Optical Link

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Introduction

An optical link is a link that uses an LED to transmit data through a medium to a photodiode. The application that we are designing for is an audio link between a stereo and speaker across a room. The medium we are using between the LED and photodiode is air.

Motivation

This design is to be used for surround sound speakers without running wire to the speaker or using radio frequency devices that will cause inference with other systems in the room.

Design

There are two parts of our design; the LED driver and the photodiode amplifier. Figure 1 shows the block diagrams for both parts. The bandwidth must be at least 44.1 kHz, which is the sampling rate for uncompressed audio. The gain of the constant gain and variable gain amps must have a gain of about 100 dB together at a distance of ten meters. This makes up for any loss in the medium. The LED is driven by a signal processor and a buffer amp. The signal processor modulates the signal before the driver amp. The LED driver amp matches the impedance of the LED to the signal processor so that the loss from the mismatched circuits is minimized. The photodiode drives an amplifier that matches the impedance of the photodiode to the larger gain circuit. The photodiode amp has a smaller gain than is needed. The rest of the necessary gain will be supplied by a variable gain amplifier that can be used to increase the gain as the distance between the LED and photodiode increases and vice versa. The variable gain amp will send the amplified signal to the signal processor, which will convert the modulated signal back to the original signal. In our design we are using a power supply voltage of 2.5 volts and a current source of 100 µA. When we first started designing the photodiode amp, the photodiode was too slow to meet the required specification. To fix this problem we found a new photodiode that was faster and would meet the required bandwidth specifications.

Design Process

The way that we went about designing our amplifier was to first find a topology that would fit our specifications. After we designed the main stages of each circuit we added another stage to meet the input and output impedances to match the connected components. Because we only had one power supply available, we changed the bias voltage supplies into current mirrors and sized them to give us the same bias as the voltage supplies. We then checked the specifications to make sure that everything worked when the amp was attached to the rest of the circuit. Necessary for manufacturing IC's we built the layout of the circuits next. Once again we tested the circuits to make sure everything still worked.

LED Driver

The LED driver is made up of seven transistors and two gain stages, which can be seen in Figure 2. Two of the transistors (T1 and T2) are current mirrors. The current mirrors are used to set the bias voltage on transistors T4 and T5. Transistors T3, T4, and T5 make up stage one which is a common gate stage. Stages one and two together have a gain of zero decibels. T3 is a diode connected device that acts like a resistor to help set the gain for this stage. T4 is the main gain transistor for the stage. T5 is used as a current source to set the bias on T4 and so that the input signal is not connected to ground. Transistors T6 and T7 make up stage two, which is a common source stage. This stage is used to set the output impedance of the driver equal to the input impedance of the LED. T6 is a diode connected device that sets the output impedance of the stage. T7 is the main gain transistor for the stage. The layout for the LED driver can be seen in Figure 4.

Photodiode Amplifier

The photodiode amplifier is made up of seven transistors and one gain stage, which can be seen in Figure 3. T8 is a current mirror to set the bias on T10 and T12. T9 and T10 are used to set the input impedance to match the photodiode, which will maximize the gain and bandwidth. T12 is used to set up the current through T11, which, along with T12, sets up the bias for T14. T14 is biased and sized to have high gain, which is why we used a PMOS instead of an NMOS. The layout for the photodiode amp can be seen in Figure 5.

Results

The LED driver has a gain of 86.36 mdB, a bandwidth of 24.31 MHz, and an output impedance of 25.04 Ω, which all meet the specifications of the design. The photodiode amplifier has a gain of 19.74 dB, a bandwidth of 82.48 MHz, and an input impedance of 51.73 Ω, which all meet the specifications of the design. The plots of the gain for both circuits, and a full table of the results can be seen in Figures 6 - 8.

Conclusion

The circuit design meets all the requirements for the LED driver and the photodiode amp. The layouts of the circuits that we made are LVS and DRC clean.

