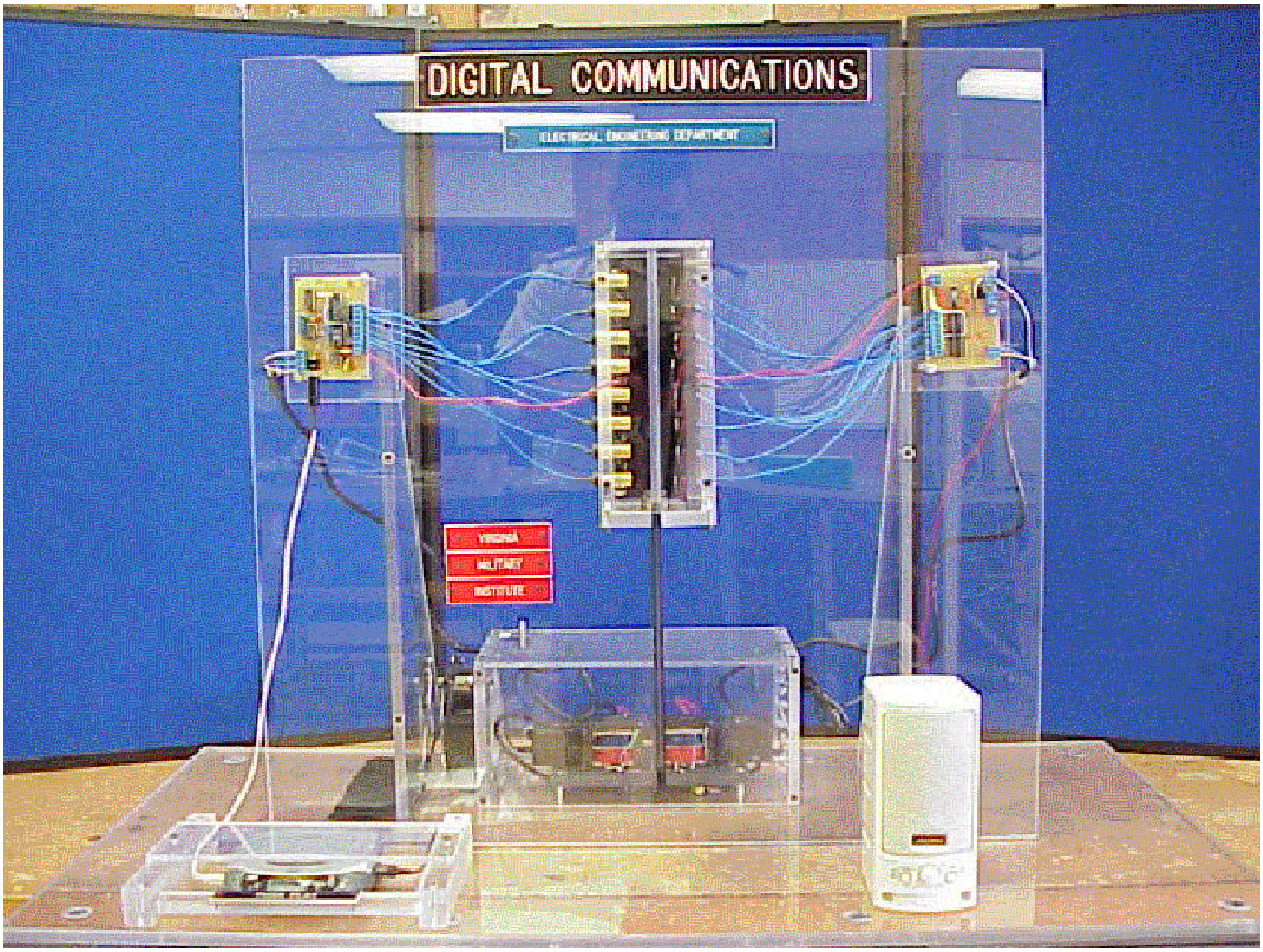
Display for the Virginia Museum of Science

