AccuBeat Ltd.
Accurate Frequency and Time

RUBIDIUM FREQUENCY STANDARD

MODEL AR- 40A

OPERATION MANUAL

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Warranty:

The Rubidium Frequency Standard purchased under your order is warranted for one year against any defects in material or workmanship.
This warranty does not cover cases of improper operation.
Do not attempt to open the unit!

Warning:

Do not operate the unit before reading this manual.

Note:

The information and specifications included in this manual are subject to change without notice.

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CONTENTS

List of Figures:

CHAPTER 1: GENERAL INFORMATION

1.1. Introduction

This manual provides general information, maintenance and theory of operation for the Rubidium Frequency Standards model **AR-40A.**

1.2. General Information

Model **AR-40A** is an extremely small, very high performance Atomic Rubidium Frequency Standard designed to operate reliably in commercial applications.
AR-40A includes a high performance Oven Controlled Crystal Oscillator (OCXO) that is locked to the Rubidium Atomic Resonance thus maintaining its very high stability and accuracy.

The **AR-40A** owes its outstanding accuracy and superb stability to a unique frequency control mechanism. The resonant transition frequency of Rubidium 87 (6,834,682,613 Hz) is used as a reference against which the OCXO output is compared. The output is multiplied to the resonance frequency and is used to drive the microwave cavity where the transition is detected by electro-optical means. The detector signal is used to lock the frequency of the OCXO output, ensuring its Medium and Long Term Stability.

The unit contains a microprocessor, which optimizes its performance vs. external disturbances. It has a unique holdover mode, which keeps the internal OCXO running with the last memorized frequency when lock is lost.
In addition, a built-in synthesizer allows a very fine digital frequency control over a wide range (option).
The unit is a perfect replacement for larger and more expensive units available in the market today, as well as for high precision oscillators.

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1.3. Specifications

Parameter	Standard Version (*)	Options (**)
Output Frequency	10MHz, sine wave, +(12±2) dBm / 50 ohm	TTL, CMOS, other frequencies
Long Term Stability (Aging):	$<1x10^{-9}$ (1st Year Aging) $<5x10^{-10}$/year (from 2nd year)	
Short Term Stability (Allan Deviation):	$<3x10^{-11}$ @ 1sec $<3x10^{-12}$ @ 100sec	$<2x10^{-11}$ @ 1sec $<2x10^{-12}$ @ 100sec
Phase Noise:	<- 95 dBc/Hz @ 10Hz <- 130 dBc/Hz @ 100Hz <- 141 dBc/Hz @ 1KHz <- 148 dBc/Hz @ 10KHz	<- 100 dBc/Hz @ 10Hz <- 140 dBc/Hz @ 100Hz <- 149 dBc/Hz @ 1KHz <- 155 dBc/Hz @ 10KHz
Harmonics:	<- 35 dBc	<- 50 dBc
Spurious:	<- 75 dBc	<- 90 dB (10MHz ± 1MHz)
Warm-up:	5 min to lock 7.5 min to $5x10^{-10}$	3.5min to lock 5 min to $5x10^{-10}$
Supply Voltage:	15Vdc ±5%	12Vdc ±4%
Supply Current:	Steady state: ~0.6A @ 15Vdc	Steady state: ~0.8A @ 12Vdc ~0.4A @ 28Vdc
	Warm-up (<6min): ~1.7 A @ 15Vdc	Warm-up (<6min.): ~1.9A @ 12Vdc ~1A @ 28Vdc
Stability/Temperature:	$\pm2x10^{-10}$ max. over -5°C to +50°C	a) $\pm5x10^{-11}$ max. over -5°C to +50°C b) Extended temp. range, contact factory
Storage Temp:	-40°C to +80°C	
Frequency Adjust:	Mechanical: $\pm5x10^{-9}$	Electrical: $\pm1.5x10^{-9}$ min/ 0 to 10VDC
	Trimmer 10 turns.	Digital: $<1x10^{-12}$ steps / $>1x10^{-6}$ range Included in this option: a) Interface box for RS232 connection to PC. b) Software
Connectors:	D-Type Subminiature 9 pins (male): see below SMA: 10MHz	
Dimensions:	77 x 57 x 35.6 mm	
Weight:	260g max.	
Magnetic Field Sensitivity:	$<4x10^{-11}$/gauss	$<2x10^{-11}$/gauss
Hold-Over Mode:	If lock is lost, (e.g. at very high temperature or shock) the internal OCXO continues to provide an output frequency with the last saved frequency and with the very good stability of an OCXO.	
Reliability:	>261,000 hrs @ 25°C, G.B. >108,000 hrs @ 60°C, G.B. per MIL HDBK-217F	
Accuracy at Shipment:	$5x10^{-11}$	
Built In Test (Bit)	Detects > 97% of all failures. "1"=High Impedance=Unlock / "0"=Short to Ground=Ok (Lock)	
(*) All specs are defined at room temperature, unless otherwise specified (**) Some combinations of options are not available		

