Laser Fan System

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***Abstract*— The design aspects of the laser fan system are explored for the purpose of velocity detection of particles. In an effort to reduce noise present during detection, the amplifier stage is located inside of the vacuum compatible case which houses the photodiode detectors. This device provides the operator with variable gain control, both local and by remote computer, as well as gain display. A method for laser alignment is also implemented by means of a DC probe under the photodiodes. This unit provides the user with the ability to obtain the highest amplitude signal, with the least amount of noise. The results indicate a consistently lower bandwidth than suggested by manufactures.**

I. Introduction

The Light Gas Gun, used at the Center for Astrophysics, Spaced Physics and Engineering Research (CASPER) laboratory for impact studies, projects particles through a vacuum chamber. These particles are propelled by high pressure helium and may not leave the barrel at constant velocities on every shot. It is necessary to have a means for measurement of particle speed as it enters the chamber. The Laser Fan System has been designed to offer many key features in accurate velocity detection of these projectiles, such as variable gain (controllable by computer or by hand), gain display, method for laser alignment, and a vacuum compatible detector/amplifier shielding case. These features are all intended to overall provide the highest signal amplitude with the lease amount of noise which will add to the body of research related to hyper-velocity impact studies. Analog Devices, producer of the AD603 Variable Gain Amplifier, suggests configurations for gain that will produce bandwidth values that are much higher than the experimental values provided.

II. Theory of Operation

Using a fanned-out and collimated laser beam focused onto two photodiodes at a given distance apart, the speed of the particles can be obtained as they pass through the beam. When an object passes through the beam, it casts a shadow onto a photodiode. This shadow will produce a small negative-going pulse that feeds into the amplifier. After amplification, the pulse is caught by an oscilloscope. Two channels are used, one for each amplifier, which will allow the operator to view the time difference between the shadow cast on the first detector versus that of the second detector. The photodiode detectors are spaced exactly forty millimeters apart and knowing the time of flight between them, the velocity can then be calculated.

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III. Amplifier Stage

A. Variable Gain Amplifier Specifications

The variable gain amplifier (VGA) chosen for this application use the AD603 produced by Analog Devices. This amplifier is a low noise variable gain setup which consists of an attenuator followed by a fixed gain amplifier. The gain of the amplifier is controllable by 1 volt DC, from -500mV to +500mV. For every 25mV change on the gain control pin, the amplifier will change 1dB. This is a linear relationship between the control voltage and the gain. The overall range of the amplifier can be set to attenuate on the low end, and amplify on the high end. Programming the gain range is accomplished by tying the output of the amplifier to the feedback pin. The Laser Fan System uses a gain range for each amplifier of -10dB to 30dB, programmed by a direct short between the output and feedback [1].

B. Bandwidth Limitations

Bandwidth proved to be an issue when programming for any range, as the amplifier did not perform as it should. With a gain range of 0 to 40dB, the amplifier should have presented a 30MHz bandwidth, though testing only showed 20MHz. For the range of -10 to 30dB the datasheet claims 90MHz bandwidth, but testing provided 30MHz. For this reason two AD603 amplifiers are placed in series at a range of -10 to 30dB to provide an overall attenuation/gain value of -20 to 60dB. The tests indicated an experimental value, with two amplifiers in this configuration, of -25.35dB to 53.67dB, and a bandwidth of approximately 59MHz. The bandwidth achieved will allow for a pulse as fast as

16.95 nanoseconds. See Appendix A for VGA schematic.