Digital Communications



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Independent Research Project EE 491
Digital Communications
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I. Introduction

Many electronic devices today communicate with each other externally and internally. The information in these devices can be numbers, words, sounds, and pictures. The simplest form of this information is digital one’s and zero’s. Sequences of one’s and zero’s are used by electronic devices to pass information back and forth as well as process the information. The concept of representing information with zero’s and one’s was devised in 1940 by Claude Shannon in his master thesis at MIT. He devised theorems that showed how digital one’s and zero’s (or bits) can be used to describe information. He then pioneered ways in which these bits can be manipulated or sent to other devices with little or no error.

To demonstrate, in simple terms, the concept of digital communication using bits, a museum display involving analog to digital conversion and laser bit communication was constructed. The exhibit also demonstrates how more bits can be used to communicate a more accurate signal. For this task, an audio information source (CD player) produces a signal that is converted to digital information. This information will then be sent to a receiver using laser light switching on and off to communicate zero’s and one’s. The receiver will pick up the laser light and convert the digital information back into an analogue signal for output to a speaker. See Figure 1 for a system block diagram. Covering some of the lasers (removing bits) will demonstrate that less bits result in a poorer signal and reduced audio quality.

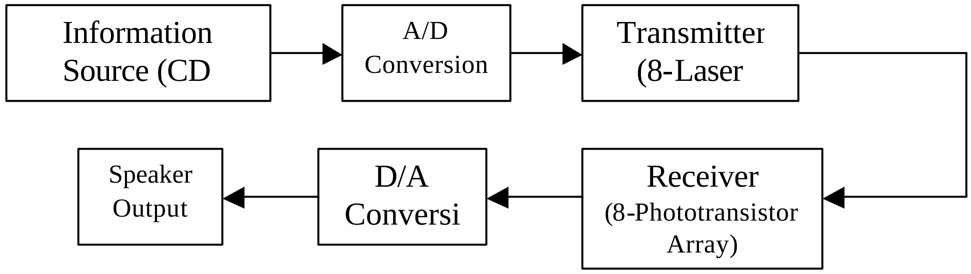


Figure 1: System block diagram for museum display

II. System Functionality

To send digital information through the laser communication device, the input audio signal must be converted into a series of digital bits. Before this can be accomplished, some formatting has to be performed on the analog audio signal coming from the CD player. The analog input is a 100-200mV$_{p-p}$ signal. It is first sent through a filtering circuit to block any DC offset and center the input signal at 0V. The signal is then amplified with a gain of 20 using an opamp. Finally, a filter and clamping circuit are used to attenuate frequencies below 10Hz and flip the negative values positive for A/D conversion. The conversion is completed using an AD7819 chip. This chip samples the analog signal at 125kHz (controlled by a clock signal from 555 timer) and outputs to an 8-bit parallel interface. Sampling is accomplished by reading the voltage level of the analog signal at a certain time interval (for this system, the sample period is 8μs). This voltage is then assigned one of 256 distinct voltage levels and given an 8-bit sequence to describe the voltage level in digital terms.

The 8-bit sequence is then sent in parallel (8 lines sending the bits all at the same time) to an array of transistors. The transistors switch 8 lasers off and on to transmit the digital sequences. A “1” turns a given laser on while a “0” turns it off. The laser light pulses are sensed by eight phototransistors that are give off a "1" when excited by laser light and a "0" when not excited.

To reverse the process for output to the audio speaker, digital to analog conversion needs to take place. To do this, the digital bits from the laser are fed into a latch (74HC161) that sustains the digital values coming from the lasers until another value overwrites it. After going through an inverter array, the 8-bit signal arrives at the D/A converter chip (the **D/A converter chip name**). This chip takes each 8-bit digital sample and converts it to one of the 256 voltage levels used by the A/D chip. The output analog signal is then amplified by a variable gain opamp circuit and taken to the speaker. The figure below**, Figure 1.0** shows the A/D converter and the analogue input from the CD player (source).

