



**HIGHPOINT SECURITY
TECHNOLOGIES Inc.**

White Paper

45 – 430 MHz
RF Sweep Generator Design

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The following paper will describe the design of an RF generator capable of generating an RF signal between approximately 45 and 400 MHz. The output level of the generator is approximately -6dBm (0.25mW) into 75 ohms and approximately -12 dBm (0.125mW) into 50 ohms.

The block diagram of the generator is shown in Figure 1 below.

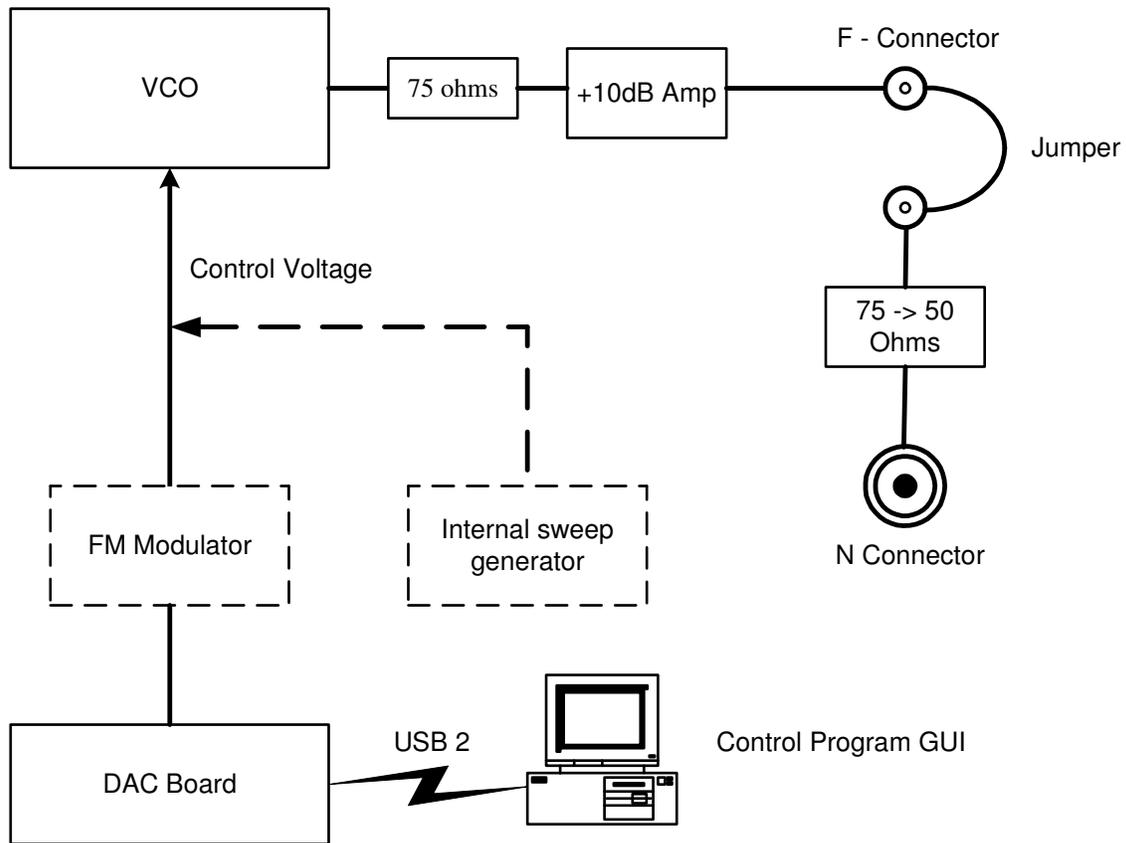


Figure 1 Block Diagram

The VCO is a modified cablevision tuner, available from The Science Workshop¹. The VCO is controlled by a USB project board². The output of the digital to analog converter is 0 to 5 volts. The VCO requires a 0 to 25 volt control signal. Therefore a high voltage operational amplifier with a gain of approximately 5 is used to amplify the output of the DAC.

^{1,2} Supplier information can be found in Appendix A at the end of this paper.

The amplifier has variable gain and offset control. The purpose for this will be outlined later in this document. Figure 2 shows the block diagram of the buffer amplifier.

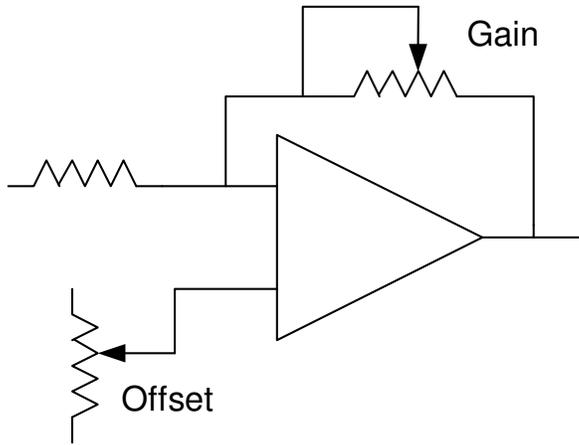


Figure 2 Buffer Amplifier

The output of the modified tuner is approximately -16dBm into $75\ \text{ohms}$. This signal is fed into a CATV amplifier with a gain of 10dB . This signal is then fed to the rear of the generator. The amplifier is used to provide signal gain, but also as a form of protection for the VCO.

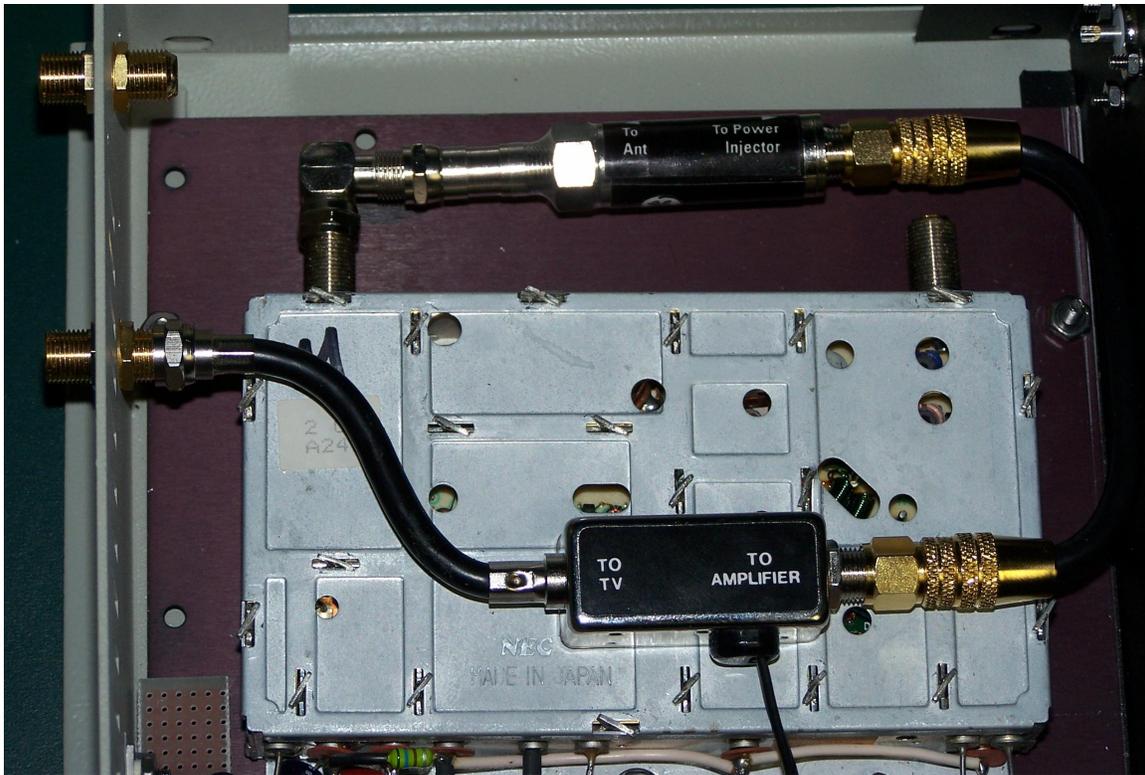


Figure 3 VCO and Power Amplifier

Figure 3 on the previous page shows the VCO and power amplifier connections. The small box marked “To TV - To Amplifier” is a power tap (transformer) used to power the 10dB amplifier. The actual amplifier is the black cylinder at the top center of the photo. On the left hand end of the amplifier is a DC block, which is used to prevent DC from entering the VCO.

Figure 4 below shows the analog control board.

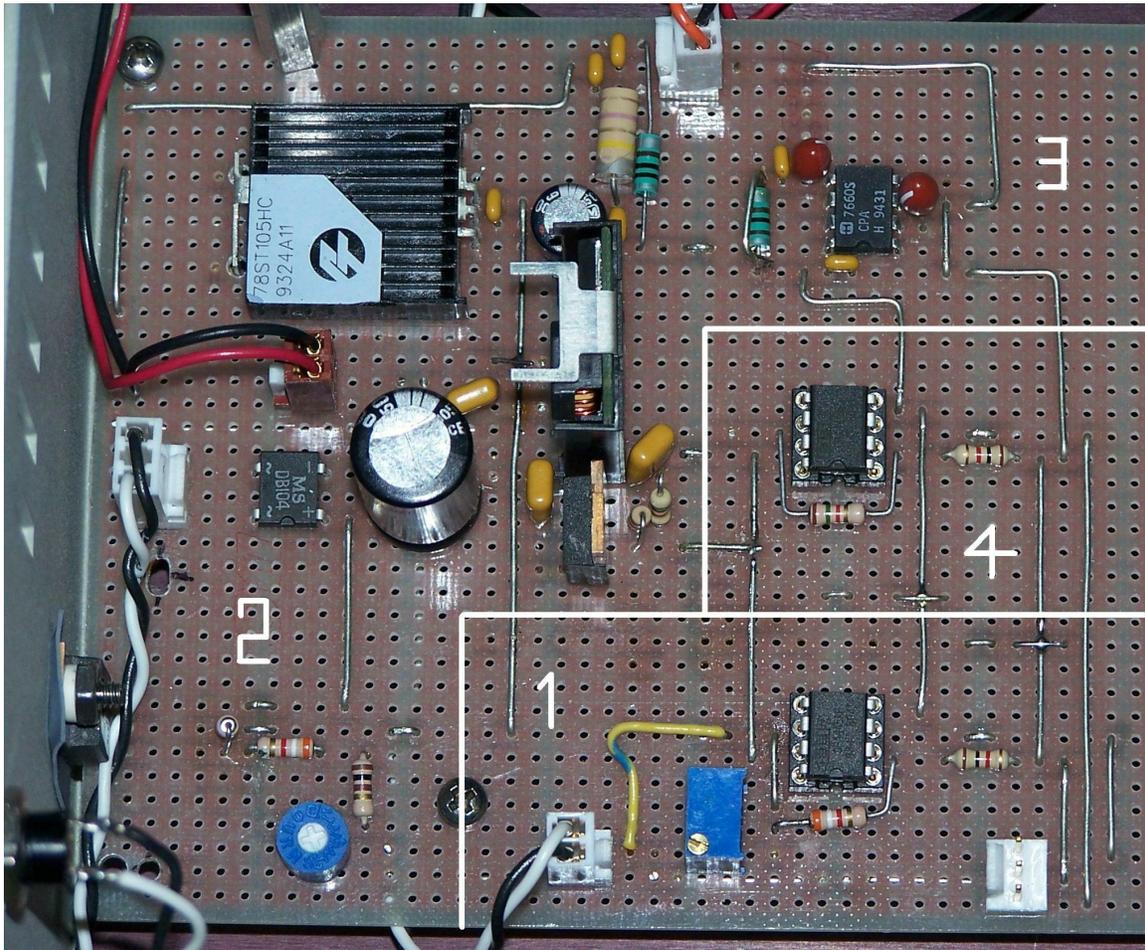


Figure 4 Analog Control & Power Supply Board

The board provides two main functions. As described earlier the signal from the DAC must be amplified in order to drive the VCO properly. This is done by section #1. Numerous voltages are required by the various components of the generator. The power supply sections 2 and 3 provide these voltages. The circuitry in section 3 is a switching inverter, which provides the $-5V$ required by the buffer amplifier. The signals from the DAC enter via the connector on the lower right of the photo. Section 4 has been reserved for future developments, which will be described later in this document.

Figure 5 below shows a top view of the generator. The board mounted on top of the analog board is the DAC board purchased from Velleman². On the left hand side of the photo you can see that the voltage regulators are mounted to the case for proper heat dissipation. On the top left is the 75 ohm jumper cable which is used to connect the 75 ohm rear output to the circuit which provides 50 ohm front panel output. This circuit has been removed for clarity.

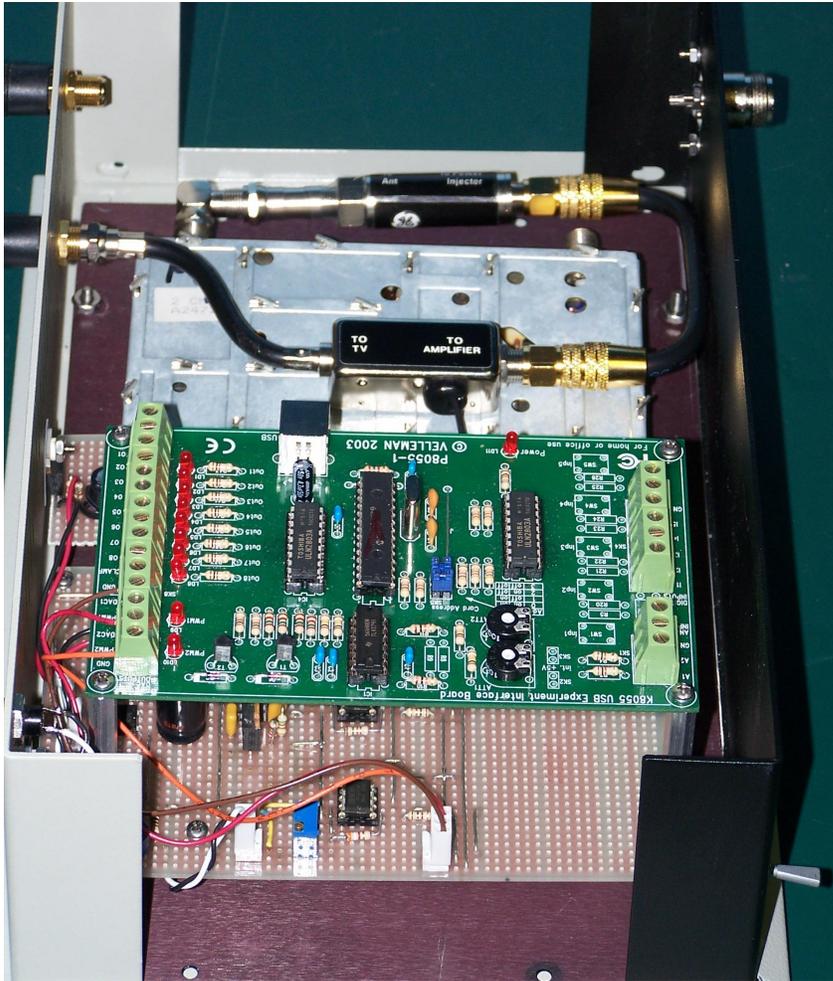


Figure 5 Top View

Figure 6 shows the Velleman project board. Most of the components on the project board are not required for the generator, and were not populated. The USB connector can be seen in the bottom left of the photo. While Velleman calls it a DAC output, the circuit, which actually produces the digital to analog voltage, is in fact a PWM (pulse width modulated) output that is passed thru a low pass filter. The output of this filter is a DC voltage. The residual PWM can cause unwanted modulation of the RF signal if the DAC output is not properly filtered.

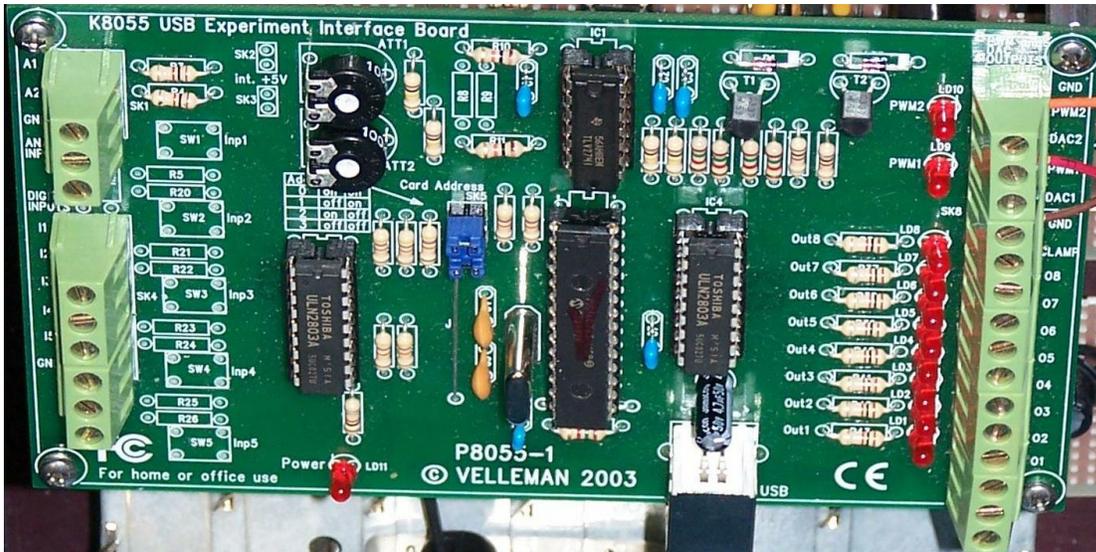
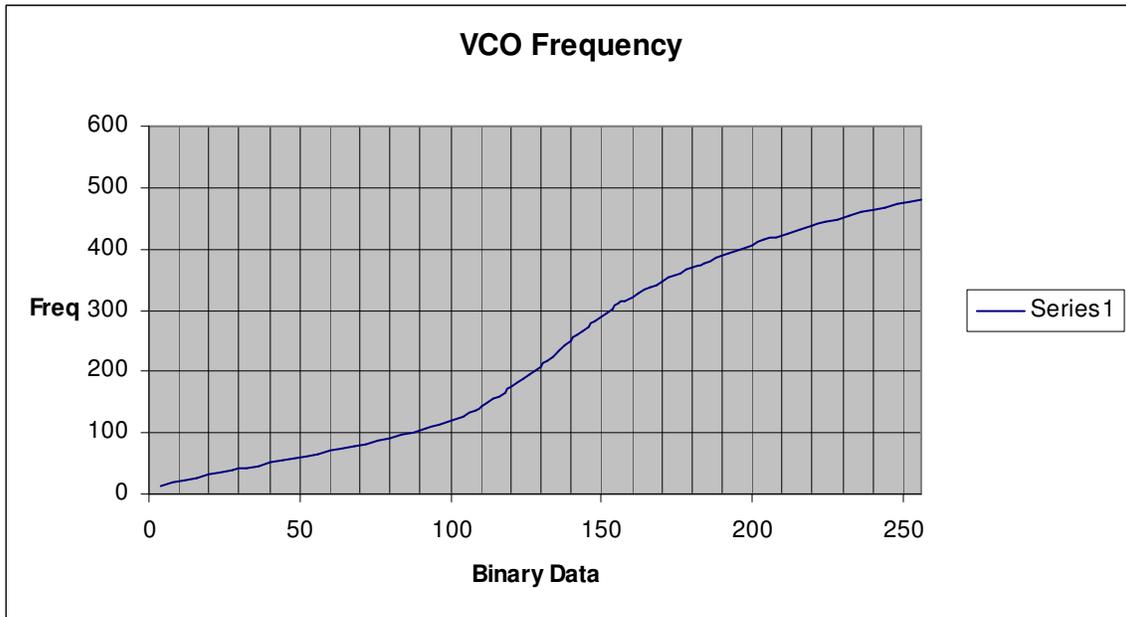
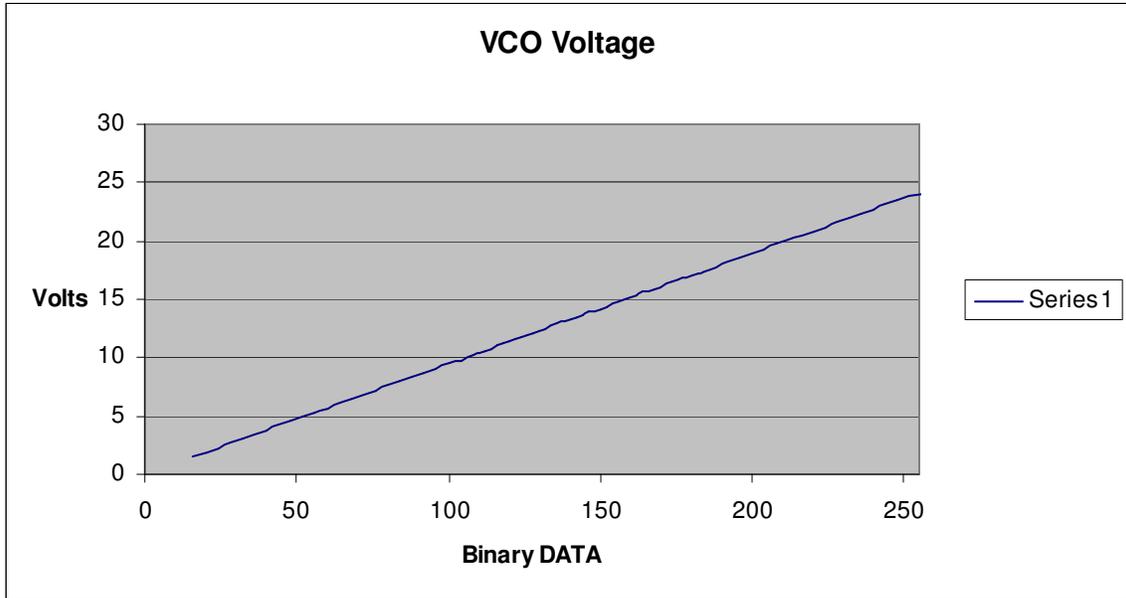


Figure 6 Velleman Board

The buffer amplifier provides more than just amplification. The VCO is controlled by a varactor circuit, that is non linear. For this reason the entire range of the varactor was not used. As you can see in the graphs below, the DAC output voltage is linear while the VCO frequency is not. For this a sweep range of 45 to 430 MHz was chosen. What is not shown in these graphs is that when the frequency output becomes non-linear, the RF output level also varies considerably.



The first revision of the buffer circuit did not have a DC offset control. It simply amplified the output of the DAC. By adding a DC offset control and a gain control to the buffer amplifier, we can calibrate the output of the DAC so that it falls within the linear portion of the curve. This will provide a greater dynamic range for the DAC. The current design must 'throw away bytes' at the beginning and end of the DAC's range. The actual decimal numbers sent to the DAC are 30 to 212. Almost 30% of the dynamic range of the DAC is lost.

This buffer design will be implemented in the next revision of the generator. Also an internal sweep generator capable of sweeping much faster than the USB controlled DAC can be purchased from The Science Workshop¹. I have not had a chance to test the board so I cannot say how suitable it would be. The faster sweep however may be useful for testing amplifiers and filters. The internal sweep circuit would be selected by a relay controlled by the Velleman board.

It may also be possible to FM modulate the RF signal by injecting an AC voltage into the buffer amplifier. These are hardware modifications, which may be implemented in the next revision of the generator.

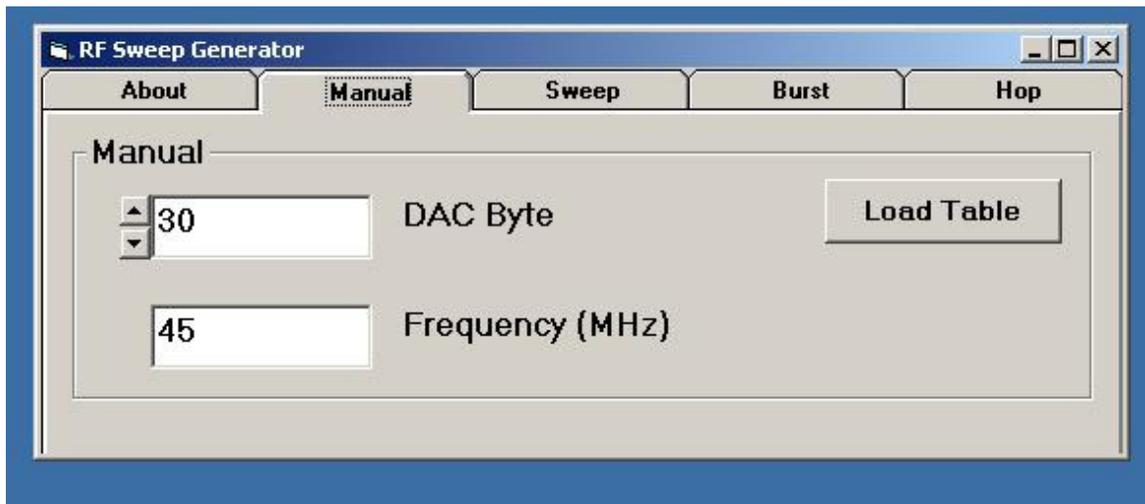
As you can see from the photographs, this generator is a prototype built from several modules. This was done so that each module could be designed, built and debugged separately. A mature design would consist of one large PCB with the VCO mounted to it. This would no doubt considerably improve the noise floor of the generator. The microprocessor can be removed from the Velleman board, and only the required components implemented on the PCB. The sweep circuit and FM modulation circuit could also be included on the PCB.

The next revision of the generator will be produced as and when time and finances permit.



Figure 7 User Interface

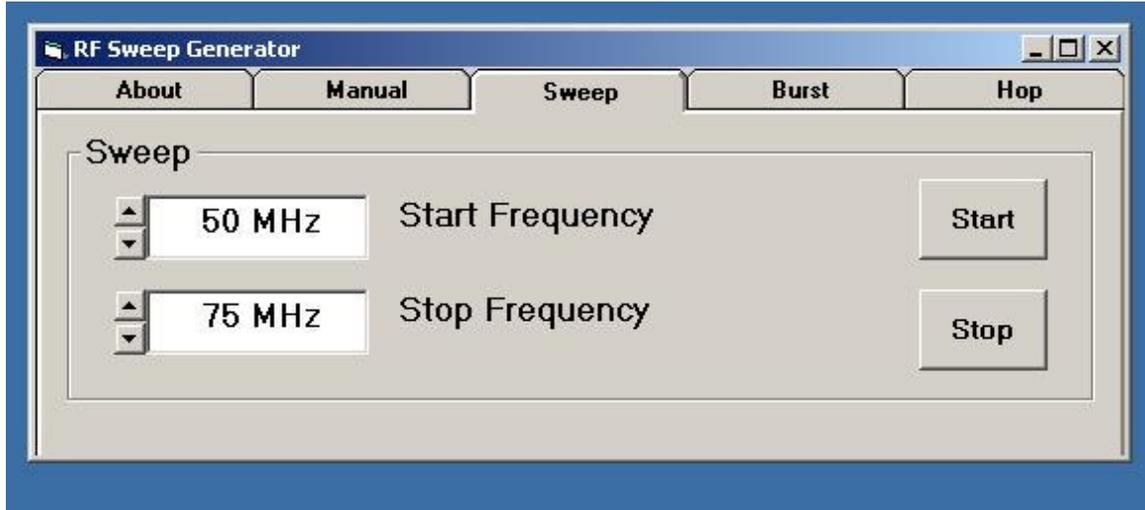
The Velleman experimenter board comes with a CD that contains a DLL and programming information so that control software can be written in a visual language like Visual Basic™ or Visual C++™. The GUI above was written in VB6 and is running on a Windows XP™ platform.



This GUI will allow the user to **Manually** change the frequency by pressing the up or down arrows. The 8 bit byte which is sent to the DAC is displayed in the box next to the arrows. This tab is used for frequency calibration.

No two VCO's are exactly the same. Therefore a table must be generated of DAC bytes and their corresponding frequencies. This table will be 256 entries long.

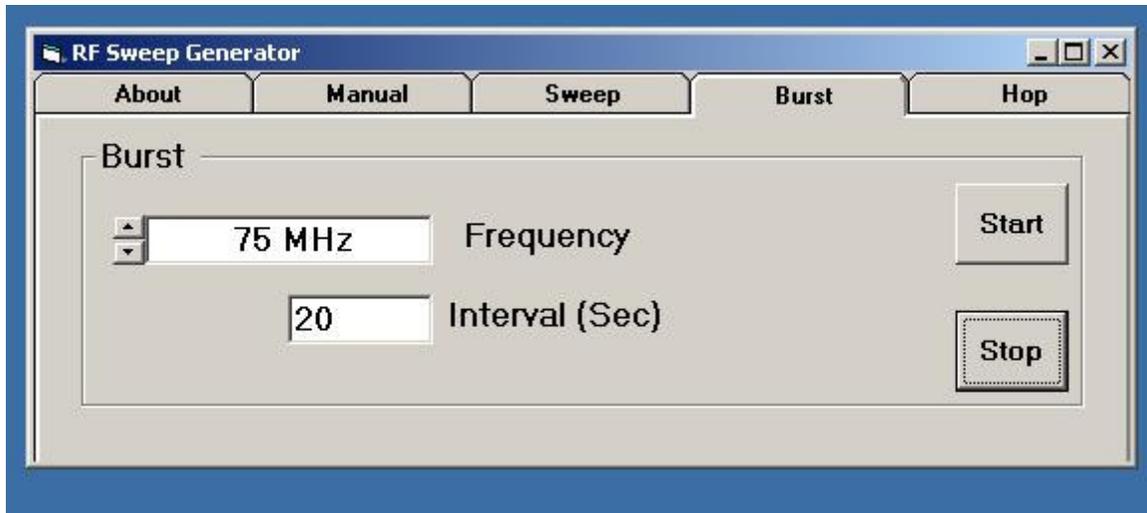
If the DAC buffer is adjusted so that a 0 from DAC produces a 45MHz RF signal then we have a resolution of $(430 - 45) / 256 \sim 1.5\text{MHz} / \text{bit}$.



The *Sweep* function is controlled by entering a start and stop frequency, using the arrows as in the manual mode. Pressing the *Start* button will start the sweep, while pressing the *Stop* button stops the sweep. Depending on the speed of your computer this may not happen immediately.



The *Frequency Hop* function is implemented by pressing the *Start* button. The signal will hop at random between the start and stop frequencies. Pressing the *Stop* button stops frequency hopping. The frequency changes once every second.



The **Burst** function causes the generator to produce a 500mS burst of RF energy at the frequency entered on the dial. The burst occurs at random time intervals.

An interesting addition to future revisions of the GUI might be a combination of Burst and Hop ...

The uses of this generator are limited only by the imagination of the programmer.

The following appendix provides information on where to purchase many of the devices mentioned in this paper.

Appendix A

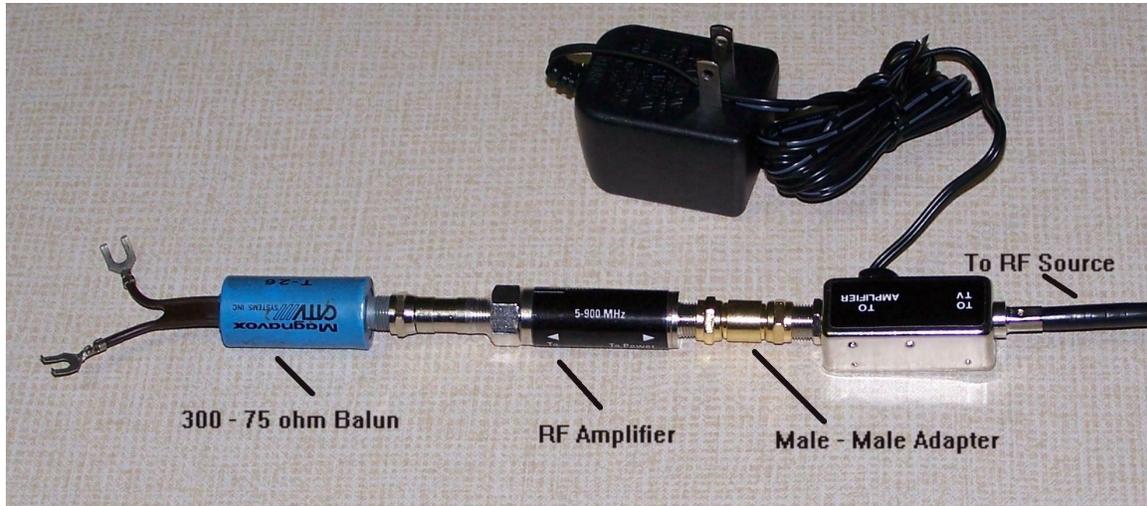
- 1) The VCO is available from Science Work Shop, where it is called a 'marker generator'. www.Science-Workshop.com
- 2) The USB card is available from www.vellemanusa.com or on Ebay from Ramsey Electronics. In either case you want the K8055 USB Experimenter Board.
- 3) Most of the other components are available from www.digikey.com
- 4) The 10dB inline amplifier was purchased on Ebay and is available from various sources including Radio Shack.



- 5) A CD that includes a parts list, software and source code is available from Highpoint Security Technologies. Email us for price and availability.

Appendix B

Here is an idea for a simple transmitter made from off the shelf parts. It may be necessary to add an attenuator between the output of the generator and the input to the amplifier. These are also available from Radio Shack. Look for a 6dB attenuator. This setup will work with any 75 ohm RF source, including a TV CH 3/4 modulator ...



Cut a dipole antenna for about mid-band and attach it to the balun. For those who forget the formula is: $\text{Wave Length(M)} = 300 / \text{Frequency (MHz)}$. You want about $\frac{1}{4}$ wave length antenna.