CHAPTER 2: INSTALLATION AND OPERATION

2.1. Introduction

This chapter contains a detailed description of the connector, recommended mounting, operating instructions and operating accessories.

2.2. SCD

The SCD (Specification Control Drawing) in **figure 1** shows the dimensions, connector type, location of the connector and mounting holes. There are two connectors:

2.1.1. SMA connector: RF output 10MHz, (12±2) dBm on 50ohm load.
Other frequencies, TTL or CMOS are optional. TTL output for maximum load 50ohm

2.1.2. D-Type Subminiature male, 9 pins. Pins functions are as follows:
pin 1 - Supply Voltage, 15.0 ± 1 Vdc, 1.7A max
Option: 11.5Vdc to 14V, 1.9A max @ 12Vdc
pin 2 - Ground
pin 3 - Lock Signal (Built in Test)
Under locked condition this pin will be shorted to ground (closed collector)
Under unlocked conditioned this pin is disconnected from ground (open collector)
pin 4 - Vref 5V (Option)
pin 5 - GND
pin 6 - TxD (Option, TBD)
pin 7 - For Factory use only
pin 8 - Freq. Adjust (Option)
pin 9 - RxD (Option, TBD)

2.3. Mounting

For optimized performance the unit should be mounted on a heat sink attached to the base plate. The heat sink surface area should be greater or equal to the Base Plate area and its thermal resistance equal or less than 1 deg/w. However, the unit works well also without the heat sink.
Mounting screws are 4-40 UNC type and should not exceed 5 mm hole depth.
Mounting holes locations are shown in **figure 1**.

2.4 Turn-on Procedure

Step by step turn-on instructions:

a) Mount the unit on a proper heat sink (see section 2.2).
b) Connect a BIT LED circuit (a proposed circuit is shown in **figure 2**).
c) Connect 15Vdc (or 12Vdc) to the Supply Voltage input.
d) Check that the current during warm-up and steady state are within the limits defined in the specifications
e) BIT LED should be illuminated after about 4 minutes.
f) Connect the RF output to oscilloscope and check the waveform and amplitude as per the specifications

CHAPTER 3: MAINTENANCE

3.1. Introduction

This chapter contains calibration instructions and malfunction indications. In general, the unit does not require scheduled maintenance. In case of malfunction it should be returned to factory for repair.

3.2. Calibration

Frequency drifts should be $<1x10^{-9}$ per year for the first year and $<5x10^{-10}$ per year afterwards. Therefore a periodical frequency calibration is recommended depending on the specific application/ requirement.
The calibration could be done in either one of the following 3 ways:

3.2.1. Mechanical calibration:
An adjustment trimmer is located on side of the unit below the "Calibration Sticker". One turn equals roughly $5x10^{-10}$ or more. The adjustment may be done as follows:
The unit is to be compared with a reference (e.g., GPS-Rb Clock AR-73A or Cs clock) by means of a high-resolution counter, or by an oscilloscope.

An example that explains how to calibrate by an oscilloscope:
A fractional frequency error of $1x10^{-10}$ results in time error of 100 nanosecond over a period of 1000sec. This could be observed on a fast oscilloscope by triggering the oscilloscope with the reference signal and measuring the phase drift on the oscilloscope in nanoseconds.

3.2.2. Electrical Analog calibration (option):
This is performed by connecting an external voltage, 0 to 10V, to pin 8, which allows adjustment range of at least $3x10^{-9}$. However, with this option the normal 10MHz is set at 5V and when the voltage is not connected the output frequency may deviate from 10MHz.

3.2.3. Electrical Digital calibration (option):
This is performed via pin 6 (TxD) and pin 9 (RxD).
When ordered, an operating software and instruction shall be provided.