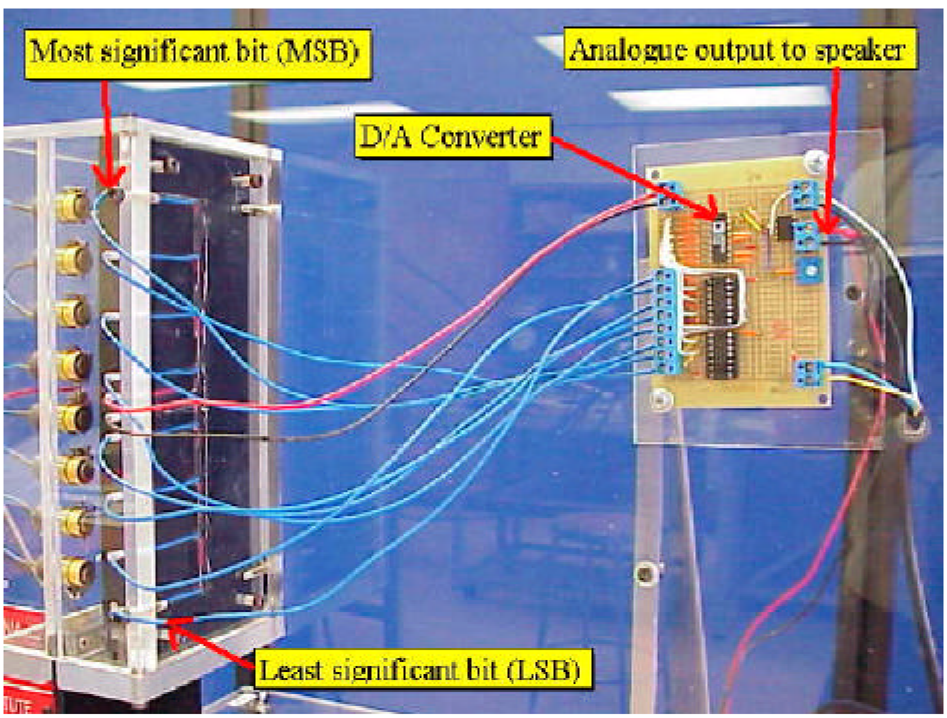


Figure 1.0

Because several digital components are used in the system, there are some synchronization problems in enabling the A/D converter chip. This problem causes the chip to enable and function correctly only 50% of the time. Switching the power supply off and on again will then enable the chip and begin proper operation. To facilitate turning the power supply on and off, a switch was added to the power supply containment box.

As the handle is slid upward, blocking the laser light from the phototransistors, communication bits used in the system are rendered useless. The D/A converter receives fewer bits and the voltage levels used to describe the original analog signal are not the same as the input. This occurrence can be heard in the form of static and distorted sound coming from the speaker. The figure below will show the D/A converter and the analogue output in **Figure 1.1.**

