I. Overview

The Sweep/Function Generator as developed by L. J. Haskell was designed and built as a multi-functional test device to help radio hobbyists align antique and vintage radios and vintage audio equipment. The design is based on one Arduino Nano micro controller as the main processor plus 2 frequency generation modules based on the AD9850 frequency generator chip. There are 4 outputs and 1 input accessed via BNC type connectors. The functions of the device are:

1. A sine wave generator of 1 volt P-P with output frequency from 1 Hz to 40 MHz set in steps of 1 Hz.
2. A square wave generator of 5 volts P-P with the same frequency range
3. An RF generator of 1 volt P-P with a frequency range of 20 KHz to 40 MHz AM modulated from 0-100% by the sine wave generator output.
4. An RF sweep generator with above output and frequency range that can be sweep at multiple rates up to about 60 Hz.
5. A sweep voltage output generating a ramp voltage that can be used to drive an oscilloscope X-axis for a sweep alignment display
6. An input via BNC connector to measure the radio response during sweeps which allows for an internal display of sweep response displayed on the LCD screen. This can be used to display response signals instead of an oscilloscope.

II. Circuit Design

Refer to the schematic diagram in Figure A in the Appendix. Component U1 is the Arduino Nano micro controller that is programmed to provide all of the control and generates the settings for the other main components. DDS1 is the module that generates the sine and square waves and is based on the Analog Devices AD9850 chip. Likewise, DDS2 is a modified DDS generator that provides the RF output that is also amplitude modulated and can be set to generate a sweep of frequencies for the alignment operation. Component DAC1 is a digital to analog converts chip that is used to generate the ramp voltage signal for the oscilloscope X-axis display sweep while the signal is input on the Y-axis of the scope. These chips are then surrounded by support circuitry. At the top left is the 7805 regulator chip that supplies the 5volts for the rest of the board. Diodes D3 and D4 are used to drop the input 9 volts to 7.5 volts so that the 7805 will need to drop less voltage and thus operate cooler. If a 7.5 volt wall plug is used, these diodes can be removed and replaced with jumper wires. Component U5 is a 3 volt regulator to provide power to the LCD display. The IC marked U3 is a level shifter to buffer 5 volt signals to the required 3 volts signals to the LCD display. The circuitry surrounding FET transistor Q1 takes the signal output from the DDS1 generator module and uses that as an input to Q1 to provide a variable resistance and thus a variable current to DDS2. In this manner, the output of DDS1 will cause AM modulation of the output of DDS2. Transistor Q2 provides a buffered low impedance output of the RF signal from DDS2. The op amp U2.2 is used to buffer the input signal from the radio into the analog input of the Arduino Nano. Resistor R12 and R13 provide high input impedance while diodes D1 and D2 provide over and under voltage protection. The combination of R18 and C12 connected to Nano pin 10, provide a DC reference signal for level shifting of the
input so that a negative signal found in AGC circuits can be translated or shifted to a positive signal for the Nano pin A0 analog to digital converter.

III. Hardware Construction

The hardware design consists of a single printed circuit board containing all the components. By placing all components on the board, the case construction is simplified by simply bolting the board to the case enclosure. No additional wiring is required. Power is supplied by a 9 volt wall module supply into a standard power jack. A parts list is supplied in the appendix along with the Gerber file download file address for constructing the circuit board. Thus construction simply consists of populating the circuit board and inserting it into the enclosure. This guide assumes the user has knowledge of tools and techniques for building the circuit board.

An enclosure has been designed by the author using clear acrylic material cut using a laser machine. The template for that is supplied in the appendix.

Before the DDS9850 module used for the RF generator is inserted onto the circuit board, it must be modified. Note that ONLY the DDS2 module is modified. The circuit diagram of the module is shown below in Figure 1 for reference on the parts on the DDS module. A link to the application note which explains how to do the AM modulation is provided as a reference in the Appendix as AN-423.

Figure 1 - Circuit diagram schematic of DDS module
Figure 2 - Bottom view of DDS module

Figure 3 - Top view of DDS module
First is to bring the RSET pin (12) out to connector. To free up the pin you have to cut the trace pin labeled as DATA, which is the same as D7 so you actually are not losing any signals. This shows where to cut the track under the board. Cut the trace where the red arrow points. See Figure 2. Then remove the 3.9K resistor, R6. Finally solder a wire from 3.9k resistor R6 pad closest to the AD9850 chip to the freed up DATA pin. See the photo in Figure 3.

Second mod is to bring the current output pins directly, without load resistors connected to them, out of the board so that they can be hooked to transformer as shown in application note. The output filter on IOUT output (pin 21) also needs to be eliminated. I simply removed all filter components and load resistors from the board, the list of removed parts is R4, R9, C1, L1, C2, C3, L2, C4, C5, L3, C6, C7, R5. I used a fine needle nosed pliers to crush and remove the components rather than risk de-soldering and damaging other components or causing solder bridges all over the place. Then to connect the IOUT to ZOUT2 pin of the module you simply solder a wire from a pad closer to board edge of R4 resistor to pad of R5 resistor, also closer to the board edge. Don’t worry if you accidentally bridge the solder to the pad of C7 since R5 and C7 are connected on the board.

As the components are placed onto the printed circuit board, note the orientation of each part. As you likely know, parts like resistors have no polarity and can be inserted in either of 2 orientations. The top of the circuit board is stenciled with guides to show which part goes where and how it must be inserted. Refer to figure A2 in the Appendix. Note the red arrows that mark keys on the components that are guides for proper placement, e.g. a dot on pin 1 for ICs and a plus sign for the positive lead of an electrolytic capacitor. The LCD is mounted offset from the surface of the board using 1/2” spacers. This places it closer to the top cover of the enclosure for easier viewing. The header that is used is 8 pins whereas the LCD has 9 pins. That 9th pin is placed outside of the connector and hence makes no contact since it is not needed (MISO signal). There is a hole on the circuit board for it if the LCD is mounted directly on the board as you wish.

**IV. Software installation**

All software is contained in the single Arduino Nano micro controller. The device is normally sold with an onboard boot loader installed. The Arduino Development Environment, freely downloadable from the website [arduino.cc](http://arduino.cc). This tool provides a code editor, management of libraries, and an uploader to place compiled onto the Arduino Nano module.

Software is supplied as both source code and a pre-built image by the author and hosted on the author’s website. The web address is shown in the Appendix. The software can be downloaded onto your local PC or Mac and compiled then uploaded onto the Nano using a micro USB cable connected to the USB port on the Arduino Nano module. It is expected that software updates will be issued from time to time as users get experience and bugs are fixed or new features added. Each release has a README file which explains the changes in the software as well as instructions to compile and upload the code to the Arduino.

It is possible as previously mentioned to upload the code from a pre-compile file supplied in the release software without the need for a full development environment. This is done using a program called XLoader. This can be obtained at the website listed in the Appendix. It is
recommended however, that the user become familiar with the development environment so that local modifications and a deeper understanding of the code can be learned.

V. Operation Modes

VI. Operational Examples

A. User Interface Overview

The user interface consists of the LCD screen and is controlled by the rotary selector. The screen is used to set frequency of the 2 generator modules as well as select the mode of operation, the rate of sweep for the sweep mode, the position of markers for the internal display and the voltage offset for the input circuit. Refer to figure 4 below.

![Figure 4 - Basic screen overview - display at startup](image)

On initial startup, the screen displays the initial settings. On the left column are the settings for mode (functional mode) which can be set to one of 3 modes:

- **FIX**, which is a fixed frequency output for the RF generator (the Function generator is always fixed and not swept)
- **SWe**, which is the external sweep mode where the RF generator is swept across a range of frequencies, and a sync signal is generated for the X-axis of an oscilloscope
- **SWi**, where the RF generator is swept and the display for the response is set on the LCD screen itself with internal software providing a sweep for the display.

Next in the left column are the **Rate** setting which sets the sweep rate, then the **Mark** setting for the sweep markers on the internal display, and finally the **Bias** setting for the level shift on the input voltage. These setting will be discussed in the sections below.
In the right column are the settings for the FN, i.e. the function generator which sets the frequency for the sine, square, and the modulation frequency. Next is the RF generator setting, and finally, the BW or bandwidth setting for sweeping the frequency. To change any of the settings, the rotary selector is used. This is the control directly below the screen. As the selector is rotated, a selected digit is shown in the color white rather than the default color for that field. For example, in the display shown, the thousands digit of the function generator is highlighted. The selector will thus highlight, as it is rotated, each digit of every field, including both the frequency fields and the function/mode fields. After a digit is selected, the selector is pushed down to set its switch to modify. While the switch is held pushed down, rotating the selector will change the value of that digit. In this way, each digit of every field can be modified to the value required for the needed operation. A little awkward at first, but practice will make the operation go smoothly.

