be able to keep up with serial characters. For maximum interface speed, it is suggested that Echoing be disabled by the "E D" command. This will allow the host to send characters at a faster rate. Flow control must be provided by the host. The 2965AR will respond with an "OK" for a correctly received data command. If your host software parses this "OK", you will be assured that the command has been correctly received and you may send your next command. You will have to verify correct operation at your host rate.

5.0 1pps Operation

5.1 **1pps In and Out.** Both the 2960AR and 2965AR are equipped with rear panel BNC receptacles which accept a 1pps input and provide a 1pps output. Use of 1pps allows synchronization of multiple 2960AR and 2965AR, as well as providing a means of auto-calibration.

5.2 The 2960AR and the 2965AR will accept a long-term stable 1pps signal, typically derived from a GPS (global positioning system) receiver or from another frequency standard. Both units will auto-adapt to the supplied 1pps and adjust the internal Rubidium Oscillator to match the long term average frequency derived from the 1pps. The auto-adaptive algorithm selects the best tuning time constant based upon the stability of your supplied 1pps.

5.3 For low-jitter 1pps inputs (<20ns), the approximate tuning time constant will be 1,000 seconds. A typical timing receiver system, such as the GPS1 (with approximately 100ns peak-peak 1pps jitter), requires a time constant of approximately 10,000 seconds (about 3 hours) for optimum tracking.

5.4 For noisier 1pps inputs, such as those from standard GPS receivers not intended for timing applications, the time constant may increase to 100,000 seconds. If the input is too noisy, as deter-

mined by the auto-adaptive algorithm, the **1 PPS LOCK** light will not illuminate.

5.5 Proper operation when tracking a 1pps signal is indicated by all three front panel LEDs illuminated green.

NOTE:

Due to these long time constants necessary to track a 1pps input, temperature variations can cause fluctuations in the relative phase of the 10MHz output and the 1pps output.

NOTE:

The Δf/f tracking range of the internal Rubidium oscillator is approximately ±1x10^{-8}. If your 1pps source is in error, but within these limits, the 2960AR/2965AR will adjust to your source. This allows multiple units to by synchronized even in the absence of an absolute reference.

CAUTION:

Do not connect the 1pps input and 1pps output on an instrument together. This will force the instrument to track a moving value and reach its adjustment limit.

5.6 The 2960AR and 2965AR are configured for automatic self-calibration. When continuously connected to a stable 1pps source, they will auto-save the disciplined frequency value into non-volatile calibration memory every 24 hours. The last-saved value will be used at next power on or when 1pps is lost. The 1pps output of a calibrated and tracking 2960AR or 2965AR has lower jitter than a typical GPS receiver making it suitable for use as a master oscillator for further 1pps systems.

6.0 PERFORMANCE TEST

6.1 The performance test detailed below verifies the functions of the 2960AR and the 2965AR.

NOTE:

Verification of the frequency and frequency stability of the 2960AR or 2965AR requires a laboratory environment of 23^{o}C ±5^{o}C.

6.2 See Table 3 for a list of recommended test equipment to perform the following measurements.

Table 3: Recommended Test Equipment

Item	Minimum Specification	Recommended
Oscilloscope	300MHz, 50Ω termination	Tektronix TDS3032B
Frequency Counter	100MHz, 12-digits.	HP53132A
Counter Time Base	<±1x10^{-11}	Novatech Instruments, Inc. Model 2965AR with GPS1 smart antenna.

6.3 **Verify Frequency Accuracy.** To verify the frequency of the 2960AR or 2965AR, set the frequency counter to display 12-digits of resolution. The frequency counter must use an external time base of accuracy better than ±1x10^{-11}.

6.4 Verify the correct frequency at each output (for 2965AR, also verify at the frequencies in Table 4). Allow the counter to average several readings. See Table 4 for frequency error limits.

