Electronic Instrumentation
Project 4

1. Optical Communications
2. Initial Design
3. PSpice Model
4. Final Design
5. Project Report
1. Optical Communications

- Data Relay Satellite
- Inter-Satellite link
- Space Station
- High-speed (10 Gbps) Optical feeder link
- Fiber-optic link
- Adaptive Optics
Transmitting an audio signal using light

Transmitter Circuit

Receiver Circuit

audio signal

Pulse Modulated Light
Modulation

• Modulation is a way to encode an electromagnetic signal so that it can be transmitted and received.

• A carrier signal (constant) is changed by the transmitter in some way based on the information to be sent.

• The receiver then recreates the signal by looking at how the carrier was changed.
Amplitude Modulation

Frequency of carrier remains constant.

Input signal alters amplitude of carrier.

Higher input voltage means higher carrier amplitude.

http://cnyack.homestead.com/files/modulation/modam.htm
Frequency Modulation

Amplitude of carrier remains constant.

Input signal alters frequency of carrier.

Higher input voltage means higher carrier frequency.

http://cnyack.homestead.com/files/modulation/modfm.htm
Pulse Width Modulation

Period of carrier remains constant.

Input signal alters duty cycle and pulse width of carrier.

Higher input voltage means pulses with longer pulse widths and higher duty cycles.

http://cnyack.homestead.com/files/modulation/modPWM.htm
Pulse width of carrier remains constant.

Input signal alters period and duty cycle of carrier.

Higher input voltage means pulses with longer periods and lower duty cycles.

http://cnyack.homestead.com/files/modulation/modppm.htm
Pulse Frequency Modulation

Duty cycle of carrier remains constant.

Input signal alters pulse width and period of carrier.

Higher input voltage means pulses with longer pulse widths and longer periods.
2. Initial Design

- The initial design for this project is a circuit consisting of a transmitter and a receiver.
- The circuit is divided into functional blocks.
  - Transmitter: Block A-B and Block B-C
  - Transmission: Block C-D
  - Receiver: Block D-E, Block E-F, Block F-G, and Block G-H
- You will need to examine each block of the circuit.
Transmitter Circuit
Input and Modulated Output
Special Capacitors

Bypass Capacitor (Low Pass Filter)

DC Blocking Capacitor (High Pass Filter)
Sample Input and Output

- When input is higher, pulses are longer
- When input is lower, pulses are shorter
Your signal is what?

The type of modulation this circuit creates is most closely categorized as pulse frequency modulation. But the pulse width is also modulated and we will use that feature.
Sampling Frequency

• The pot (used as a variable resistor) controls your sampling frequency
• Input frequency in audible range
  • max range (20 - 20kHz)
  • representative range (500 - 4kHz)
• Sampling frequency should be between 8kHz and 48kHz to reconstruct sound
• Input amplitude should not exceed 2Vp-p
  • Function generator can provide 1.2Vp-p
Receiver Circuit

Add a 100 Ohm resistor in series with the speaker to avoid failures.
Receive Light Signal

Add a 100 Ohm resistor in series with the speaker to avoid failures.
Inverting Amplifier (Pre-Amp)

Add a 100 Ohm resistor in series with the speaker to avoid failures.
Add a 100 Ohm resistor in series with the speaker to avoid failures.
Audio Amplifier Details

- Increases gain 10X (not needed)
- Add a 100 Ohm resistor in series with the speaker to avoid failures.
Special Capacitors

Add a 100 Ohm resistor in series with the speaker to avoid failures.
3. PSpice Model

• You will compare the performance of your circuit to a PSpice model.
• The PSpice for the initial design will be given to you.
• You will use the PSpice to help you make decisions about how to create your final design.
Comparing Output of Blocks

• Take pictures of the signal on each side of the circuit block.
  • A on channel 1 and B on channel 2
  • B on channel 1 and C on channel 2
• Take all measurements relative to ground
• Does the block behave as expected?
• How does it compare to the PSpice output?
Comparing Output of Blocks

“wide-angle” view
- Shows overall shape and size of input and output

“close-up” view
- Output divided by 10
- Shows sampling frequency
- Shows shape of samples
4. Final Design

• The signal is reconstructed well enough by the initial design that it will be audible.
• In order to improve the quality of the signal, you will add an integrator, which will more exactly reconstruct it.
• Types of integrators
  • passive integrator (low pass filter)
  • active integrator (op amp integrator circuit)
• You will then improve the signal further with a smoothing capacitor.
Passive Integration

\[ V_{out} = \frac{1}{RC} \int V_{in} \, dt \]

\[ f_C = \frac{1}{2\pi RC} \]

Integration works only at high frequencies \( f >> f_c \). Unfortunately, your amplitude will also decrease.
Active Integration

\[ V_{out} = \frac{-1}{R_iC} \int V_{in} \, dt \]

\[ f_C = \frac{1}{2\pi R_f C} \]

- Integration works at \( f >> f_c \)
- Your gain goes from \(-R_f/R_i\) to \(-1/R_iC\)
- The amplitude of your signal will decrease or increase depending on components
Input at A vs. Output at H

Before addition of integrator

After addition of integrator
Recall what the smoothing capacitor did to the output of the half wave rectifier.
Input at A vs. Output at H

Before smoothing capacitor

After smoothing capacitor
Project Packet

• Initial Data with Function Generator
  • PSpice
  • Mobile Studio plots from circuit
  • Brief Comparison
  • Block Description
  • For
    • Overall System: A-H

• Initial Data with Audio
  • Mobile Studio plots from circuit
  • For E-F and A-H
Project Packet

• Final Data (integrator only) with Function Generator
  • PSpice
  • Mobile Studio plots from circuit
  • Brief Comparison
  • For E-F and A-H

• Final Data (integrator and smoothing) PSpice only
  • PSpice
  • Compare to without smoothing
  • For E-F and A-H
Project Packet

• Final Data with Integrator (and possibly Smoothing) with Audio
  • Mobile Studio plots from circuit
  • For E-F and A-H

• Extra Credit
  • Mobile Studio picture of A-H with input from function generator and integrated, smoothed output. Indicate values of components and where used.
Work in teams

• Put the transmitter on one protoboard and the receiver on a second.
  • One pair do the transmitter circuit
    • This is the easier circuit, so maybe also start the PSpice simulation.
  • The other pair build the receiver circuit
• One report for the entire team
  • Report is closer to an experiment report than a project report
  • See details in handout.