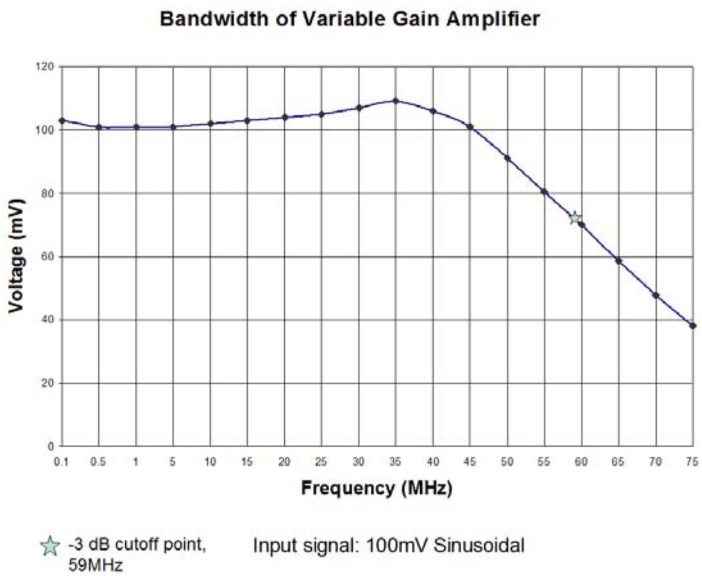

Figure 1. Output curve of two stage variable gain amplifier. Depicts -3dB cutoff point at 0dB gain level. 59MHz Bandwidth is achieved with a programmed gain range of -20dB to 60dB.

IV. Control and Display of Gain

A. Gain Control

Control of the gain is available through a scaling network which consists of a potentiometer for local control with a voltage range of 0 to 5V applied to the inverting input of an instrumentation amplifier (INA118) and a 2.5V voltage reference (REF03) on the non-inverting input. This design also makes it ideal for remote computer control. The instrumentation amplifier feeds into an inverting amplifier (OPA177) with an attenuation factor of -.2. When the potentiometer is at 0V the instrumentation amplifier will output 2.5v. With 5V from the potentiometer, the instrumentation amplifier will output -2.5V. With this value of attenuation, the inverting amplifier provides the gain control pins on the AD603 with a range of -500mV to +500mV from a 0 to 5V source. See Appendix B for Scaling Network Schematics.

B. Gain Display

The current attenuation/gain value in use is displayed on a rack-mount control unit using the DMS-40PC-1-RS panel-mount voltmeter. This meter is produced by Datel and has an input voltage range of +-2V. The voltage it reads is produced by an instrumentation amplifier [2] followed by an inverting amplifier with an attenuation factor of -.153. This allows a control voltage from 0 to 5V, and because the gain output of the VGA is linear, it will accurately convert the gain control voltage to a DC voltage equivalent to the gain of the amplifiers. This unit is connected in such a way that with either local or remote control it will still read the correct gain of the system. See Appendix C for Gain Display Schematic.

V. Laser Alignment

When the laser beam is positioned onto the photodiodes, the beam may look as though it is centered, when in fact it may be off. The alignment feature of the laser fan system allows the user to view the amount of DC conducted from each individual diode. When the DC values for each diode are equal, this indicates equivalent amounts of laser light incident on the detectors. By using a buffer circuit, the alignment probe does not affect the load impedance as seen by the photodiode, thus not affecting the typical performance characteristics.

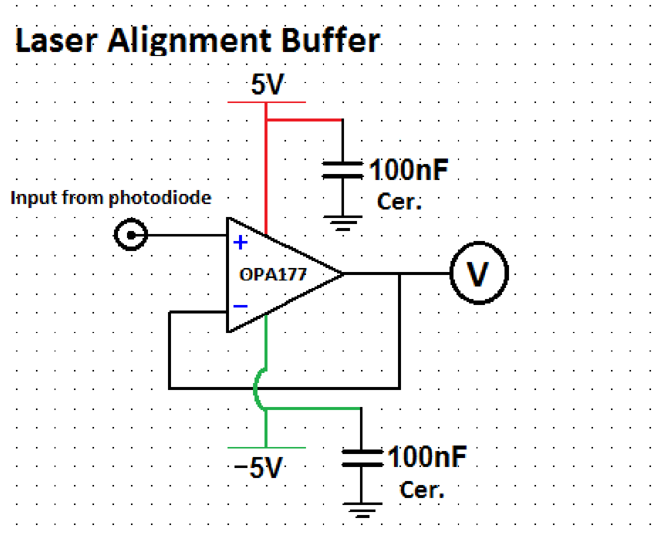

Figure 2. Buffer used to probe DC from photodiode. Connects to MMCX socket on input side of VGA.