B. Fixed Mode for Function and RF Generator Operation

The FIX mode of operation is used to generator fixed frequencies on both the function generator and the RF generator. Note, of course, the the function generator always generates a fixed frequency. With the mode set to FIX, the frequency is set for the FN setting for the function generator and by modifying the RF setting, the frequency of the RF generator is changed. While in this mode the BW, Rate, Mark, and Bias settings have no affect of the operation. However, Amplitude Modulation of the RF generator by the frequency of the FN generator is active. To control the level of modulation, the R1 Pot (furthest left) is rotated to the desired level. To change the level of the FN generator sine wave, the R11 pot (lower center on the board) is used. The square wave output is not able to be adjusted but is fixed at 5 volts peak-to-peak. Finally, the level of the RF generator is set using the R6 pot, the furthest right control.

C. External Sweep Operation

In the external sweep mode, the device will output an RF signal at the set center frequency across a range of frequencies according to the bandwidth setting. In addition, the modulation is active and is set by the FN generator for the frequency and R1 for the modulation level. For example, is the display overview in Figure 4, we have an RF frequency of 455KHz and a bandwidth of 20KHz. So the sweep will run from 445KHz to 465 KHz. As the frequency is sweep, the voltage output on the Sync output, BNC 4, is ramped from approximately 0 to 5 volts. This is connected to the X-axis of the oscilloscope to show a proper X-Y graph of response. See the section on alignment examples. There is a single marker at the center frequency which is set by a small delay on the ramp sync signal. This shows up as a bright spot on the scope allowing for precise settings. The Marker control (Mark) has no affect on the markers displayed; it is only used for the internal display. The Rate setting is used to decrease or increase the rate of sweep. Currently, there are relative numbers used to specify the delay between sweeps, not the actual rate, so this is a little bit of a misnomer. Note also that increasing the value of Rate increases the delay of the sweep thus slowing the rate of the sweep. (I may change this someday based on feedback). For Release v1.0, the rates vary from about 60Hz to 0.5 Hz for a sweep frequency.
**D. Internal Sweep Operation**

The internal sweep operation removes the need for an external oscilloscope. The LCD display is used to show the radio’s response to the generated RF signal. The function generator and RF generator as well as the bandwidth are all set as above for the external sweep. The rate is also chosen to specify the sweep rate. However, for the internal sweep, the sync output is disabled since it is not used. In addition, two other settings are needed. First the marker setting is used to set the width of the markers on the display to show the output bandwidth of a radio response. Currently, the marker value is a number from 0 to 9. Each number adds 10% of the bandwidth to the marker position. So, if the bandwidth is set to 20KHz and the RF frequency set to 455KHz, a marker position of 5 would shows markers at 445KHZ and 465KHz.

The bias setting is used to specify a vertical offset to the display. The bias varies the level shifting of the input voltage by 0 to 5 volts in 0.5 volt steps. Thus a setting of 5 would cause an input voltages of +/- 2.5 volts to be seen as an input of 0 to 5 volts. The best value of this setting is discussed in the operational examples section.
VII. Operational Examples

1. AM IF Alignment - External Display

Certainly, the RF generator can be used as a fixed modulated source for the classic IF alignment using a voltmeter to measure the peak of the response signal from the radio's IF stage. To do this, simply set the mode as FIX and set the RF frequency to the proper value, typically 455KHz, the FN generator to a modulation frequency such as 400. Then adjust the modulation level to about 30% and use this as the signal source as specified in the radio's alignment instructions.

But we want to discuss the sweep alignment process here to show the sweep functionality of the device. For an AM sweep with an external display, the RF frequency should be set to the radio's IF frequency, e.g. 455KHz, according to the circuit schematic. The FN frequency is set to 400Hz typically, and modulation level to about 30%. The mode is set to SWe and the Rate to 0 initially. The BW is set to a wide range initially such as 40KHz. The SYNC output is connected to the X input of an oscilloscope (typically channel 1) and the Y axis is connected to the output of the detector, usually the top of the volume control. Set the scope sweep to the X/Y setting. One of the probes is connected to circuit ground on the radio. Of course, be sure to run an AC/DC radio through an isolation transformer for power to prevent damage to the scope. Follow the directions for radio alignment on the best way to align each stage. I prefer to tune each IF stage separately so that interaction of the stages is minimized. By first aligning the detector, then the 2nd IF, then the first IF, interaction is minimized. The scope will display a signal that you will attempt to peak at the point of the bright marker which is the center frequency of the sweep. See figure 5. Change the rate to slow down the sweep for best viewing and change to BW setting to fine tune the peaking frequency.

Figure 6 - AM IF Peaking on External Scope Display
2. AM IF Alignment - Internal Display

The AM IF alignment using the internal display is similar to the external mode. Set the frequency of the FN, RF, BW, and rate as stated under the external method. Set the mode to SWi. Set the Mark to a position like 5 to show the bandwidth of the response. Set the bias level to 9, i.e. 4.5 volts (would like to set it to 5 volts but you cannot now. Yes, indeed, I need to fix this). This will level shift a negative detector voltage (think AGC) to a positive voltage so the Arduino ADC can measure it. Connect the input to the detector output, typically the top of the volume control.

Adjust the Rate to get a good display. Some radios do not handle a fast sweep. For the internal display, a slow sweep works well since we do not have to worry about fiddling with a scope X/Y display. See figure 6 for a typical display that is peaked. (Note that this figure does not show the Bias setting as the photo was taken before that feature was implemented. I need to update this at some point.)

![Figure 6 - Internal AM IF Peaking Display](image-url)
3. FM IF Alignment

Typically, the alignment of the IF transformers on an FM radio calls for unmodulated frequency inserted at the front end of the radio and peaked using the level of the output signal on the display of the oscilloscope. The classic IF frequency for the FM radio is 10.7 MHz. As with AM IF alignment, it is best to start from the last stages, working forward, aligning each IF transformer by injecting the RF signal at the grid of the tube driving the IF stage. Thus for this operation, the mode is set to SW, the RF generator frequency is set to 10.7MHz, BW to something reasonable like 500KHz. As before the SYNC output is connected to the X-axis input of the oscilloscope and the output of the IF stage is connected to the Y-axis channel. Again, this is very similar to the AM IF sweep alignment. A classic output is shown in Figure 7.

![Figure 7 - FM IF Peaking Display](image-url)
4. FM Detector Alignment - External Display

The alignment of the FM detector typically generates what is known as the classic “S-curve” showing the response of the detector across the bandwidth needed centered at the IF frequency. The goal is to get a clean linear slope as the frequency is swept across the bandwidth of the IF circuit. To perform this operation, we follow the detailed instructions given for the radio under test. This typically calls for an unmodulated signal swept across a bandwidth of 500KHz centered on the IF frequency. The Rate can be adjusted for the best display. The SYNC is connected as before to the X-axis channel. A typical output is shown in Figure 8.

![Figure 8 - FM Detector S-Curve Display](image-url)
5. FM Detector Alignment - Internal Display

The alignment of the FM detector using the internal display is similar to the external operation. The RF frequency is set to the IF value, typically 10.7MHz. Bandwidth is set to 500KHz to start and can be adjusted for the best display. For the internal, the Mark can now be used to set up the markers. The Bias is set to 5 giving a 2.5 volt offset. This is used because the typical voltage off of the detector is targeted for +/- 2.5 volts depending on the RF output voltage level. Thus with a Bias of 5 (2.5 volts), the input voltage of +/- 2.5 is shifted to 0 to 5 volts and can then be properly converted for display. The device input is connected to the detector circuit as directed by the alignment instructions. See Figure 9 for a typical display.

![Figure 9 - FM Detector S-Curve Display on Internal LCD](image-url)
Figure A1 - Circuit Design Schematic
Figure A2 - Top view of Circuit Board
Figure A3 - Side view showing LCD header and exposed pin 9
Here are links to important documents as mentioned in the text above:

1. Analog Devices AN-423 PDF on how to accomplish Amplitude Modulation with the AD9850
2. XLoader website for download http://russemotto.com/xloader/
3. 