Motivation

Nitrogen-vacancy (NV) centers are point defects in diamonds that have the property of photoluminescence, making them easy to detect. NV centers are considered good candidates for stationary qubits in quantum information processing because they have a long spin decoherence time, as well as a bright and stable photoluminescence. Photon interference can entangle the electron spin states of distant NV centers. Furthermore, the electron spins at NV centers may be manipulated by applying an electric field. Nicole aims to combine NV centers with microdisk cavities, which will speed up the emission rate from the NV center and construct a network of cavities and NV centers. The stark tuning of the electric field shifts the NV centers frequency to match the optical cavity frequency. However, as the electric field requires a relatively large voltage range, 0V to 200V, a device is needed to output this range of voltage and a program to manage the output amount.

Consequently, I assembled the device while Chuting made the program. Together, we tested the device to determine if it could be used to deliver relatively stable voltages in powering electric fields.

Design and Construction of Device

The device is designed to take in two small input voltages between zero and five volts, and have two output voltages of up to 200V, depending on the amount of input voltage. The input voltage will be delivered by a Data Acquisition (DAQ) board and readily adjusted using a MATLAB program written by Chuting.

The device consists of a chassis, an AC power entry module, a Condor 48V power supply, two PiezoMaster VP7206 amplifiers, and four Bayonet Niell Concelman (BNC) connectors. Figure 1 shows how these parts are connected. The AC power entry module is used to take in 120V from a typical American AC outlet to power the Condor power supply. The power supply is then connected to both of the PiezoMaster amplifiers (called amplifier 1 and amplifier 2). The input voltages from the DAQ board are each directed through a different BNC connector and each BNC connector is connected to a different amplifier. Amplifier 1 outputs to the third BNC connector and amplifier 2 outputs to the fourth BNC connector. The amplifiers are grounded to the chassis.
Figure 1: schematic diagram of the device.
Testing and Results

The device was tested at an input of 1V, 3V, and 5V for each amplifier. At each voltage, data was collected for a 60 second period and a 600 second period. Sixty second and 600 second plots for an input of 1V for amplifier 1 are shown in Figure 2a and Figure 2c. The sample rate for 60 seconds test was 1000 Hz and 60 Hz for the 600 seconds test. \( V_i \) is the input voltage and \( V_o \) is the output voltage with a voltage divider. A voltage divider was used such that the voltage was small enough (less than 10V) for the DAQ board to read. The divider was constructed using a 20Ω resistor and a 1Ω resistor, thus outputting \( 1/21 \) of the input. Since the voltage divider has a multiplication factor of approximately 22.15, the actual output of the amplifier would be 22.15 times the output shown on the graphs. A histogram of the number of data points for the range of output voltages is presented as Figure 2b and Figure 2d.
We can see that the 600 second collection period generates a greater fluctuation of output voltage than the 60 second collection period (the many small spikes in both graphs are likely due to the digital to analogue converter from the DAQ board). From Figure 2a, an input voltage of 0.9951V outputs 1.7245V (with the voltage divider). Thus the actual output is 38.20V. In Figure 2c, an input voltage of 0.9950 outputs an actual voltage of 38.20V.

Figure 2b and Figure 2d also demonstrate this as the spread of the 60 second period is much smaller than the 600 second period, leading to a greater standard deviation for the latter. Figure 2b shows a standard deviation of 0.00025 and Figure 2d shows a standard deviation of 0.4.

The nitrogen-vacancy center frequency shift against both longitudinal and transverse output standard deviations may be calculated. For amplifier 1 with the 60 second collection period, the NV frequency shifts against longitudinal output and transverse output by 0.023 and 0.0570, respectively. For the 600 second collection period, the shift was 0.16 and 0.381, respectively.

**Conclusion**

Both the longitudinal and transverse output standard deviations for the device are less than those shown in Figure 3. This confirms that this device may be used, at least initially, to control the electric fields used to manipulate the electron spins at NV centers. The reason being that our spectrometer’s spectral resolution is on the order of 10 to 15GHz (much larger than 1GHz). Further refinement of the device or better equipment may be needed to reduce the amount of noise in the output voltage.

Figure 3:

\[ \Delta d_{\parallel} F_{\parallel} / V_a = 0.42(2) \text{ GHz} / \text{V} \quad \text{and} \quad d_{\perp} F_{\perp} / V_a = 1.03(3) \text{ GHz} / \text{V}. \]