3.3. Holdover Mode

The voltage on pin 3 in the D-Type connector signals the output of a Built In Test (BIT) mechanism that detects 97% of all failures. “0” logic (open collector) shows a proper lock of the internal OCXO to the Physic Package. “1” logic (short to ground) designate unlock condition.
When the BIT goes to “1” (unlock), the unit goes into a Holdover mode, where the internal OCXO, continues to provide a relatively accurate frequency output with the last saved frequency (from 1 hour before lock lost) and with a relatively good stability of a high performance OCXO. This allows time for replacement the unit and repair.

CHAPTER 4: PRINCIPLES OF OPERATION & DESCRIPTION OF MAIN SUB-ASSEMBLIES

4.1. Introduction

The chapter gives an overview of the principles of operation of a Rubidium Frequency Standard (RFS) and describes the main subassemblies in the **AR-40A** unit.

4.2. Functional Block Diagram

A functional block diagram is shown in **figure 3.** This diagram describes the Frequency Lock Loop (FLL) of the RFS. The main subassemblies are described in sections 4.3 to 4.5.

4.3. The OCXO

The oscillator is a high performance Oven-Controlled Voltage-Controlled-Crystal Oscillator (OCXO). SC cut crystal is optional.

4.4. The Physics Package

The Physics Package includes a Lamp Subassembly, a Cavity Subassembly, a "C-Field" Coil and double Magnetic Shield. The lamp is an RF discharge, Rb^{87} Lamp that emits a red light, which is directed into the Cavity Subassembly. The light is filtered by a Rb^{85} Filter Cell, transmitted through a Rb^{87} Resonance Cell and finally detected by a Photo-Diode Detector. The Resonance Cell is located inside the Microwave Cavity.
A Step Recovery Diode (SRD), located on the Cavity generates a nominal frequency of 6, 834, 622, 613Hz. When this frequency deviates from the precise Rb^{87} Resonance Frequency the Photo-Diode senses a change in the light transmitted through the Resonance Cell. This change is amplified by the Preamplifier and is used to control the OCXO as explained in section 4.5.
The atomic resonance frequency however is sensitive to external magnetic fields. Therefore a double magnetic shield is used to attenuate external fields by a factor of about 5000. The “C-Field” coils set the magnetic field. Controlling the current via this coil enables the mechanical and analog frequency adjustments that were described before.

4.5. THE Electronic Board

The electronic board contains the following circuits:
a. A multiplier circuit from 10MHz to 90MHz.
b. A Direct Digital Synthesizer that provides an adjustment frequency around 5.3MHz. This frequency together with the 90MHz is being injected into the SRD in the Physics Package.
c. An Digital FLL circuit that contains a preamp circuit, a microprocessor and a D/A.
The D/A provides a correction signal to the OCXO, locking it to the Rb atomic resonance frequency.
The microprocessor controls various functions of the unit including, the correction signal to the OCXO, the BIT circuit, the DDS and more.
d. Temperature control circuits to control the ovens in the Physics Package.
e. Power supply circuits which includes regulators and DC to DC power supplies to provide the various voltages necessary for the operation of the various circuit.

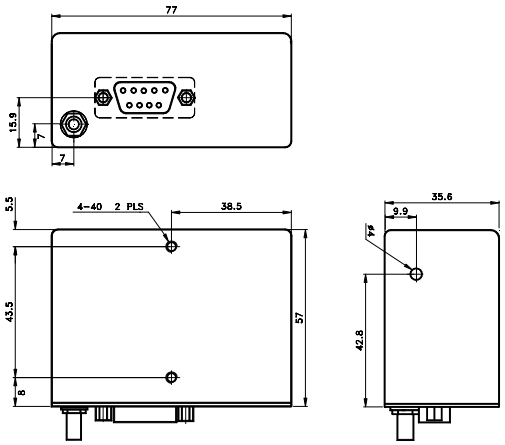
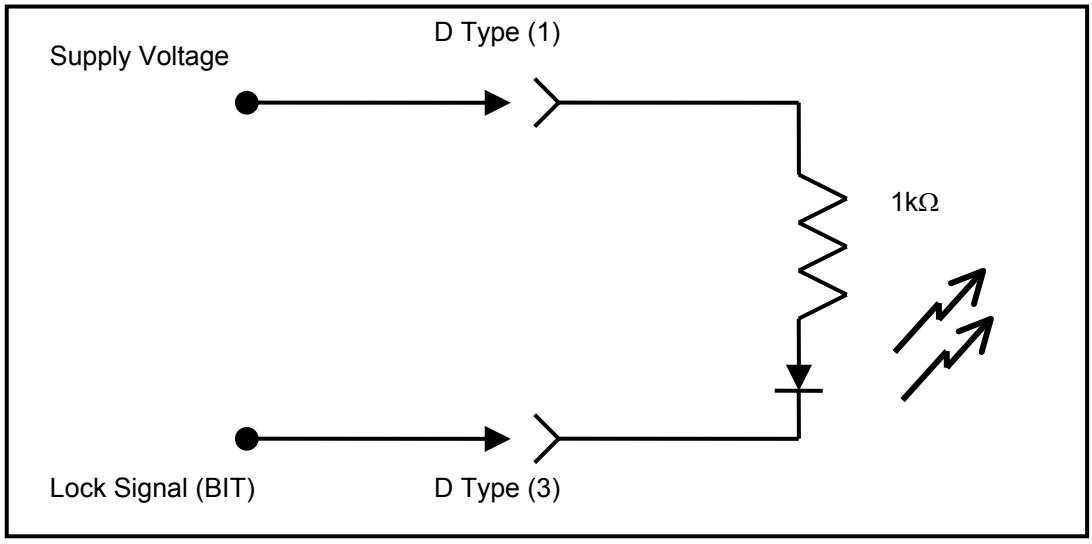


