TECHNICAL MANUAL

TM0110-2

RUBIDIUM FREQUENCY STANDARD

MODEL FE-5680A SERIES

OPTION 2

OPERATION AND MAINTENANCE INSTRUCTIONS

FREQUENCY ELECTRONICS, INC.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

Section 1. TECHNICAL DESCRIPTION

EQUIPMENT DESCRIPTION 1-1

General 1-1.1

The **Rubidium Frequency Standard (RFS) FE-5680A Series** consists of self-contained, solid-state, modular, atomic frequency standards available in various options, depending on the output frequency, package, and supply voltage requirements. The entire series may be grouped into several versions according to the output interface, which can be adapted to different requirements.

The simplest version provides a sine wave output at 50.255+ MHz (FE-5680A Option 01).

Another version uses a factory-set direct digital synthesizer (DDS) in the output interface allowing virtually any user specified output frequency from 1 Hz to 20 MHz for square wave and sine wave. The standard sinusoidal frequency generated by the **RFS** is 10 MHz. The following standard frequencies are also available: 2.048, 5, 10.23,13 and 15 MHz.

A third version incorporates a digital communication link in addition to the DDS output (FE-5680A Option 02). This enables remote adjustment of the output frequency by computer through an RS-232 interface.

Refer to Table 1 for a summary of the FE-5680A Series by option. Different options may be combined to form customized configurations based on output frequency, packaging and supply voltage requirements.

Controls 1-1.2

There is one external frequency adjustment control on the **RFS**. With the external frequency adjust potentiometer, the setting resolution is 1×10^{-11} over a range of 3×10^{-9}.

Packaging/Connectors 1-1.3

The standard **RFS** package is illustrated in Figure 1, and measures .98 x 3.47 x 4.92 inches.

Input power is supplied through a 9-pin D-subminiature connector. The RF output is supplied on an SMA coax connector.

Input/Output functions for the **RFS** are defined in Table 2.

Reference Data 1-1.4

Reference data applicable to the **RFS** are listed in Table 3. The data include output signal characteristics, environmental requirements and input requirements.