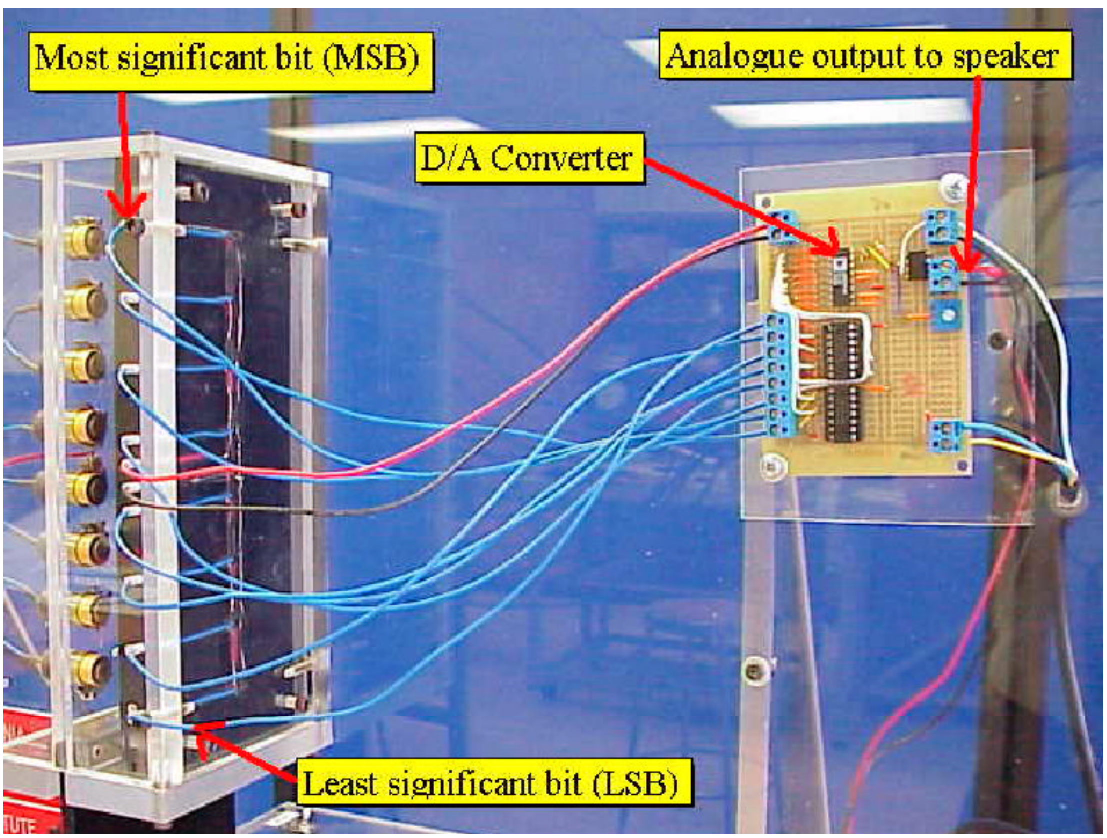


Figure 1.1

III. Museum Concept

This system was designed to be integrated into a museum display. The goal of this system is to give a basic understand of digital communications to all museum patrons. This exhibit is set forth to demonstrate a digital signal and show how it works. A digital signal can be thought of as a sentence or story containing information. We communicate by speaking to someone who hears with his or her ears and interprets the sound into words that we understand. Computers and electronic devices communicate in the exact same way with digital signals. Pieces of information called bits are like letters. These letters in turn form words that computers use to mean different things.

Think of the CD player as someone talking. The CD player generates an analogue signal that is converted to an 8-bit digital signal. The following is a chart explaining how this processes works.

Binary	Hexadecimal	Decimal	Output Voltage
0000 0000	**00**	**0**	**0**
0000 0001	**01**	**1**	**0.010 V**
0000 0010	**02**	**2**	**0.020 V**
0000 1111	**0F**	**15**	**0.150 V**
0001 0000	**10**	**16**	**0.160 V**
0111 1111	**7F**	**127**	**1.270 V**
1000 0000	**80**	**128**	**1.280 V**
1100 0000	**C0**	**192**	**1.920 V**
1111 1111	**FF**	**255**	**2.55 V**

The process is known as analogue to digital conversion. The A/D chip samples the voltage at different levels, and gives the voltage a corresponding digital code. This signal is then sent to an array of 8 lasers. The lasers then transmit from one side of the display to the other. This is to simulate transmission in open space. Both sides of the display are independent of each other, there is no physical connection. The lasers are turning on and off at an incredibly fast rate. On the other side are sensors that sense the laser light. The digital signals outputted from the lasers are then sent to a digital to analogue converter. The signal can then be heard from the speaker. The sound coming from the CD player, was converted to a digital signal, was sent to the other electronic device, changed back to analogue, and comes out of the speaker so we can hear it.