Figure 1: Outline Drawing Model AR-40A (measurements are in mm).

Figure 2: Built-In-Test LED circuit (proposed circuit to connect to the BIT pin)



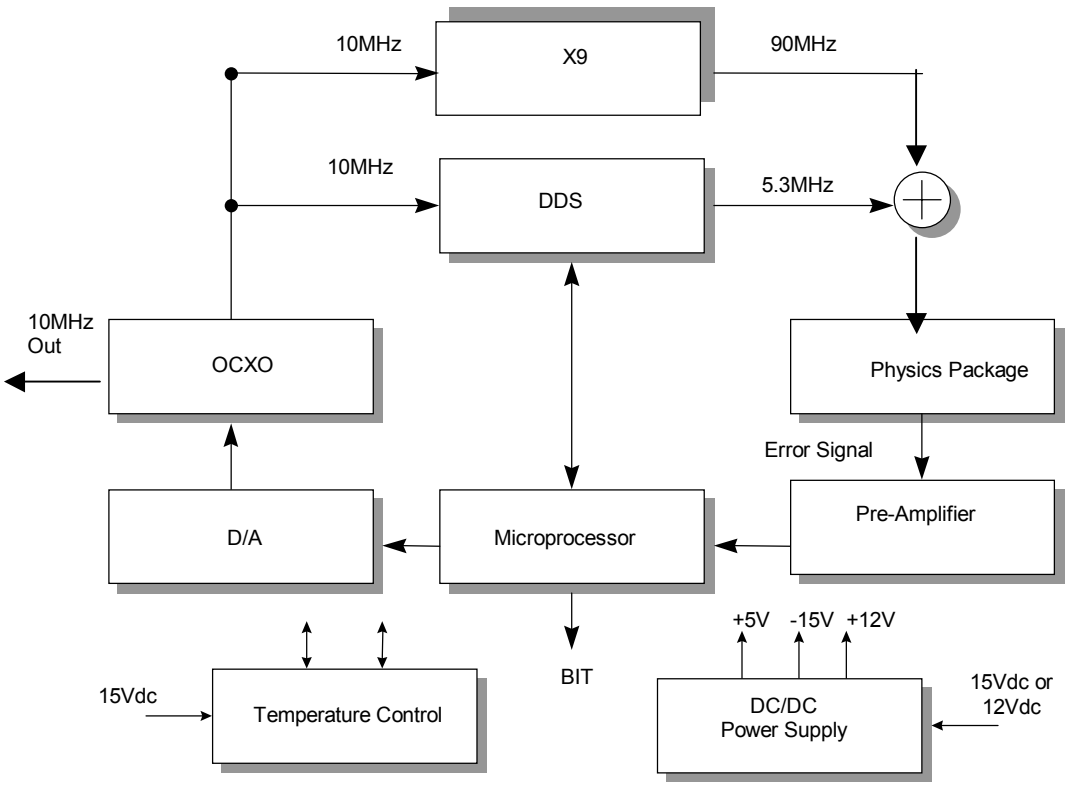


Figure 3: Functional block diagram, model AR-40A (basic model 15Vdc or 12Vdc))