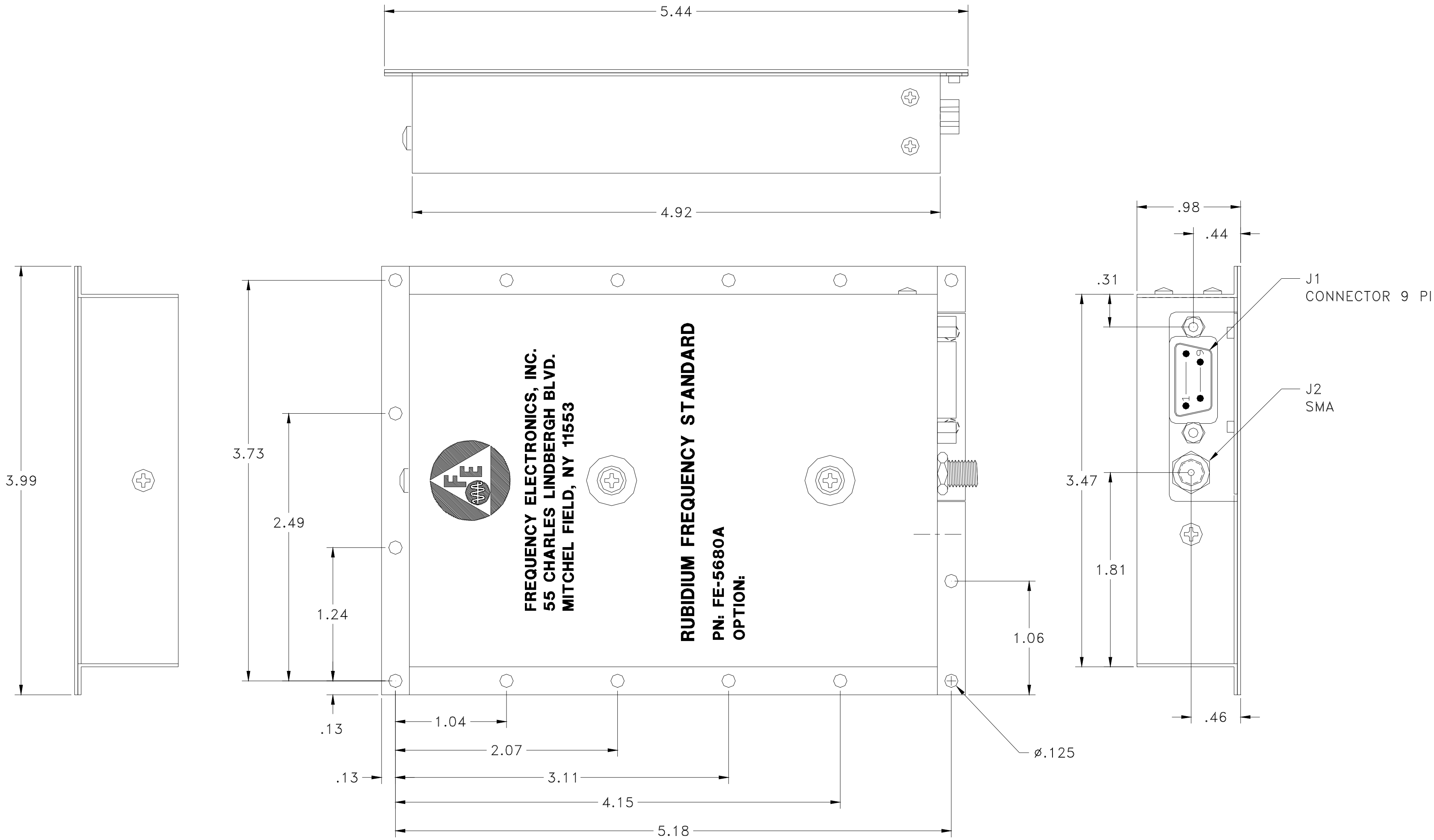

FIGURE 1. RUBIDIUM STANDARD OUTLINE MODEL FE-5680A

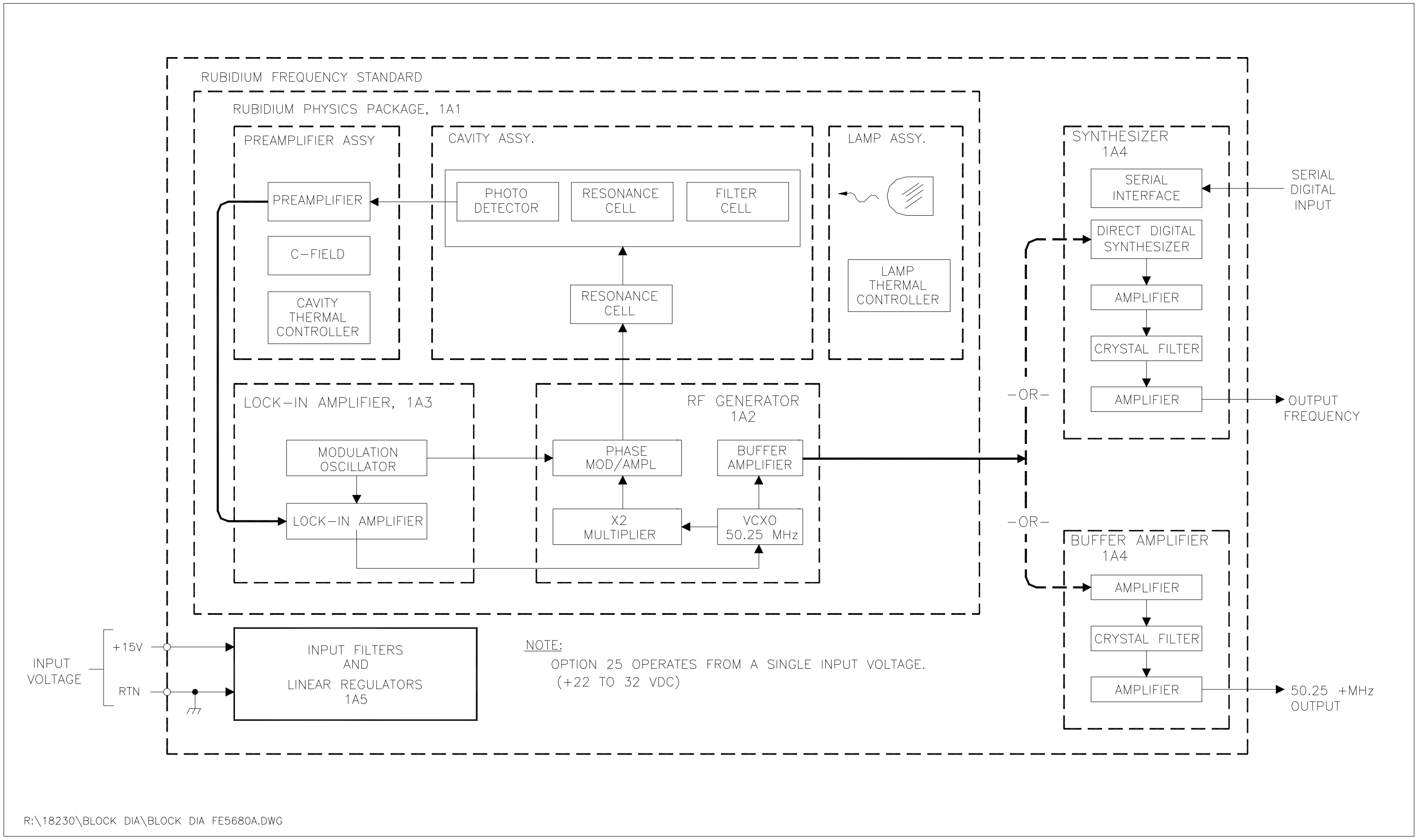

FIGURE 2. RUBIDIUM FREQUENCY STANDARD BLOCK DIAGRAM MODEL FE-5680A

TABLE 1. RUBIDIUM FREQUENCY STANDARD FE-5680A OPTION SUMMARY

OPTION	DESCRIPTION
01	50.255055 MHz Sine Wave
02	Remote Digital Control - RS-232; Resolution: 1.8 x 10^{-7} Hz
03	5 MHz-FEI Standard Frequency
04	15 MHz-FEI Standard Frequency
05	13 MHz-FEI Standard Frequency
06	2.048 MHz-FEI Standard Frequency
07	10.23 MHz-FEI Standard Frequency
08	Customer Specified Frequency – 1 Hz to 20 MHz.
09	Square Wave Output: TTL
16	Improved Spurious: -80 dBc at ±5 MHz from carrier.
18	Conformally-coated PC Boards
21	Increased RF output level of 1.0 Vrms (+13 dBm).
22	Unit is foamed for operation in severe shock and vibration environment.
25	Operates on a single +22 to 32 Vdc supply voltage instead of +15.
26	Loop Lock Indicator reversed < 1 Vdc = Unlocked > 3 Vdc = Locked
28	Improved Drift Stability: 4 x 10^{-12}/day and 5 x 10^{-10}/year
29	Improved Drift Stability: 2 x 10^{-10}/year after 1 year
30	Analog Tuning: 0 to 10V