Directory Path

/afs/umich.edu/class/eecs413/f07/groups/group1/Project2

LED Driver:	/One	/One_Schematic
Photodiode Amp:	/Two_Amp	/Two_Amp_schematic

Parts Used

LED - SFH4550 Photodiode - TEMT3700

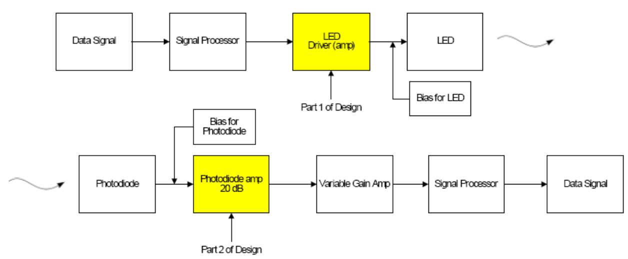

Figure 1 - Block diagram for both circuits

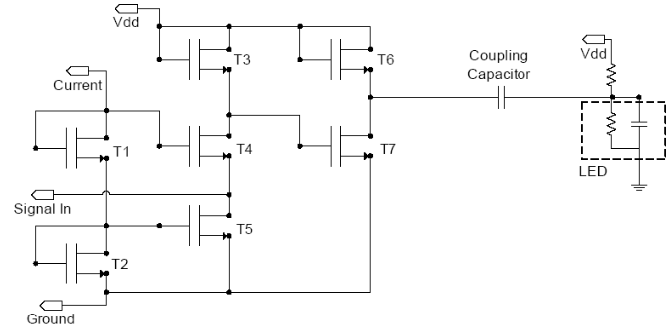

Figure 2 - Circuit Schematic for LED Driver

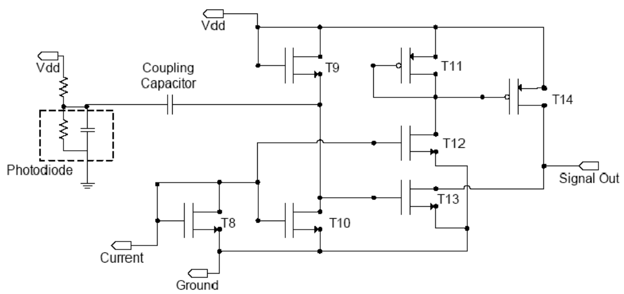

Figure 3 - Circuit Schematic for Photodiode Amp

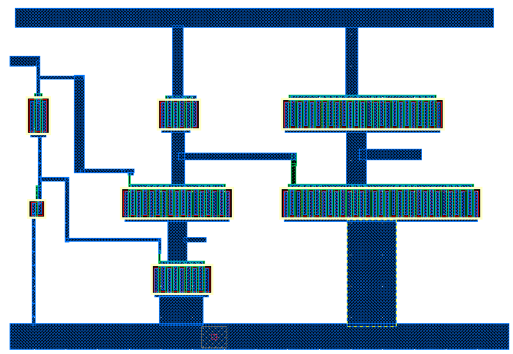

Figure 4 - Layout for LED Driver

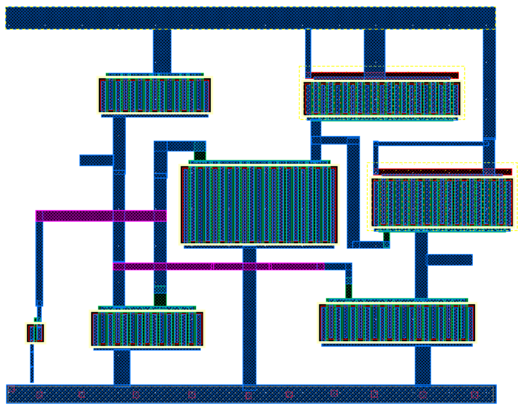

Figure 5 - Layout for Photodiode Amp

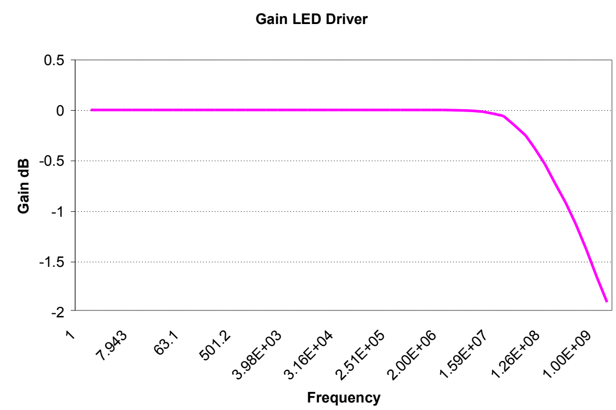

Figure 6 - Gain LED driver

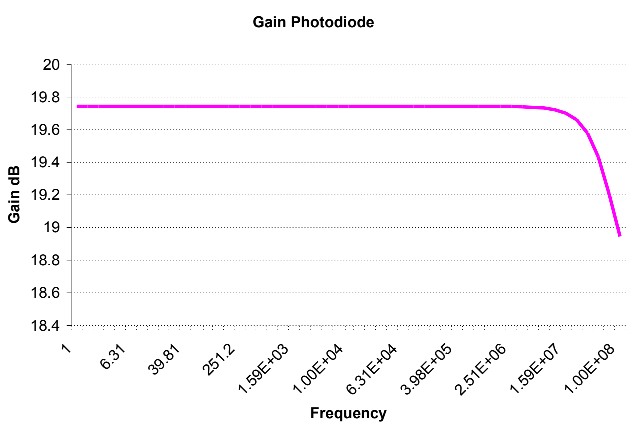

Figure 7 - Gain Photodiode Amp

Parts

	LED	Photodiode
Resistance	50 Ω	100 Ω
Capacitance	500 pF	4 pF

Specifications

	LED Driver
Output Impedance	25 Ω
Bandwidth	> 44.1 kHz
Gain	0 dB ± 1dB

	Photodiode Amp
Input Impedance	50 Ω
Bandwidth	> 44.1 k Hz
Gain	20 dB ± 1dB

Design

	LED Driver
Output Impedance	25.04Ω
Bandwidth	24.31 M Hz
Gain	86.36 mdB

	Photodiode Amp
Input Impedance	51.73Ω
Bandwidth	82.48 M HZ
Gain	19.74 dB

LED Driver

Transistors	W	L
T1	10 um	240.0 nm
T2	2 um	240.0 nm
T3	20 um	240.0 nm
T4	63.4 um	240.0 nm
T5	30 um	240.0 nm
T6	96 um	240.0 nm
T7	120 um	240.0 nm

Photodiode Amplifier

Transistors	W	L
T8	2 um	240.0 nm
T9	57.96 um	240.0 nm
T10	57.96 um	240.0 nm
T11	80.0 um	240.0 nm
T12	200 um	240.0 nm
T13	108.0 um	240.0 nm
T14	90.4 um	240.0 nm

Figure 8 - Results for both circuits