6.5 **Amplitude Verification.** Establish a measurement function of Volts RMS on the oscilloscope. Connect a 50Ω coaxial cable from the 2960AR or 2965AR to the oscilloscope (set to 50Ω termination) Verify an amplitude of 1.0Vrms±0.25Vrms on each output.

6.6 This concludes the verification of the 2960AR.

6.7 To verify the synthesizer output on the 2965AR, install the 2965AR as directed in the Serial Operation part of Section 3. Connect your host controller and operate the 2965AR per Section 4. The test limits assume a stable environment of 18-28^{o}C.

6.8 **Output Flatness Verification.** (2965AR synthesizer output only). Set the 2965AR to the values of Table 4. Using the Vrms measure of the oscillo-

scope, verify that the readings are within the tolerances shown.

Table 4: Frequency Test Points

Frequency	Δf	Tolerance
100kHz	±5μHz	1.0Vrms±0.25Vrms
1MHz	±50μHz	1.0Vrms±0.25Vrms
5MHz	±250μHz	1.0Vrms±0.25Vrms
10MHz	±500μHz	1.0Vrms±0.25Vrms
30MHz	±1.5mHz	1.0Vrms±0.5Vrms
50MHz	±2.5mHz	1.0Vrms±0.5Vrms

6.9 This concludes the verification test of the 2965AR.

7.0 CALIBRATION

7.1 The 2960AR and 2965AR require no routine adjustments for typical operation.

NOTE:

There are no periodic user adjustments required for operation of the 2960AR or 2965AR. When necessary, calibration should be performed "closed-case" using an external 1pps source.

7.2 Closed-case calibration is obtained by connecting the instrument to a known stable and accurate 1pps source, such as a GPS1. (Faster tracking is obtained by using another 2960AR/2965AR already tracking and stabilized to a 1pps source.)

7.3 Verify that the 1 PPS TRACKING light illuminates green. A stable 1pps source will allow this illumination within 15 minutes after connection.

7.4 Leave the unit tracking the 1pps in a stable environment for a minimum of 5 days. During this time, the internal auto-adaptive algorithm will measure and qualify the 1pps source adjusting the frequency to the long term average of the 1pps source.

7.5 Best calibration performance is obtained in an environment stable to $23^oC \pm 3^oC$ *or better.*

NOTE:

The auto-adaptive frequency adjustment has a resolution of $\pm 5.12 \times 10^{-13}$.

7.6 Longer calibration periods are indicated for obtaining maximum performance from the 2960AR or 2965AR. Whenever possible, the units should remain connected to a stable 1pps source.

WARRANTY

NOVATECH INSTRUMENTS, INC. warrants that all instruments it manufactures are free from defects in material and workmanship and agrees to replace or repair any instrument found defective during a period of one year from date of shipment to original purchaser.

This warranty is limited to replacing or repairing defective instruments that have been returned by purchaser, at the purchaser's expense, to NOVATECH INSTRUMENTS, INC. and that have not been subjected to misuse, neglect, improper installation, repair alteration or accident. NOVATECH INSTRUMENTS, INC. shall have the sole right to final determination regarding the existence and cause of a defect.

This warranty is in lieu of any other warranty, either expressed or implied, including but not limited to any warranty of merchantability or fitness for a particular purpose. In no event shall seller be liable for collateral or consequential damages. Some states do not allow limitations or exclusion of consequential damages so this limitation may not apply to you.

All instruments manufactured by NOVATECH INSTRUMENTS, INC. should be inspected as soon as they are received by the purchaser. If an instrument is damaged in shipment the purchaser should immediately file a claim with the transportation company. Any instrument returned to NOVATECH INSTRUMENTS, INC. should be shipped in its original shipping container or other rigid container and supported with adequate shock absorbing material.

This warranty constitutes the full understanding between NOVATECH INSTRUMENTS, INC. and the purchaser and no agreement extending or modifying it will be binding on NOVATECH INSTRUMENTS, INC. unless made in writing and signed by an authorized official of NOVATECH INSTRUMENTS, INC.

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