VI. Noise Reduction and Circuit Protection

A. Power Supply

Every aspect of the power distribution is highly filtered by means of inductors and capacitors. The cutoff frequency of these low-pass filters is approximately 4 kHz [2], which will help to eliminate some of the noise that may propagate through the power supply. Each of the voltages produced by the power supply are fused before the voltage regulators, and then again once they reach the detector/amplifier housing.

B. Photodiodes

The bias voltage applied to the photodiodes is regulated by a voltage reference of 10V(REF01), which has an input voltage of 15VDC. The output uses a 100nF ceramic capacitor as suggested by the datasheet, then a 2.2uF tantalum capacitor both connected to ground. These capacitors are then followed by a 600ohm ferrite bead which is in series with a 62.5mA fuse on the output. The next set of filtration comes directly at the photodiodes which consists of a 600ohm ferrite bead in series and a 10nF capacitor in parallel with the diode. This will send unwanted noise to ground that may find its way into the connection between the photodiode and the power distribution. See Appendix D for Voltage Reference schematic.

VII. Shielding

A. Isolation

The amplifiers, detectors, alignment buffers, and voltage references are all housed inside of an aluminum case. This case is grounded which shields the electronics from noise interference. The photodiodes are located approximately 20mm away from the connection to the first stage of the amplifiers which reduces the amount of noise present in the system. This case uses aluminum dividers which separate the two channels which consist of identical circuits. The housing provides optical isolation in addition to the electro-magnetic shielding. Power supply distribution boards are isolated from both channels, connected only by small holes just big enough for wires to enter the amplifier housing area. The power supply inputs, alignment signals, and gain control enter and exit the housing through a 9-pin D-subminiature connection (RS-232).

B. Vacuum Compatible

This unit has been designed to be vacuum compatible for use in the work chamber of the light gas gun. The construction of the case takes advantage of vented screws to avoid virtual leaks in the system due to gasses trapped in the threads of the screws and in the cavity located inside the screw holes. In addition to using vented screws, the mounts for securing the amplifier stages in a vertical orientation are drilled completely through before tapping in an effort to eliminate cavities where air can accumulate. Instead of taking measures to seal the feed-through connections, they are left unchanged, as to allow gasses to be evacuated through the SMA bulkheads, photodiode mounts, and RS-232 connection. These are all evacuation points for the interior of the housing so the chamber will be able to maintain a stable pressure during experimentation.

VIII. Discussion

After much trial and error, the suggested bandwidth values provided by the AD603 datasheet could not be obtained. With several gain range settings, the largest bandwidth proved to be 60 MHz. Because the maximum gain for this setting is 30dB, it is necessary to place two amplifier stages in series to provide enough gain to capture the small signals produced by the detection of particles in the Light Gas Gun. It may be necessary to get in contact with the manufacturer, Analog Devices, to find out what parameters are missing to obtain the proper bandwidth range.

IX. Conclusion

The variable gain aspect of the Laser Fan System provides a method for eliminating noise on the system, allowing the user to accurately view the pulses produced by the particles. Much testing showed that bandwidth of the amplifier system proved to be a menace, but was overcome by adding more amplification stages at a lower individual gain. Although the results are 59 MHz and not the manufacturer suggested 90 MHz, the overall bandwidth achieved is acceptable.

Acknowledgments

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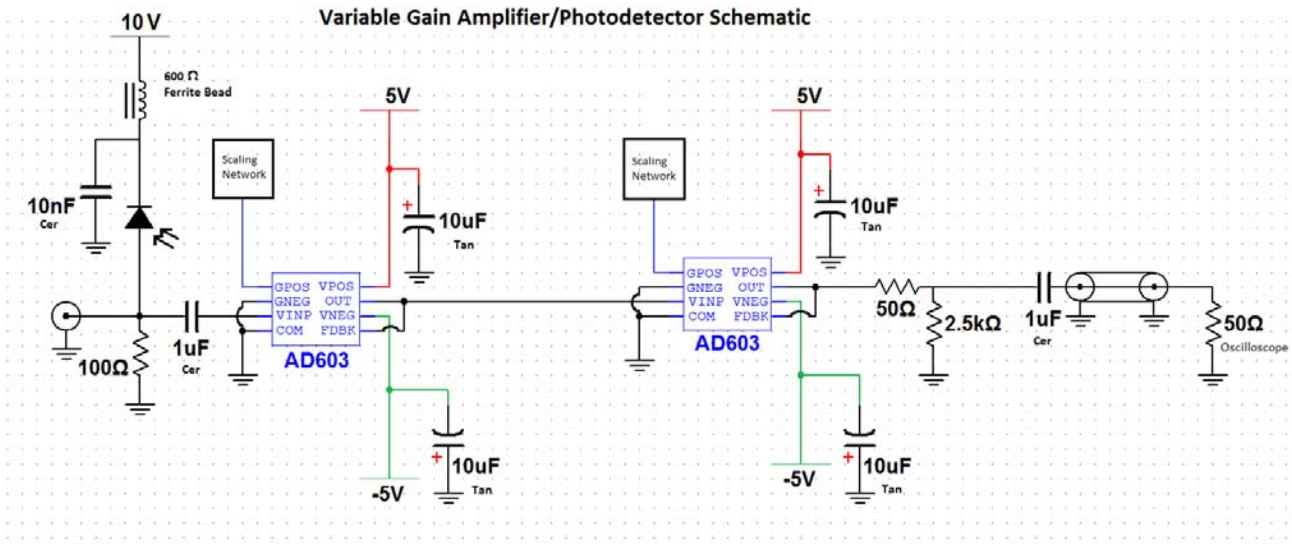
References

[1] AD603 Datasheet Rev. 1, Analog Devices, Inc 2010 Page 12 of 24

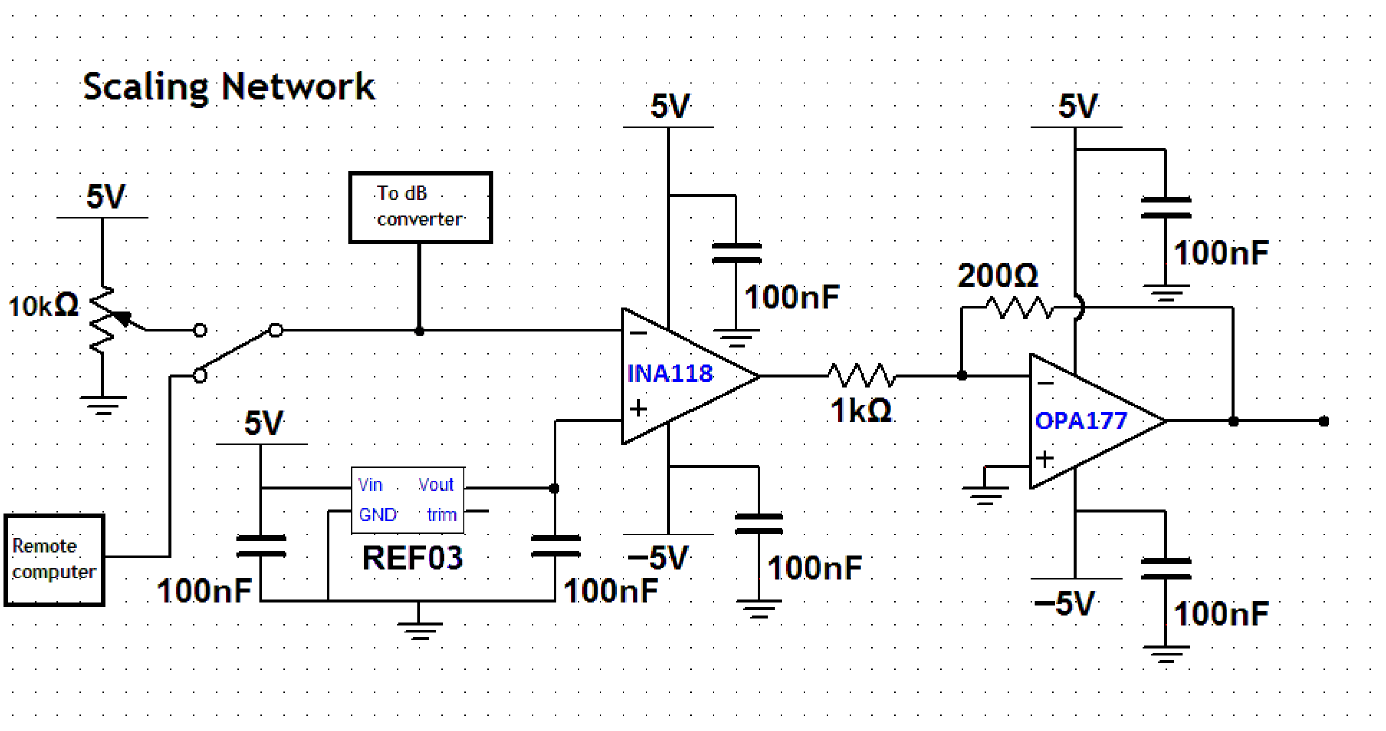
[2] Paynter, Robert T. Introductory Electronic Devices and Circuits, 7th Edition. New Jersey: Pearson Prentice Hall, 2006.

APPENDICES

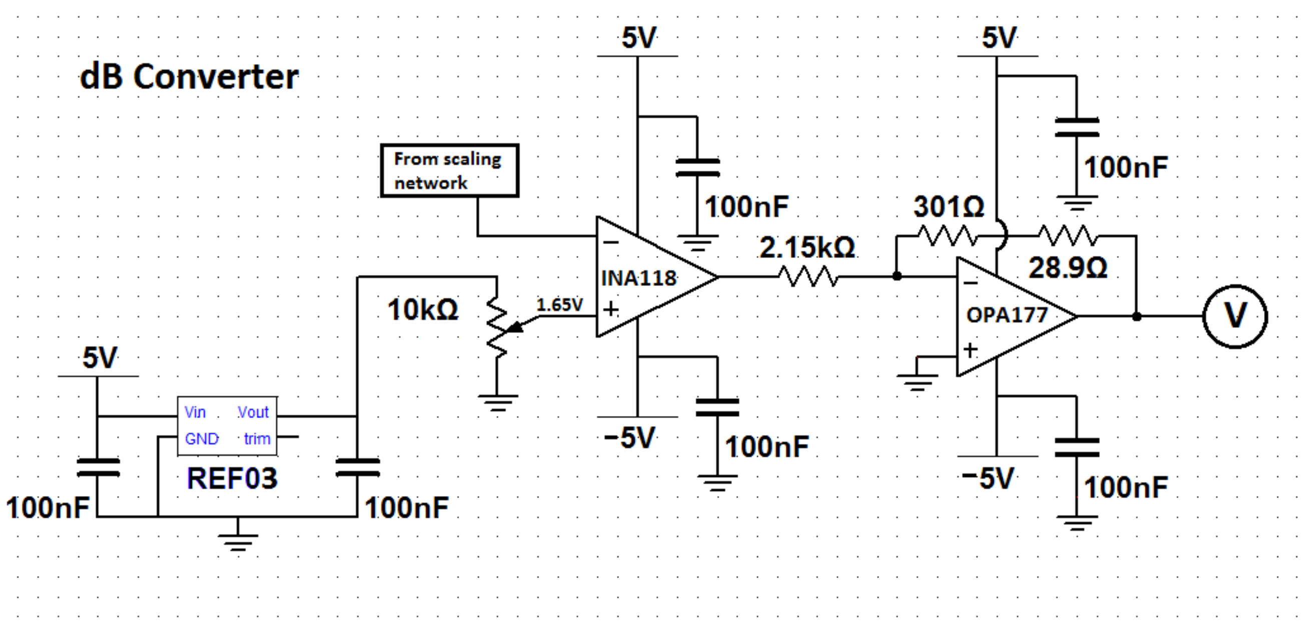
A. Schematic of Variable Gain Amplifier



B. Schematic of Scaling Network for Gain Control



C. Schematic of Gain Display dB to DC Converter



D. Schematic of Voltage Reference for Photodiode