31	Short Term Stability: 5 x $10^{-12}\sqrt{\tau}$
32	Frequency vs. Temperature: ±1 x 10^{-10}
35	Analog Tuning: 7 x 10^{-9} range
36-44	Extended temperature ranges from-55°C to +71°C
45	Drift Stability: 1 x 10^{-11}/month.
46	Reverse Voltage Protection.
48	Frequency vs. Temperature: ±5 x 10^{-11}.
50	Special Configuration # 1
55	Special Marking
57	Special Configuration # 2

TABLE 2A. CONNECTOR FUNCTIONS (EXCEPT OPTIONS 25)

PIN	FUNCTION	NOTES
J1-1	+15V	DC power input
J1-2	+15V Return	Provides DC return
J1-3	Loop Lock Indicator	Indicates whether or not the output frequency is stabilized to the Rb atomic reference
J1-4	NOT USED	
J1-5	GROUND	Provides DC return, RS-232 return
J1-6	NOT USED	
J1-7	NOT USED	
J1-8	RS-232 Rx	
J1-9	RS-232 Tx	
J2	Frequency Output	

TABLE 2B. CONNECTOR FUNCTIONS: OPTION 25

PIN	FUNCTION	NOTES
J1-1	+22 TO 32 Vdc	DC power input
J1-2	+22 TO 32V Return	Provides DC return
J1-3	Loop Lock Indicator	Indicates whether or not the output frequency is stabilized to the Rb atomic reference
J1-4	NOT USED	
J1-5	GROUND	Provides DC return, RS-232 return
J1-6	NOT USED	
J1-7	NOT USED	
J1-8	RS-232 Rx	
J1-9	RS-232 Tx	
J2	Frequency Output	

