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A precise reference frequency not only for your ham radio station
Rev 0.4

A ham radio station needs a stable reference frequency if you want to move to very high frequencies or operating modes with very narrow bandwidths.

Probably the worst case is reached if both aspects combine like it is the case in deep space satellite communication:
1.) Due to the very high distances between the satellite and the ground station the operating frequency is moved up to make use of high gain antennas with a reasonable size.
2.) At the same time the bandwidth of the signal is reduced to achieve higher S/N ratios.

I intend to prepare myself for the reception of deep space satellite signals as the next generation of ham radio satellites is in design and will hopefully be launched in the next 2 years. Therefore recently I started to work on a suitable concept for the local oscillator generation of my system.

I decided to buy a surplus Rubidium Frequency Standard and selected the model FE-5680A from Frequency Electronics Inc. After some search I bought mine from Guy Ovadia (guy@orcon-tech.com) who provided a very professional and kind service.

I have chosen a version of the FE-5680A module, which includes a DDS (direct digital synthesis) IC AD9830A from Analog Devices and thus provides a sinusoidal output signal of approx. 6 dBm with a user specified output frequency from 1 Hz to 20 MHz. This "Option 2" allows the remote adjustment of the output frequency by a computer through an RS-232 interface. Please note that there are multiple different versions of the FE-5680A available. This module has the size .98 x 3.47 x 4.92 inches respectively 25 x 88 x 125 mm. The input power of 15 V DC is supplied through a 9-pin Sub-D connector. The current consumption is approx. 2 A during the start-up time and once the operating temperature of the module is reached it is reduced to 0.75A. My module did not supply the RF signal outside the module nor was the RS232 connection externally available. You will find instructions on the necessary modifications later in this article.

Rubidium Frequency Standard FE-5680A

Here is the pin-out of the 9 pin SUB-D connector:

PIN	FUNCTION	NOTES
J1-1	+15V	DC power input
J1-2	GROUND	Provides DC return, RS-232 return
J1-3	Loop Lock Indicator	Indicates whether or not the output frequency is stabilized to the Rb atomic reference. Low output means it is locked. It should go low a few minutes after power up (it takes longer when the unit is cold). If you connect a 5-10 kOhm resistor from J1-1 to the anode of a LED and connect the cathode of the LED to J1-3, the LED will go on when the unit is locked.
J1-4	NOT USED	
J1-5	GROUND	Provides DC return, RS-232 return
J1-6	1 PPS output	1 pulse per second output signal
J1-7	NOT USED	
J1-8	RS-232 Rx	True RS-232 signal with ±12V
J1-9	RS-232 Tx	True RS-232 signal with ±12V

The parameters of the serial connection are: 9600 baud, 8 bits, one stop bit, no parity, no flow control.

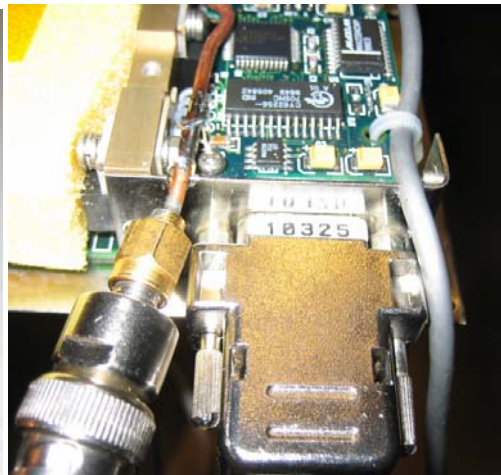Here are the technical data of my FE-5680A module:

PARAMETER	SPECIFICATION
Output Frequency	Programmable from 1 Hz to 20 MHz with a resolution of $<1 \times 10^{-12}$ Hz
Type	Sinusoidal
Amplitude (minimum)	0.5 Vrms into 50 Ohm (+7dBm)
Adjustment Resolution	$<1 \times 10^{-12}$ over range of 3.8×10^{-5}
C-field potentiometer Resolution	1×10^{-11} over range of 3×10^{-9}
Drift	2×10^{-9} / year respect. 2×10^{-11} / day
Short Term Stability: 1 sec 100 sec	1.4×10^{-11} t
Retrace	5×10^{-11}
Phase Noise (fo = 10 MHz)	-100 dBc @ 10 Hz, -125 dBc @ 100 Hz, -145 dBc @ 1000 Hz
Input Voltage Sensitivity	2×10^{-11} / (15V to 16V)
Frequency vs. Temperature	$\pm 3 \times 10^{-10}$ (@ -5°C to +50°C)
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
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 respectively 15.3 oz.

As my module did not supply the RF signal outside the module nor was the RS232 connection externally available I modified the module and routed these signals out. You can find pictures of the modification on the next pages.
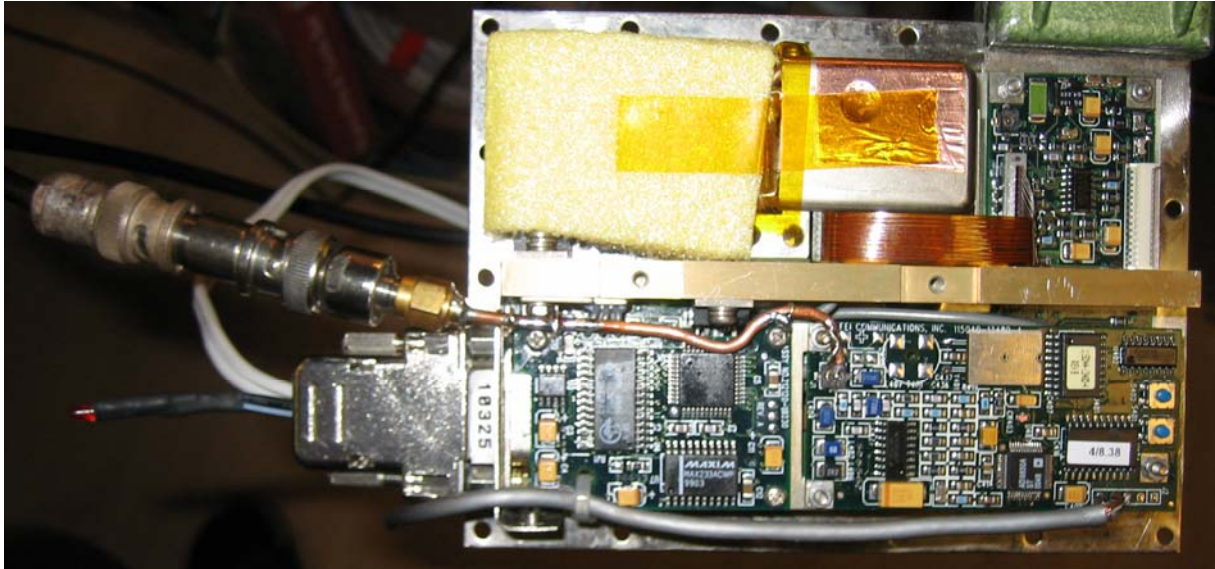
To route the signals outside the modules I had to make some modifications. I started with the lid of the cabinet where I added 2 openings around the Sub-D connector to route 2 additional cables to the outside.

Modified lid to route the RF and RS232 signals out   Left RF semi-rigid cable, right RS232 cable

This is the top view of the open FE-5680A module with the additional RF semi-rigid and RS232 cables. On top you see the physics package covered by foam for thermal insulation. On the bottom right you see the DDS (Direct Digital Synthesis) board where you find the RF- and the RS232 signals which have to be routed outside.
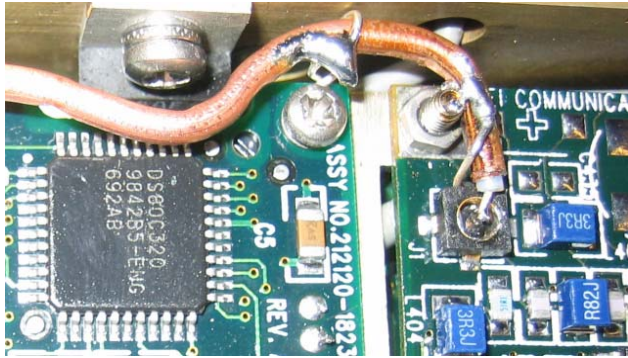

Detailed view of the DDS board where the 2 cables are connected to the PCB

Front view with closed lid and lock LED

Front view with closed lid

| Detailed view, where to tap the RF signal | Detailed view of the RS-232 connection |

The centre pin of the semi-rigid cable is soldered to the centre pin of the Hirose RF jack. The shield of the semi-rigid cable is soldered to multiple ground connections of the PCB.

The RS-232 signals are available at a 5 pin connector on the lower right of the DDS-PCB. Only the 3 leftmost pins are used. The signals at the connector, which I removed to solder the wires directly to the board, are from left to right:

PIN	FUNCTION	NOTES
1	GND	goes to Ground of the computer which is pin 5 on a female 9-pin Sub-D connector
2	TXD	goes to RXD of the computer which is pin 2 on a female 9-pin Sub-D connector
3	RXD	goes to TXD of the computer which is pin 3 on a female 9-pin Sub-D connector
4	+5V	don't connect it
5	+5V	don't connect it

Now it is time to verify that an output signal is available. Below please find the measured output spectrum of my module after start-up (when it is locked). As you can see, the default frequency is 8.388608 MHz (2^{23} Hz).
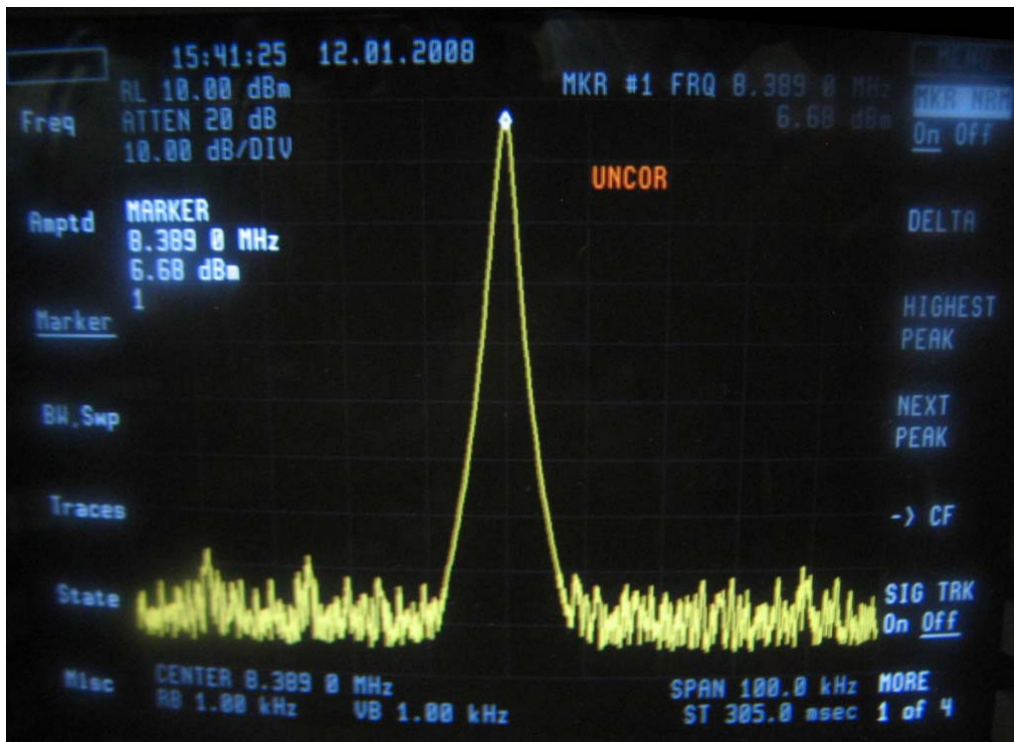
Measured output spectrum of FE5680A

Next the output frequency can be programmed. The instructions below for programming the unit were found on the internet in an article from Don Latham (see http://www.leapsecond.com/museum/fei5650a/). All credits are due to him for figuring out the commands and to Guy Ovadia (guy@orcon-tech.com) for providing them to me.

With the power supply disconnected you should connect the RS232 cable to the computer and the to the FE-5680A module. Now reconnect power to the device. Open a terminal program such as window's HyperTerminal. Configure the terminal program to open the COM port, which you connected the cable to. Set the terminal to 9600 baud, no parity, 8 data bit, 1 stop bit and no flow control.

Enter a capital "S" to the terminal, and press Enter. You should get a response similar to this:
R=50255057.012932Hz F=2ABB504000000000
If you don't get it, make sure your terminal program is set to output CR / LF characters when pressing Enter.

The command structure for setting the frequency is F=abcdefgh (+Enter).
Abcdefgh is a 4-byte hex word, such as 32AB56DF.

The output frequency is given by: $N / (2^{32}) * Fref$
Where:
"N" is the 4-byte hex word you entered (ranging from 0 to $2^{32}-1$)
"Fref" is a reference frequency of approximately 50.255 MHz.

The reference frequency is given by the R=xxxxx response to the "S" command you entered. You can also measure the reference frequency yourself. It is available at a test point at the top of the DDS board.

Here are the values I derived and used for my device:
R=Fref=50255056.353937 Hz
An output frequency of 8,388608 MHz with a level of 7,0 dBm was the result of F=2ABB503E3D4E4400.
An output frequency of 8,9733 MHz with a level of 7,0 dBm was the result of F=2DB5503E3D4E4400.
An output frequency of 10,000000 MHz with a level of 6,6 dBm was the result of F=32F0AB000000.

A more detailed description about the programming of the DDS IC AD9830A can be found in the respective datasheet, which you can download from the Analog Devices website.

In practice, it seems that the unit only likes frequencies somewhat close to the originally set frequency. There is probably a band-pass filter somewhere on the board that attenuates the signal for frequencies far from the original one. It has been reported by others that a frequency range of 1.5 MHz to 15 MHz gives a decent measurable output. I have not yet verified this myself. If you can find out where this bandpass filter is and how to change or remove it, it may be possible to get a wider frequency range – although it is probably limited by the Nyquist frequency of about 25 MHz. Please share your findings with me and I will be happy to add it to this little documentation.

Finally there is an "E" command that stores the frequency settings in a non volatile memory in the unit. It works fine and avoids the need to reprogram the unit after each power up unless you want to change the frequency.

To make life for all of us a bit easier, Duane C. Johnson (redrok@redrok.com) wrote a nice little program to conveniently operate the FE-5680A. He was kind enough to share it with us – thank you very much Duane.

The program is written in BASIC. Duane used Borland's Power Basic as this will also support COM4. You could also run it using native BASIC if you use only COM1 or COM2. Please note that the program will only start when the FE-5680A unit is properly connected and powered up.

The program includes:
1.) Native BASIC .bas source-code
2.) A compiled .exe executable
3.) A .cfg configuration file for selecting the com port and a preset frequency. Please make sure that this file resides in the same directory as the .exe file.
4.) Some notes in a .txt text file.

You can download the 4 files in a ZIP-archive named "FE5860A.ZIP" from Duane's website at http://www.redrok.com. The archive can also be accessed directly at http://www.redrok.com/FE5680A.zip. In case you might have trouble to access his website I will be happy to send you my latest copy by Email.

Duane C. Johnson also found out that you can greatly lower the acceptable minimum output frequency by soldering an electrolytic capacitor across the chip capacitor shown in the picture of the DDS board to the right. He used a 33uF capacitor because it was the smallest he could fit in the box but suggests that larger caps would be even better. Please note the polarity as marked in the picture !

I have not yet tried the modification myself but will certainly do so whenever I will open my module next time.
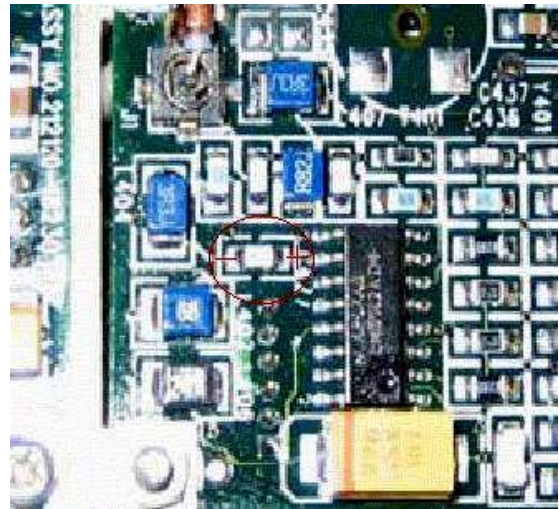
Capacitor to be modified on DDS board

I always appreciate feedback and suggestions for improvements. Please send it to my Email address below.

Many thanks in advance.

Best regards

Matthias

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