IV. Operating the system

The system can be powered from a standard 120V power outlet. The on and off switch located at the back of the display controls the power for the whole system. For a good user friendly interface it would be useful to have the system powered up at the beginning of the morning before the museum opens. Then a separate switch will allow sound to be heard from the speaker. When a museum patron presses a button it will allow sound to be heard, although the system will always have power being supplied to it. The system is not limited to CD player for its input source. The system could also be connected to a laptop. A prerecorded sound track could be played from a collection of MP3'r or any other media files. This would help in reducing the risk of theft. The only interaction that the museum patron would be able to have with the display is through the handle. This handle illustrates the importance of bits. The handle is moved upwards to block more bits, the quality of sound decreases. The most significant bit is the very top laser; this laser transmits the most important information of the sound signal. Finally, when all bits are blocked no sound will be heard through the speaker.

VI. Troubleshooting the system

The system design is fairly straight forward and easily trouble-shooted. As long as the display is isolated from the museum patrons, only periodic parts might need to be replaced. The system also has a periodic problem with powering up occasionally. This is caused by the A/D chip locking up, due to a timing issue. By switching the system on and off a couple times the device will work 2/3 of the time on the initial power up. It is recommended that once the system is powered and working; that it remains on until the museum closes. The lasers will also need to be replaced when they burn out. In order to insure that all lasers are still working properly check to see if they are emitting any “red light”. When the system is on all lasers can be seen as on by the human eye. For further trouble shooting of the system please see ***appendix A*** for all schematics. **Note**: Both system, the receiver and transmitter, are completely isolated from each other and have no physical connection.

VII. Conclusion

The digital communication display effectively demonstrates the basics of digital conversion and bit transfer. Inputting an analog signal, an 8-bit digital signal is used to transmit information to a receiver that attempts to reproduce the original analog signal with the information that it has received. When bits are blocked from being received, the original input data cannot be replicated for the speaker output. This exhibit allows these concepts to be demonstrated and understood by a non-technical audience.

Works Sited

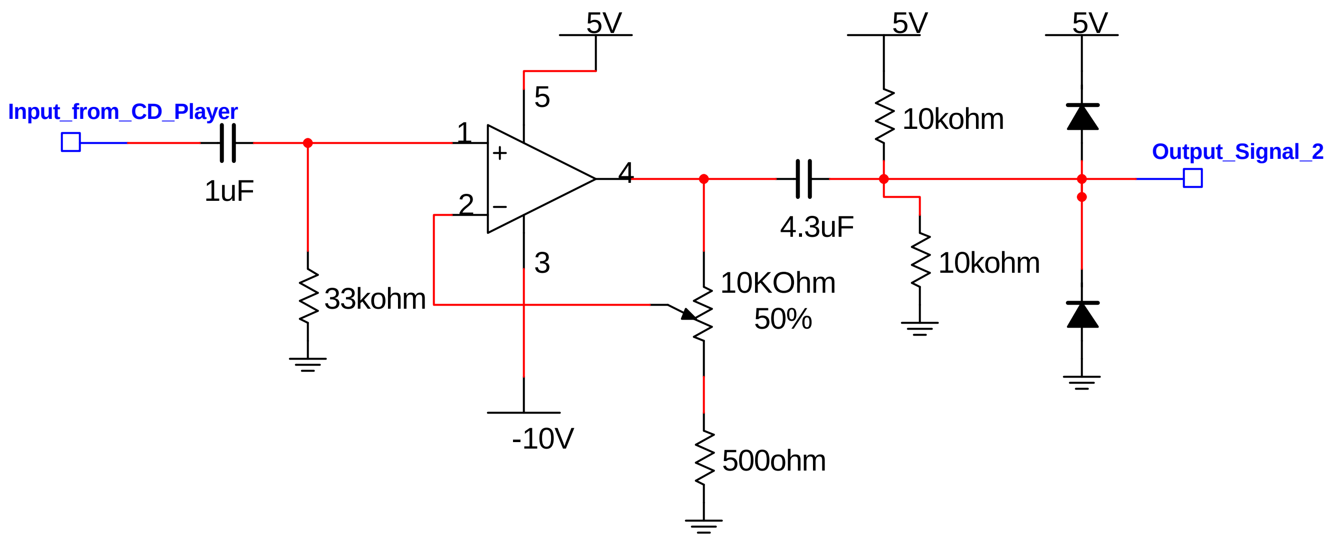
http://www.digitalcentury.com/encyclo/update/shannon.html