TABLE 3. REFERENCE DATA for RUBIDIUM FREQUENCY STANDARD FE-5680A

PARAMETER	SPECIFICATION
Frequency	10 MHz*
Type	Sinusoidal
Amplitude (minimum)	0.5 Vrms into 50Ω (+7dBm)
Adjustment Resolution	<1 x 10^{-12} over range of 3.8 x 10^{-5}
C-field potentiometer Resolution	1 x 10^{-11} over range of 3 x 10^{-9}
Drift	2 x 10^{-9} /year 2 x 10^{-11} /day
Short Term Stability: 1 sec ≤ 100 sec	1.4 x 10^{-11} t
Retrace	5 x 10^{-11}
Phase Noise (fo = 10 MHz)	@ 10 Hz: -100 dBc @ 100 Hz: -125 dBc @ 1000 Hz: -145 dBc
Input Voltage Sensitivity	2 x 10^{-11} / (15V to 16V)
Frequency vs. Temperature (-5°C to +50°C)	±3 x 10^{-10}
Spurious Outputs	-60 dBc
Harmonics	-30 dBc
Loop Lock Indication	> 3Vdc = Unlocked < 1Vdc = Locked
Input Power (@ 25°C)	11 watts steady state, 27 watts peak
DC Input Voltage/Current	15V to 18V @ 1.8A peak and 0.7A steady-state except Opt 25: +22V to +32V @ 1.25 peak, 0.5A s-state
Ripple	+15V: <0.1 Vrms
Warm-up Time	< 5 minutes to lock @ 25°C
Size	25 x 88 x 125 mm .98 x 3.47 x 4.92 inches
Weight	434 grams 15.3 0z.

***May be factory set at any frequency from 1 Hz to 20 MHz**

FUNCTIONAL DESCRIPTION 1-2

Frequency Lock Loop 1-2.1

The **RFS** uses the property of atomic resonance in a Rubidium Physics Package to control the output frequency of a 50.255x MHz Voltage Controlled Crystal Oscillator (VCXO) with a Frequency Lock Loop (FLL). The FLL functional blocks consist of the RF Generator, Lock-in Amplifier, and the Rubidium Physics Package. Figure 2 provides a functional block diagram of the RFS. Frequency locking of the VCXO is accomplished by operating the Rubidium Physics Package as a frequency discriminator, i.e., departures of a frequency derived from an input signal (50.255xMHz from the VCXO) from a defined center frequency (Rubidium atomic resonance) produce a dc output signal (control voltage). This dc output signal has a magnitude and polarity directly related to the magnitude and direction of deviation from the defined Rb center frequency. Once the FLL has been established, the system generates a loop-locked indication which can be monitored on pin 3 of the J1 connector. Depending on the option selected, the 50.255x MHz VCXO output is used as the clock input for direct digital synthesis within the Synthesizer or the Digitally Programmable Synthesizer, or the Buffer Amplifier.

Voltage Regulator 1-2.2

The RFS is powered by the Linear Regulator which requires a +15 Vdc input voltage. Input current requirements are 1.8A peak and 700 mA steady state for the +15 V input.

Option 25 is powered by a Switching Regulator which accepts a single +22 to +32 Vdc input voltage and supplies +15V to the RFS. The peak input current requirement is 1.25A: steady state operating current is 500 mA.

Rubidium Physics Package Operation 1-2.3

The Rubidium Physics Package incorporates a rubidium cell, rubidium lamp, and servo electronics to utilize the ground-state hyperfine transition of the rubidium atom, at approximately 6.834x GHz. The VCXO is locked to the rubidium atomic resonance in the following manner. The VCXO frequency of 50.255x MHz is an exact sub-multiple (÷136) of the atomic resonance frequency at 6.834x GHz. A microwave signal, having a frequency in the vicinity of 6.834x GHz, is generated from the nominal 50.255x MHz VCXO input. This microwave signal is used to resonate vaporized rubidium atoms within a sealed glass Rb resonance cell that is placed in a low

Q microwave cavity. The microwave frequency generation method is designed so that the VCXO frequency is exactly 50.255x MHz when the microwave frequency is exactly equal to 6.834x GHz. The frequency of the signal applied to the microwave cavity can be maintained equal to 6.834x GHz by generating an error signal when the frequency varies, and using this error signal to servo the VCXO via its control voltage.

The error signal is generated in the physics package. Light from the rubidium lamp, produced by an excited plasma discharge, is filtered and passed through the rubidium resonance cell where it interacts with rubidium atoms in the vapor. After passing through the resonance cell, this light is incident upon a photocell. When the applied microwave frequency is equal to 6.834x GHz, the rubidium atoms are resonated by the microwave field in the cavity; this causes the light reaching the photocell to decrease. The decrease in light, when the microwave frequency is equal to the sharply defined Rubidium frequency, is then converted electronically to an error signal with phase and amplitude information that is used to steer the VCXO via its control voltage and keep it on frequency at 50.255x MHz.

VCXO Operation 1-2.4

The VCXO operates nominally at 50.255x MHz. The VCXO has two isolated outputs; one output is provided to the Rubidium Physics Package for comparison purposes, and the other output is provided to either the Synthesizer or Remote Programmable Synthesizer, or to the Buffer Amplifier (for option 1).

Output Frequency Synthesis 1-2.5

Option 1 uses a Buffer Amplifier to provide a 50.255055 MHz non-programmable sinewave output. This version is for systems that have their own synthesis capabilities.

For options 03 through 07, standard output frequencies of 2.048, 5, 10.23, 13 and 15 MHz are provided by the Direct Digital Synthesizer (DDS) within the Synthesizer. Corresponding standard output frequencies and options are as follows:

Option	Standard Frequency (MHz)
03	5

04	15
05	13
06	2.048
07	10.23

Option 08 is reserved for customer specified output frequencies between 1 Hz and 20 MHz.

Option 09 produces a TTL wave output between 1 Hz and 20 MHz at a duty cycle of 50%.

Option 02 output is RS-232 remote-controllable with a resolution of $<1x10^{-12}$ Hz.

The basic functional blocks of the Direct Digital Synthesizer consist of a Phase Accumulator (which is clocked and tunable). A Look-Up Table (part of a ROM), a Digital-to-Analog Converter (DAC) and Alias Filter. The Phase Accumulator contains a BCD counter which accumulates changes in phase for each incoming clock cycle and then generates a linear progression of digital numbers (words) corresponding to phase of the desired output waveform. These words are then fed to the ROM Look-Up Table. In the Look-Up Table, each discrete phase point corresponds to a discrete amplitude value representing sampled value of a 360° sine function. The Look-Up Table can be considered a digital phase-to-amplitude converter. The digital words from the Look-Up Table drive the Digital-to-Analog Converter (DAC) which approximates the ideal amplitude value for a given clock cycles. The output of the DAC is a staircase waveform whose individual steps correspond to clock cycles. The output of the DAC is further filtered via an alias filter. The resultant signal from the DDS is amplified, passed through a crystal filter, and further amplified to produce standard output frequency waveforms with exceptional spectral purity including very low spurious, harmonic, and phase noise content.

Section 2. OPERATION AND USE

INSTALLTION 2-1

Site Selection 2-1.1

The selected installation site should be within standard ambient temperature and ranges as specified in Table 3, and should be free from strong surrounding magnetic fields.

Cabling Data 2-1.2

Use Table 4 to configure cabling for the **RFS**.

TABLE 4. CABLING DATA

DESIGNATION	UNIT CONNECTOR	MATING CONNECTOR
J1	DE9PU	DE9S
J2	SMA Female	SMA Male

TURN-ON PROCEDURE 2-2

Perform the following steps to verify the **RFS** is operating properly. If the unit does not meet all requirements refer to **REPAIR** section of this manual.

a. Connect power to the power conector (J1) of Rubidium Frequency Standard (**RFS**) under test.

b. For all options except Option 25: Connect pin 1 to a DC Power Supply capable of supplying +15 Vdc at a peak current of 1.8A.

For Option 25: Connect pin 1 to a DC Power Supply capable of supplying +22 to 32 Vdc at a peak current of 1.25A.

c. Connect pins 2 (all options) and labeled **return** to the DC Power Supply Return.

d. Turn on power and allow the **RFS** to warm up for 5 minutes.

e. Measure the **LOOP LOCKED** Indicator Voltage (pin 3) and verify it is less than 1 Vdc.

f. Measure frequency at SMA connector J2. (Note: frequency accuracy of the FE-5680A is better than most counters).

FREQUENCY ADJUSTMENT 2-3

Introduction 2-3.1

The FE-5680A output frequency can be adjusted digitally over the RS-232 interface (pins 8 and 9). This feature is available as option 2, and is not available on units purchased without this option. The frequency can be adjusted with a resolution of 1.7854E-7 Hz. For an FE-5680A device with an output frequency of 10 MHz, this corresponds to a relative frequency setting resolution of 1.7854E-14.

In order to perform frequency adjustments to the FE-5680A over the serial interface, commands conforming to the protocol described in this section must be sent. The signal levels must conform to the RS-232C requirements. Commands are sent to the FE-5680A using the TX line (pin 9), and responses from the FE-5680A are received on the RX line (pin 8). The TX and RX signals are referenced to system ground, pin 5.

This Section describes the serial message protocol between the FE-5680A and a computer.

Protocol Format 2-3.2

Each message is comprised of a command header and optional data. The command header has a command ID, message length and command checksum. Some messages may have data as well. If data is present, data is appended after the command checksum and its length is dependent of the specific command.

Command format:

[Command ID] [Message length] [Command checksum] [Data…Data…Data…] [Data Checksum]

Where:

Command ID – 8 bit unsigned integer
Message Length – 16 bit unsigned integer
Command Checksum – 8 bit unsigned integer
Data – Variable length data
Data Checksum – 8 bit unsigned integer calculated by taking the exclusive-or of each byte

Table 5 illustrates the byte ordering of the serial message protocol. If a particular command does not have any associating data, then the message length is 4 bytes.

Table 5

Message Section	Offset	Description
Command Header	0	Command ID
	1	Low-byte of message length
	2	High byte of message length
	3	Check of byte offset 0,1, and 2
Data	4	Data Byte 0
	5	Data Byte 1
	.	
	.	
	.	
	n	Data Byte n
	n+1	Checksum of byte 4 to n

Commands 2-3.3

2-3.3.1 Set Frequency Offset, Save to EEPROM – 2Ch

This command is used to perform a frequency adjustment which will be "remembered" by the FE-5680A. If the FE-5680A is turned off after this type of frequency adjustment, it will return to the adjusted frequency setting after being powered on at a later time. Typically this command is used for infrequent frequency adjustments used to correct the FE-5680A output for frequency aging effects.

The offset sent to the FE-5680A with this command is saved in EEPROM memory. The EEPROM can be written to at least 100,000 times with no loss of information, however, if too many writes are performed (more than 100,000) the validity of the stored values could become questionable. It is recommended that this command be used no more than once per hour. This insures a life of >10 years for the EEPROM memory.

Input Command: 2C 09 00 25 aa bb cc dd <cs>

Data:

aa bb cc dd — 32 bit signed integer where aa is the most significant byte and dd is the least significant byte of the 32 bit signed integer.

Data Length: 4 bytes

Command Length: 9 bytes

Remarks: This command sets the frequency offset. Value represents a 32 bit signed integer.

Range:
7F FF FF FF = 2,147,483,647 = +383 Hz
80 00 00 00 = -2,147,483,647 = -383 Hz

2-3.3.2 Set Frequency Offset, Don't Save to EEPROM – 2Eh

This command is used to perform a frequency adjustment which will ***not*** be "remembered" by the FE-5680A. If the FE-5680A is turned off after this type of frequency adjustment, it will return to the pre-adjusted frequency setting after being powered on at a later time. Typically this command is used for locking the FE-5680A to a more stable reference. There is no limit on how often this command can be sent to the FE-5680A.

Input Command: 2E 09 00 27 aa bb cc dd <cs>

Data:

aa bb cc dd — 32 bit signed integer where aa is the most significant byte and dd is the least significant byte of the 32 bit signed integer.

Data Length: 4 bytes

Command Length: 9 bytes

Remarks: This command sets the frequency offset. Value represents a 32bit signed integer.

Range:
7F FF FF FF = 2,147,483,647 = +383 Hz
80 00 00 00 = -2,147,483,647 = -383 Hz

2-3.3.3 Request Frequency Offset – 2Dh

Input Command: 2D 04 00 29

Command Length: 4 bytes

Response: 2D 09 00 24 aa bb cc dd <cs>

Data:

aa bb cc dd — 32 bit signed integer where aa is the most significant byte and dd is the least significant byte of the 32 bit signed integer.

Data Length: 4 bytes

Response Length: 9 bytes

Remarks: This command reads the Frequency Offset value. Value represents a 32 bit signed integer.

Section 3. REPAIRS

GENERAL 3-1

The Rubidium Frequency Standard (RFS) is not field repairable. All units that need repair should be shipped to the address given below. Prior to returning any units, contact the Marketing Department at extension 5030 to obtain an RMA number.

Frequency Electronics, Inc.
55 Charles Lindbergh Blvd.
Mitchel Field, NY 11553
Tel (516) 794-4500
Fax (516) 794-4340