Appendix A

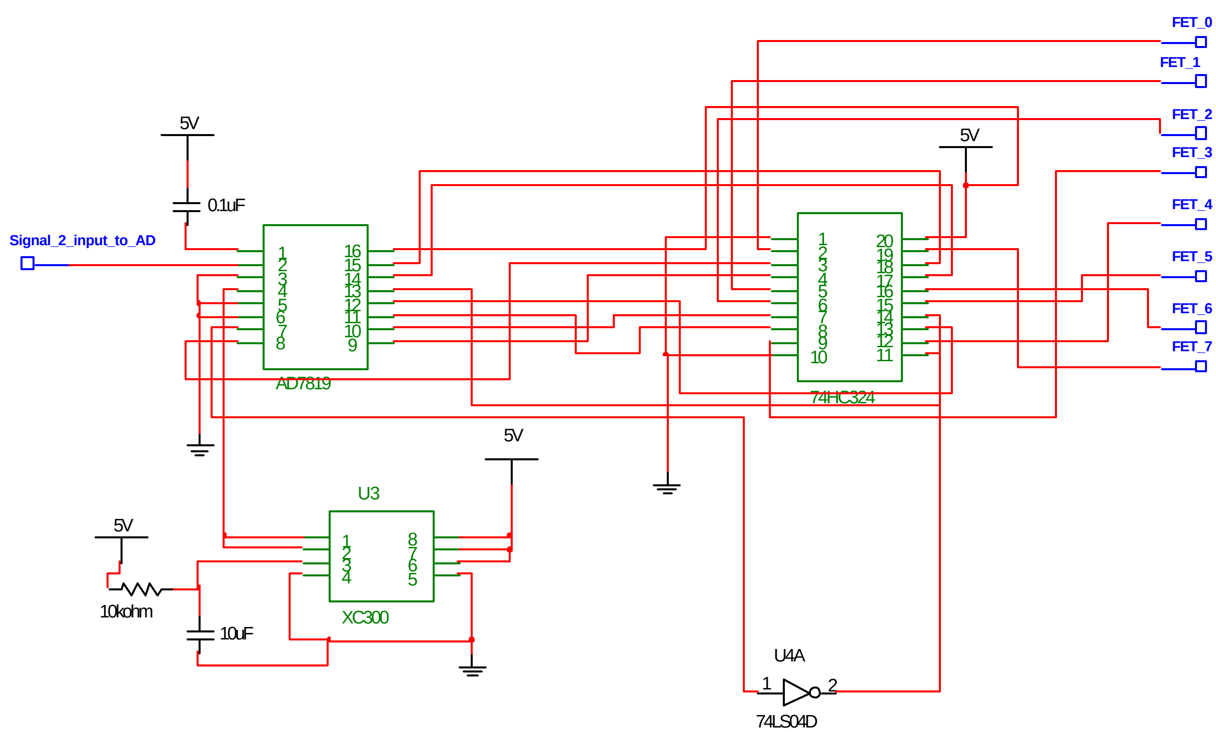
Schematics for Device

Schematics:

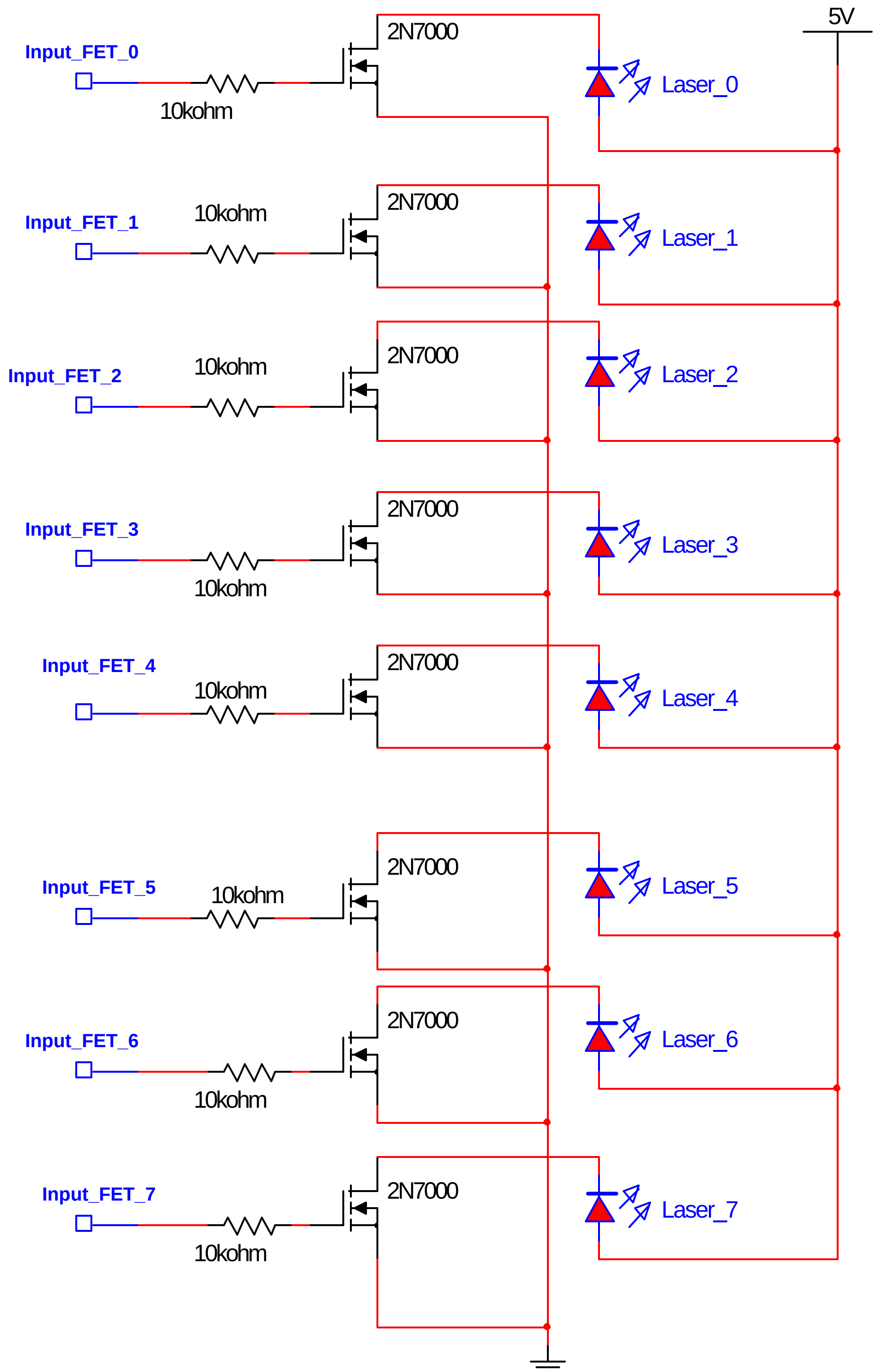
Transmitter:



Output Signal 2 to Analog to Digital Converter Input to FET Inputs:



FET inputs to Laser inputs:



Laser outputs to Receiver/Output Speaker: