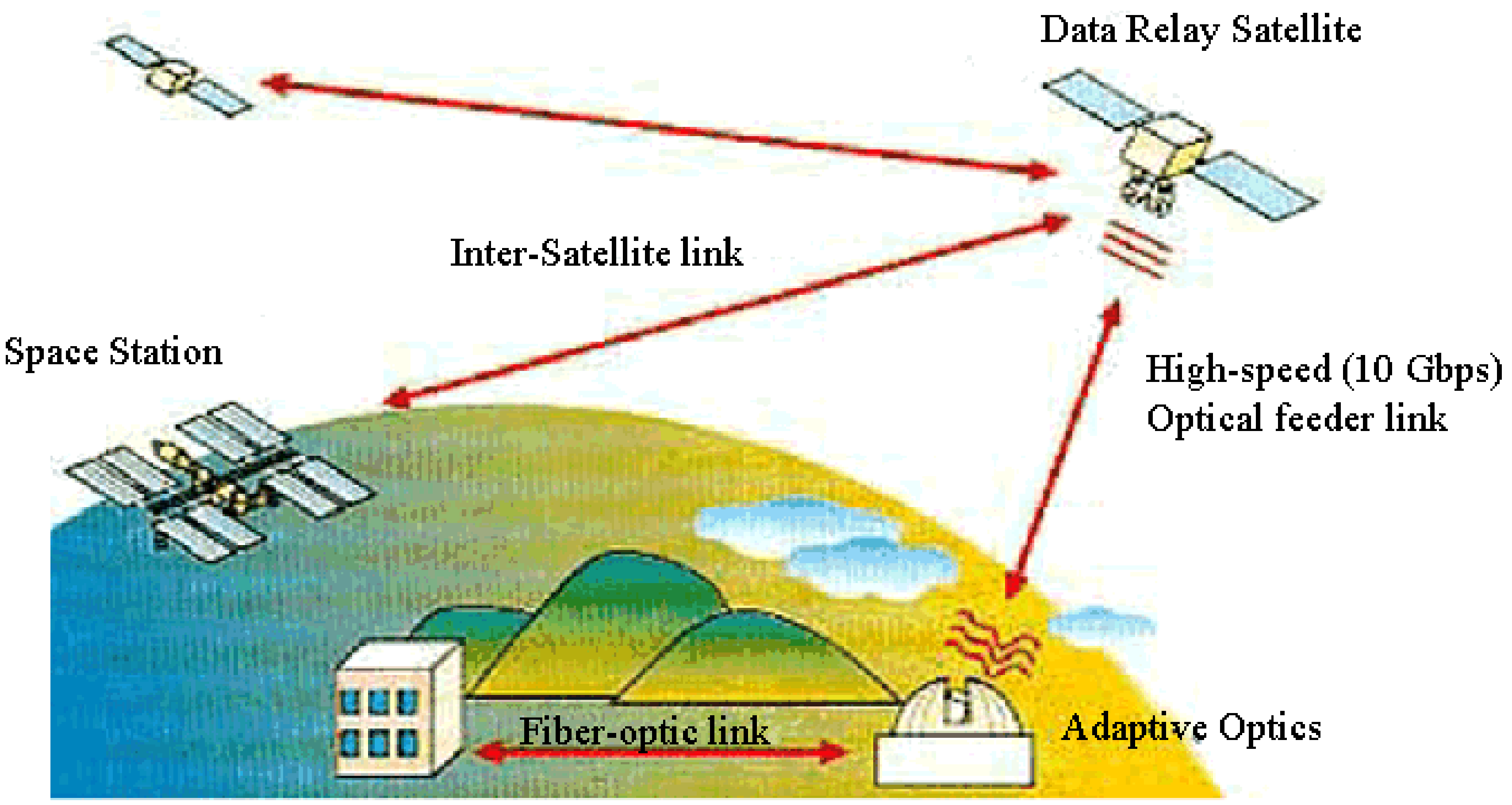
# Electronic Instrumentation

## Project 4

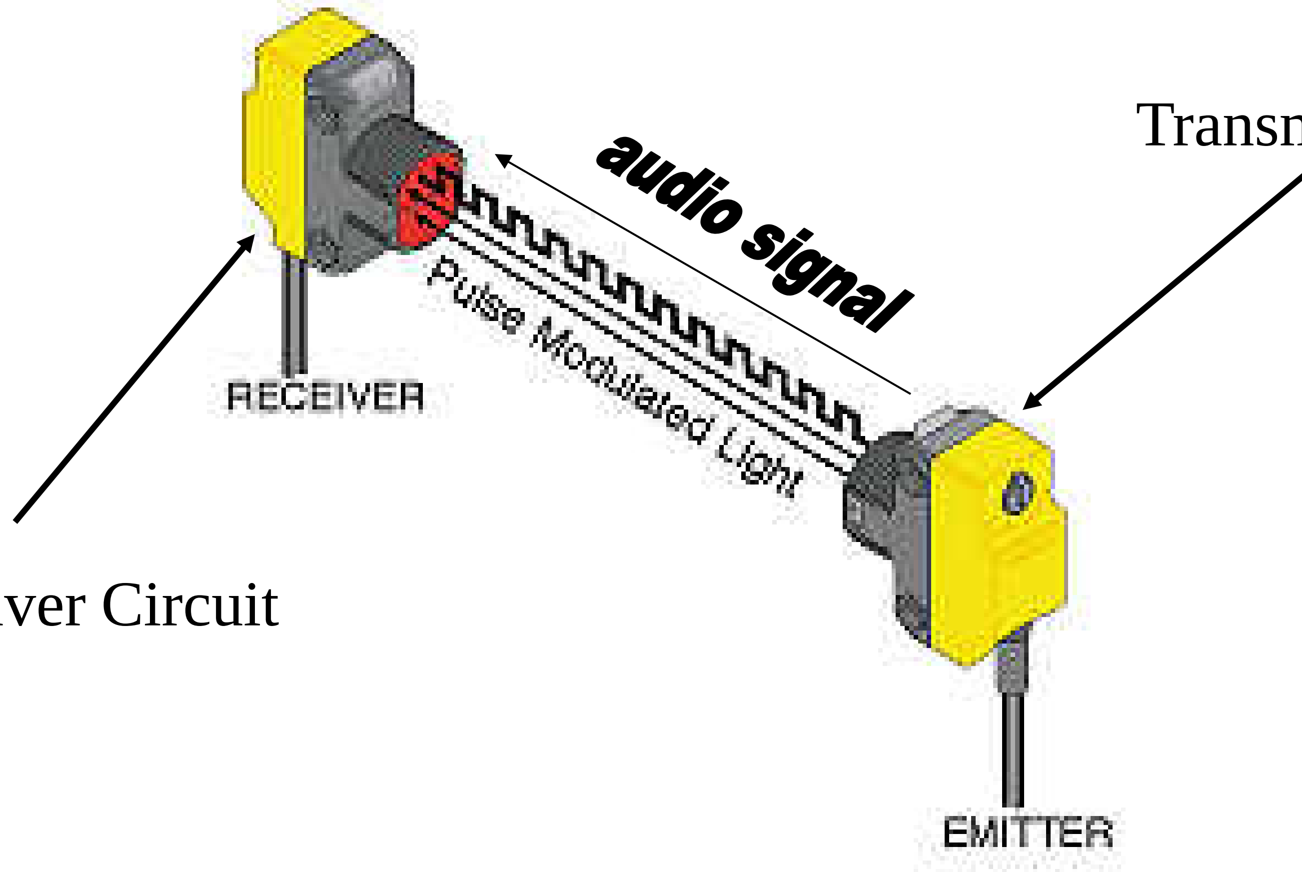
- 1. Optical Communications
- 2. Initial Design
- 3. PSpice Model
- 4. Final Design
- 5. Project Report

# 1. Optical Communications



# *Transmitting an audio signal using light*

Transmitter Circuit

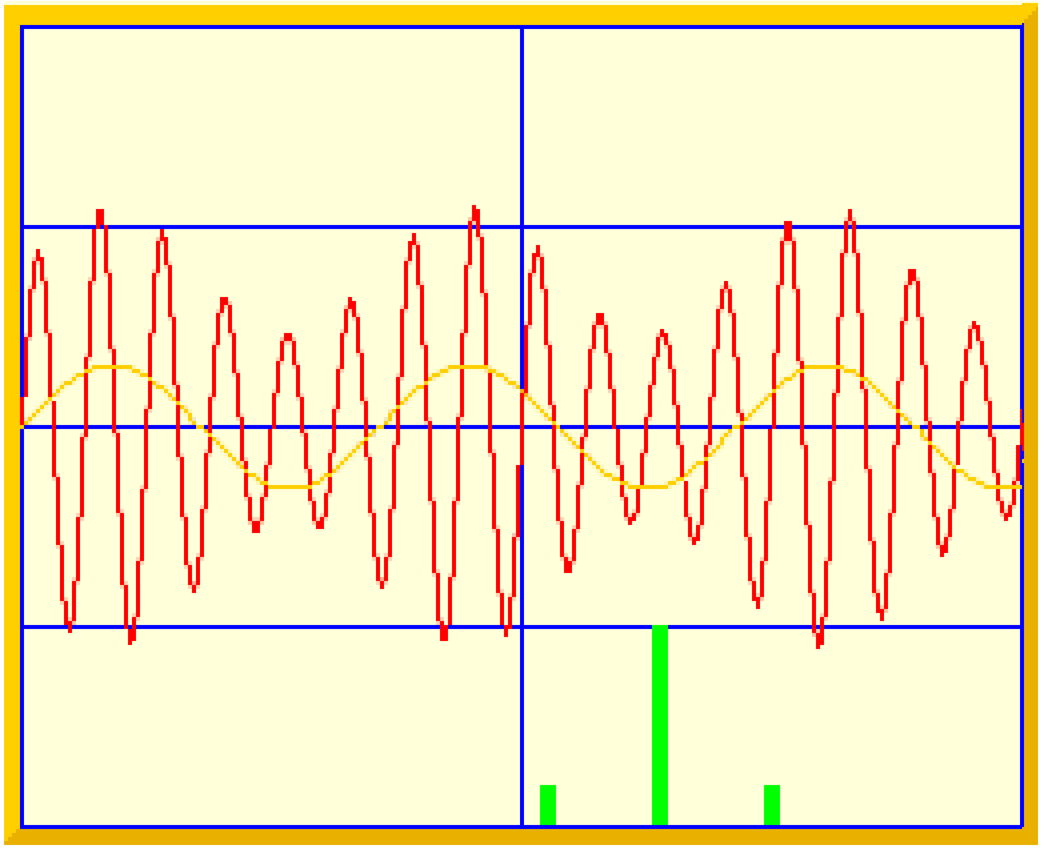



Receiver Circuit

# 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*



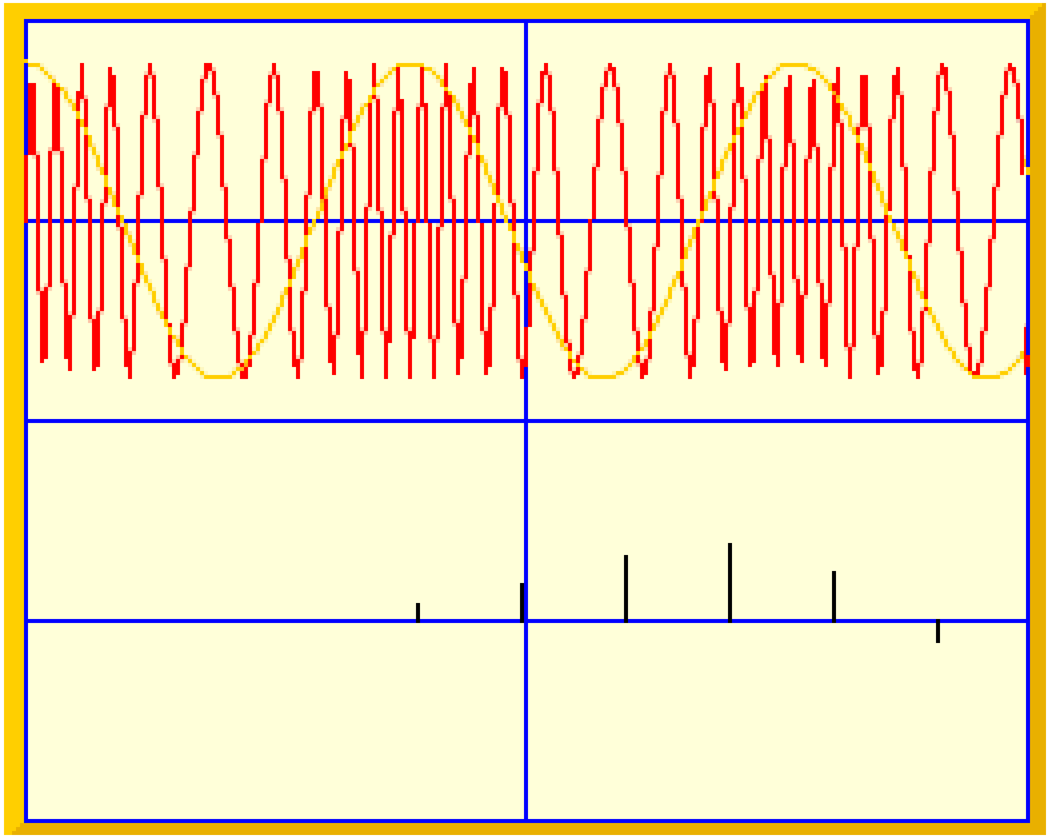
Frequency of carrier remains constant.

Input signal alters amplitude of carrier.

Higher input voltage means higher carrier amplitude.

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

# *Frequency Modulation*



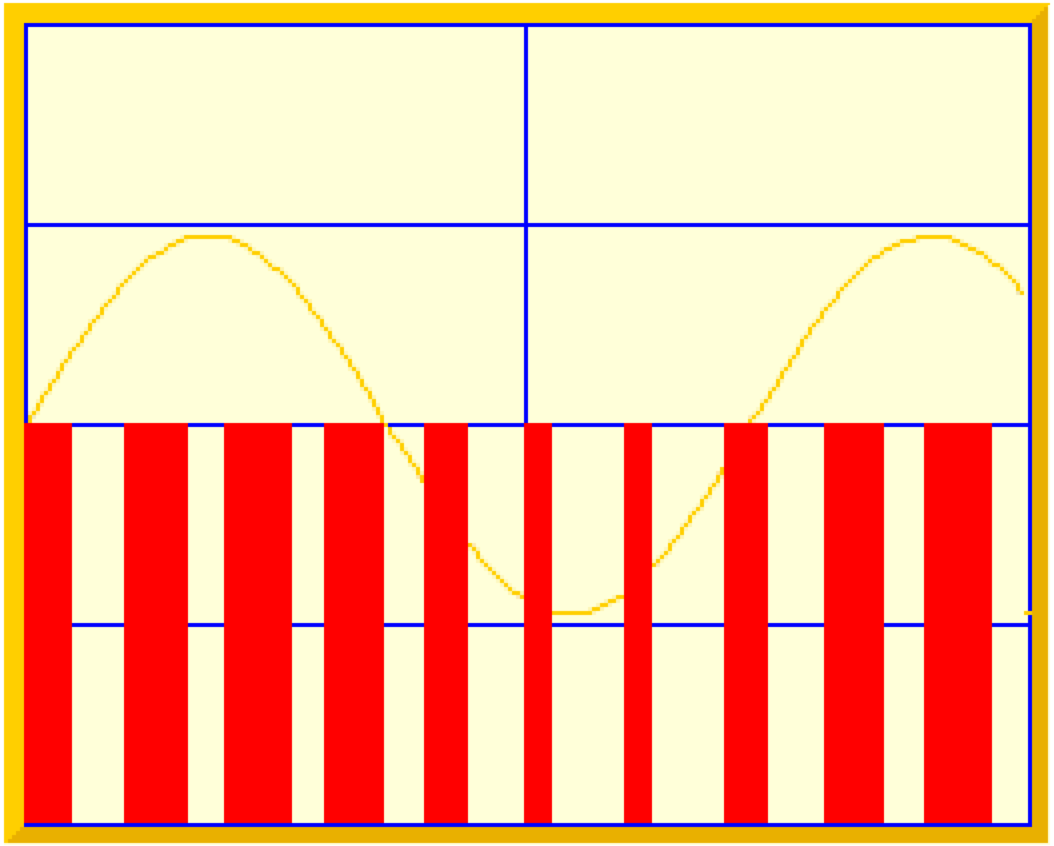
Amplitude of carrier remains constant.

Input signal alters frequency of carrier.

Higher input voltage means higher carrier frequency.

http://cnyack.homestead.com/files/modulation/modfm.htm

# *Pulse Width Modulation*



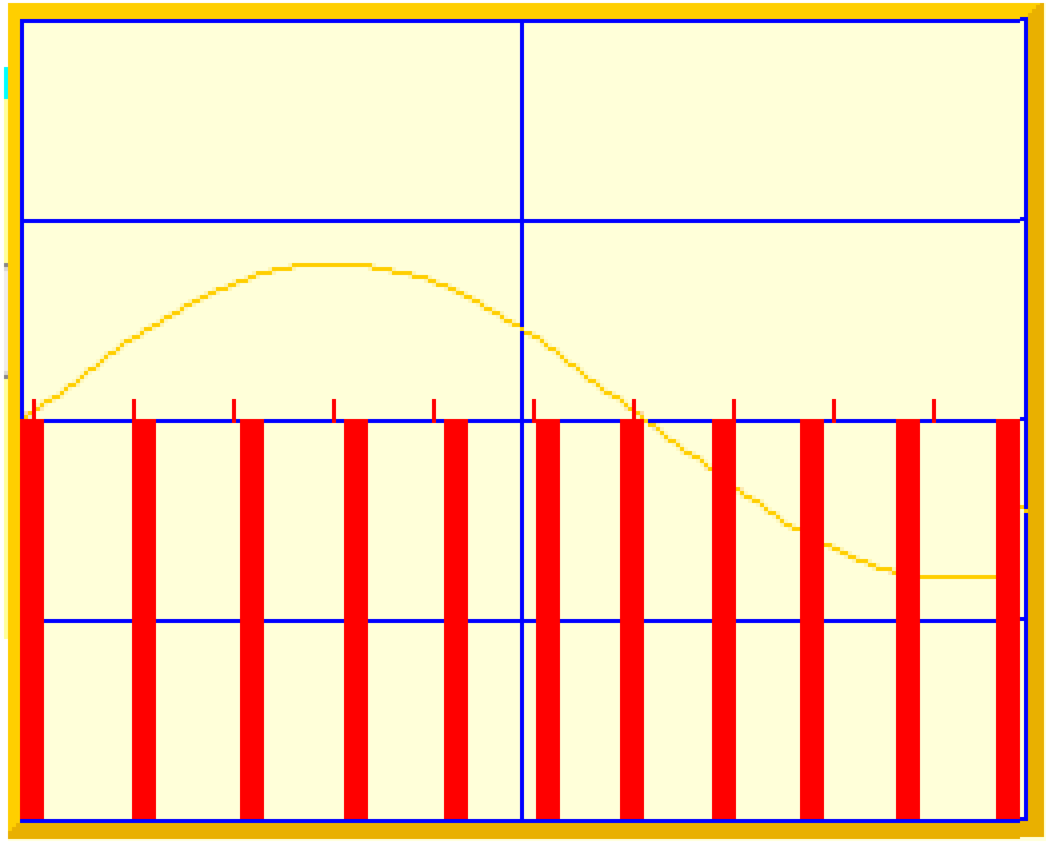
Period of carrier remains constant.

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 Position Modulation*



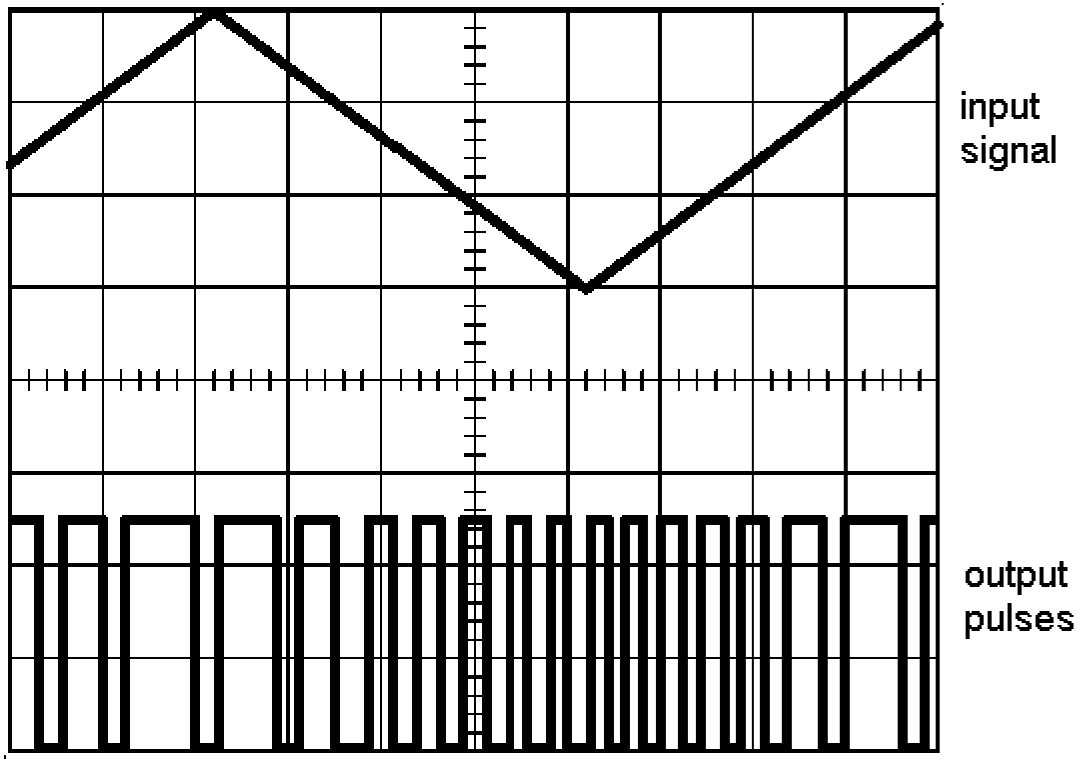
Pulse width of carrier remains constant.

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*

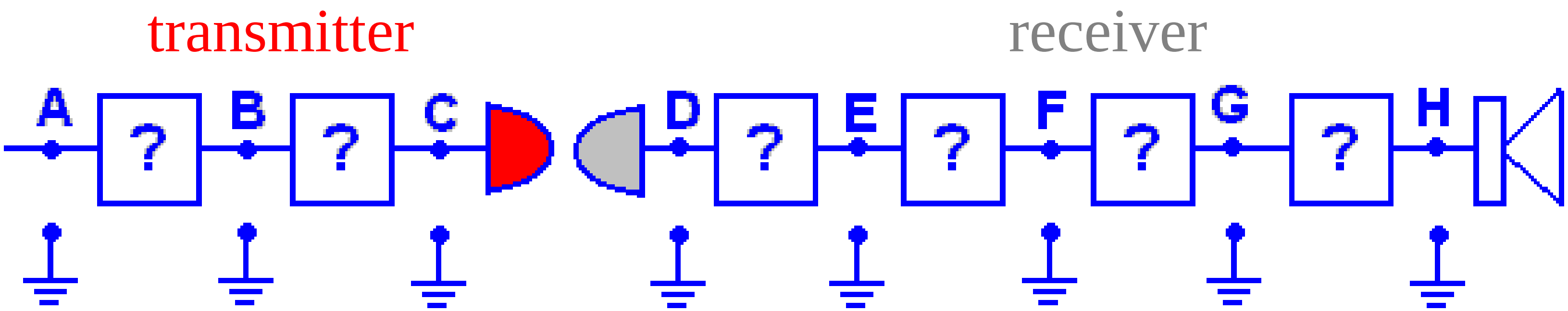



Duty cycle of carrier remains constant.

Input signal alters pulse width and period of carrier.

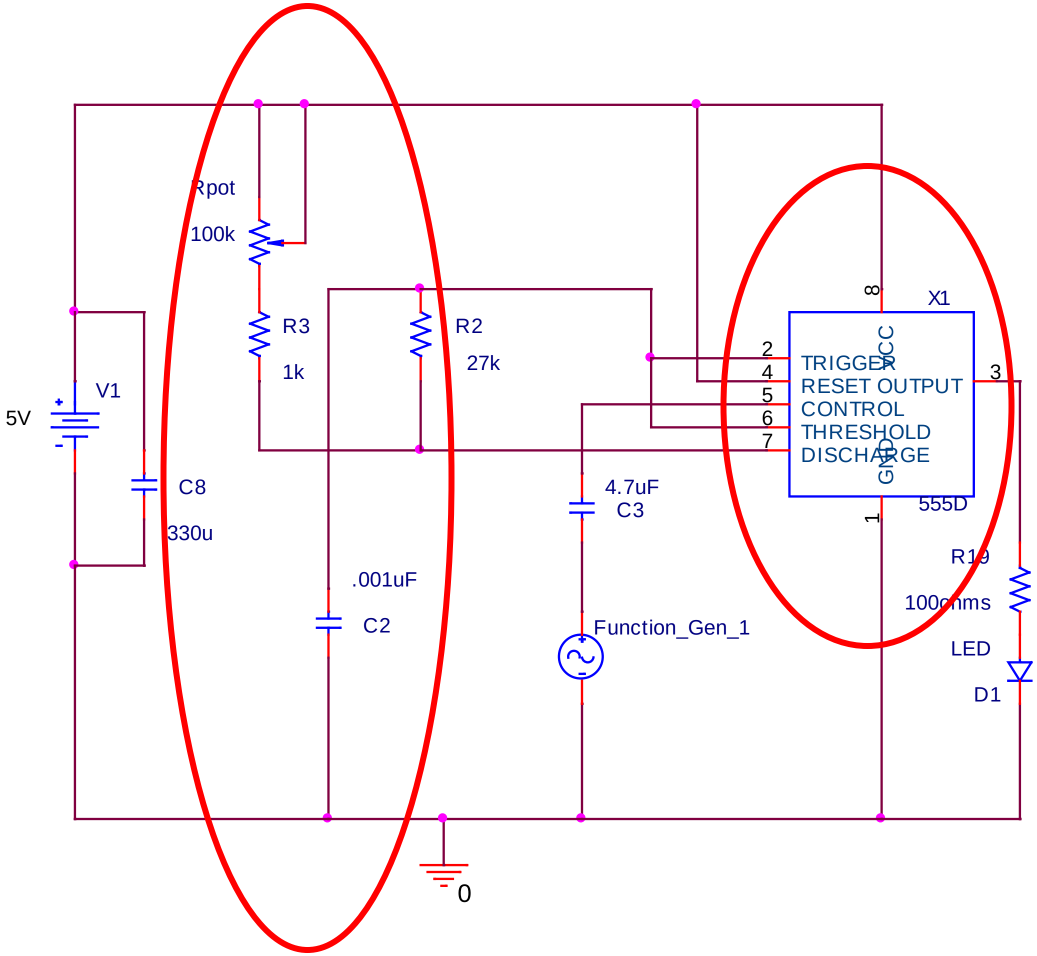
Higher input voltage means pulses with longer pulse widths and longer periods.

# 2. Initial Design

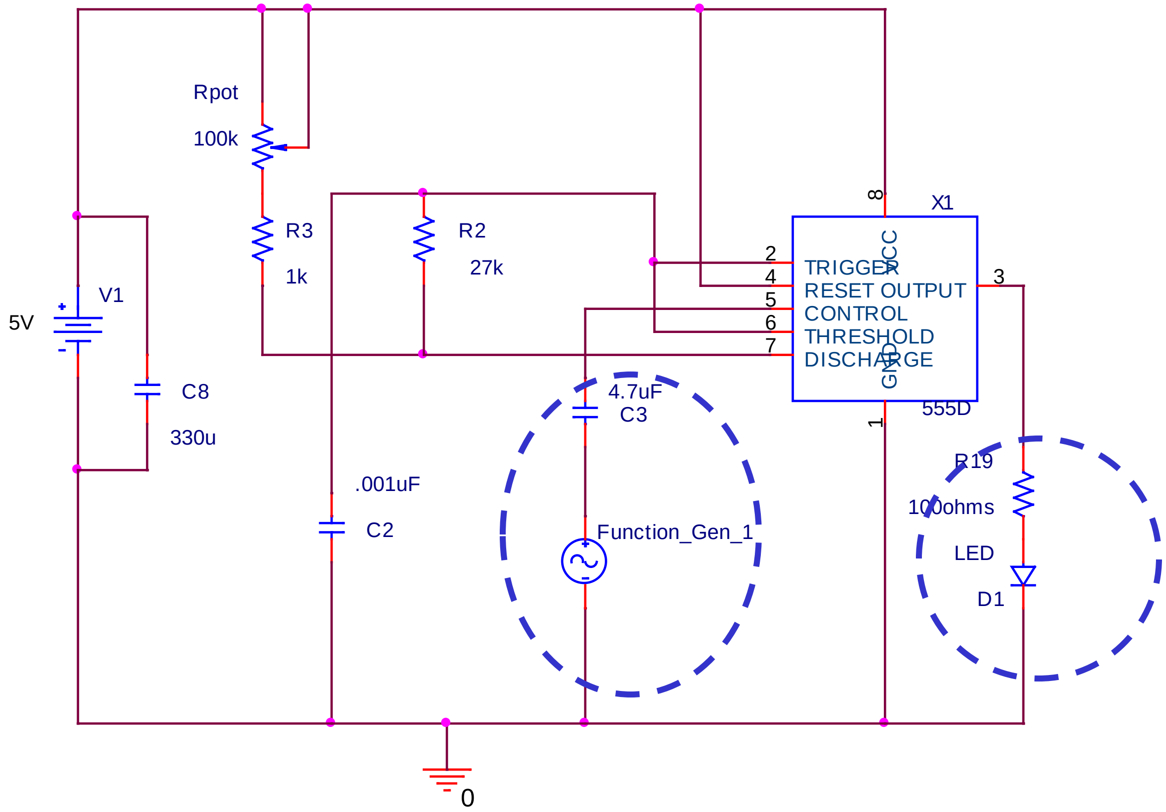



- The initial design for this project is a circuit consisting of a transmitter and a receiver.
- The circuit is divided into functional blocks.
  - Transmitter: Block A-B and Block B-C
  - Transmission: Block C-D
  - Receiver: Block D-E, Block E-F, Block F-G, and Block G-H
- You will need to examine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

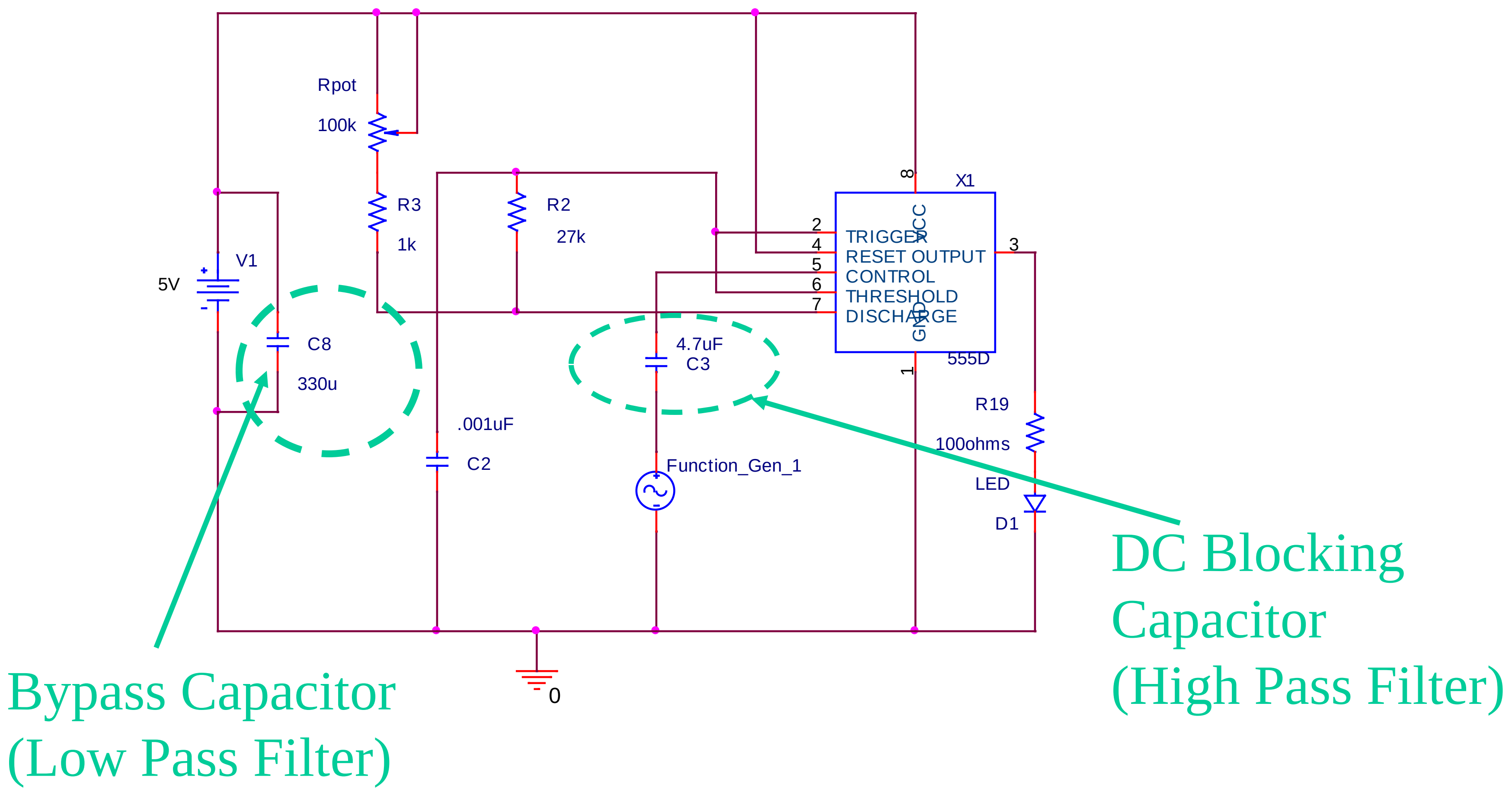
# *Transmitter Circuit*



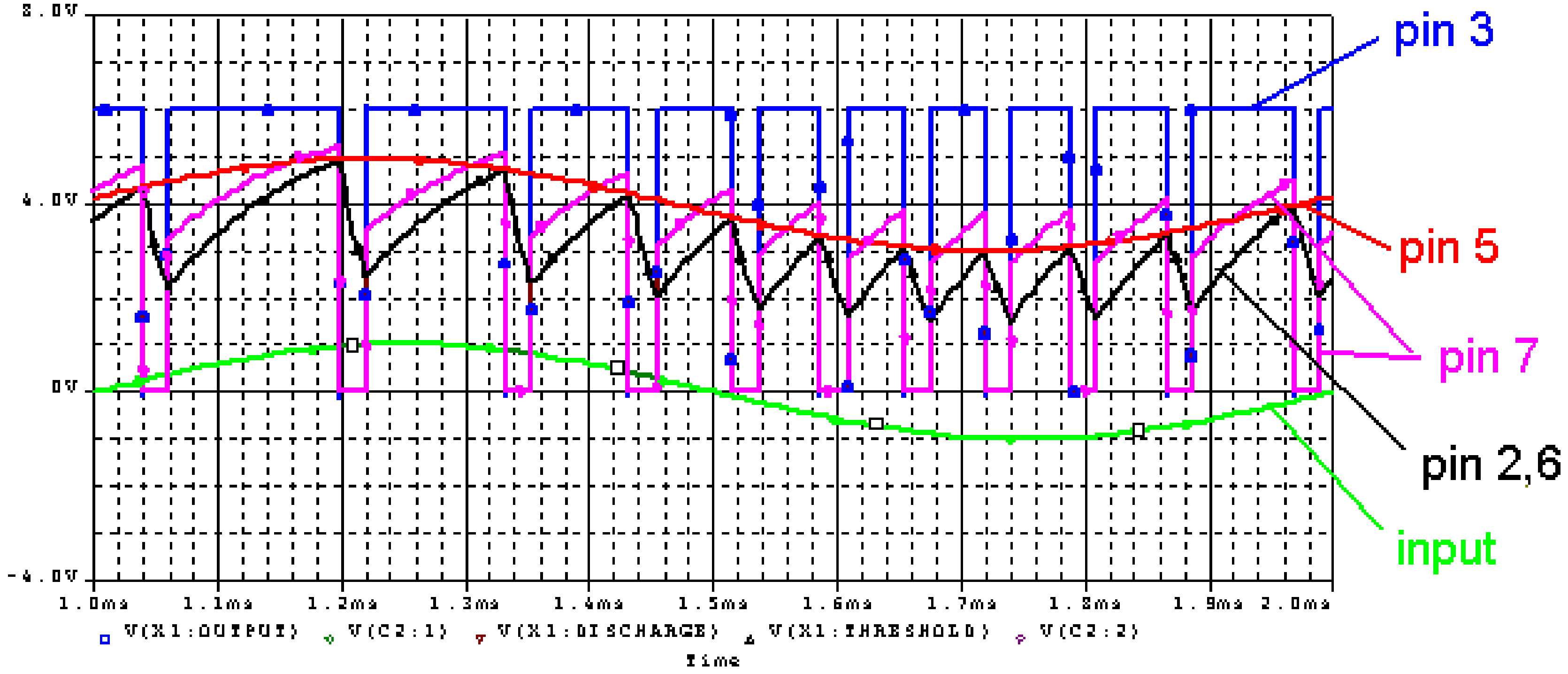
# *Input and Modulated Output*



# Special Capacitors

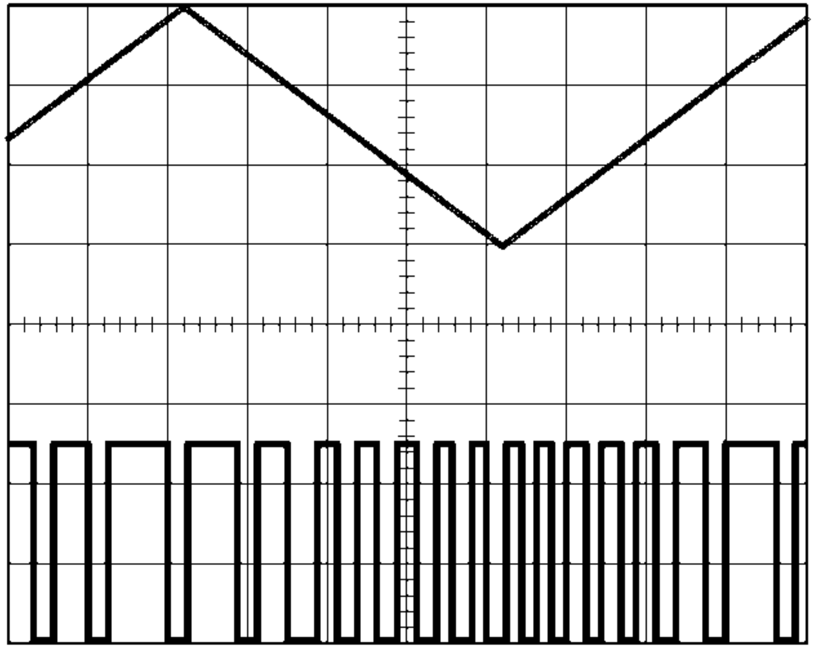


# *Sample Input and Output*




- When input is higher, pulses are longer
- When input is lower, pulses are shorter

# *Your signal is what?*



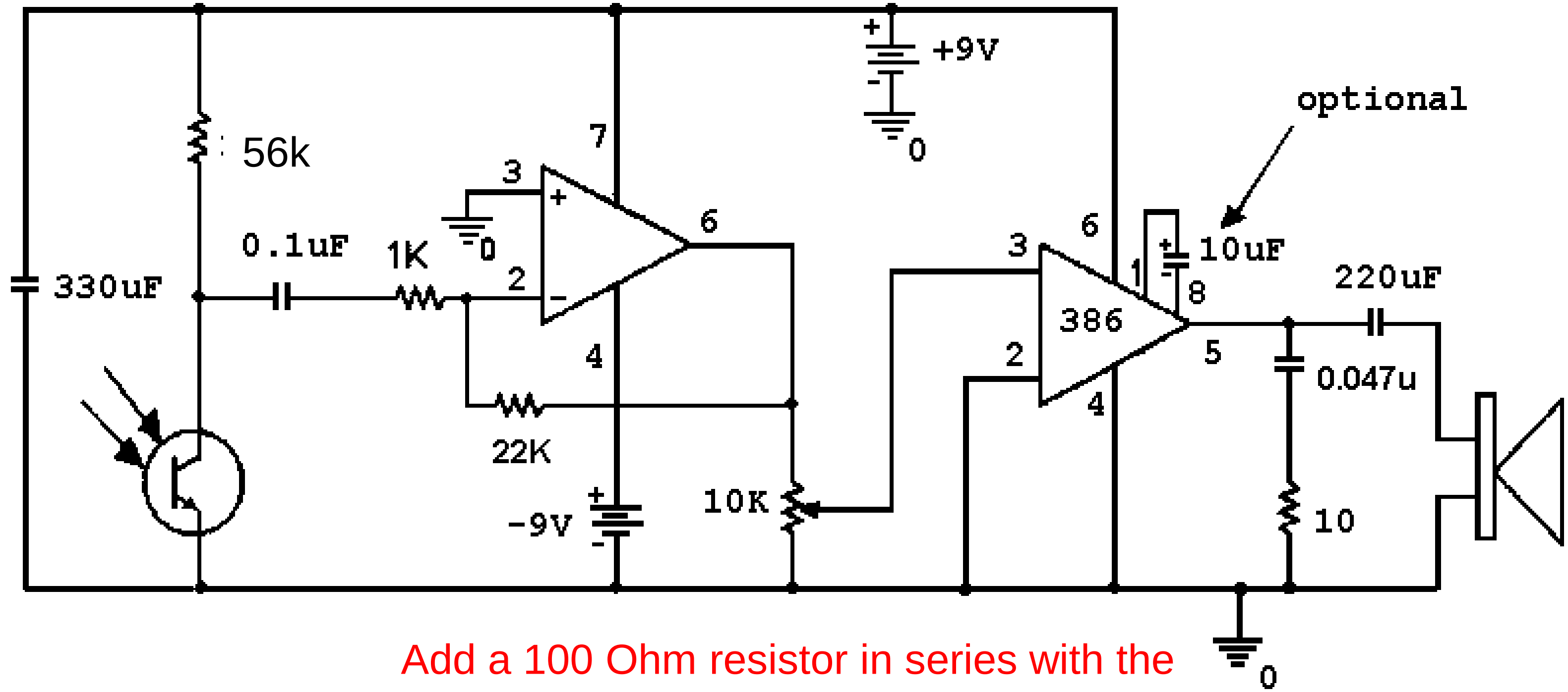
The type of modulation this circuit creates is most closely categorized as pulse frequency modulation.

But the pulse width is also modulated and we will use that feature.

# *Sampling Frequency*

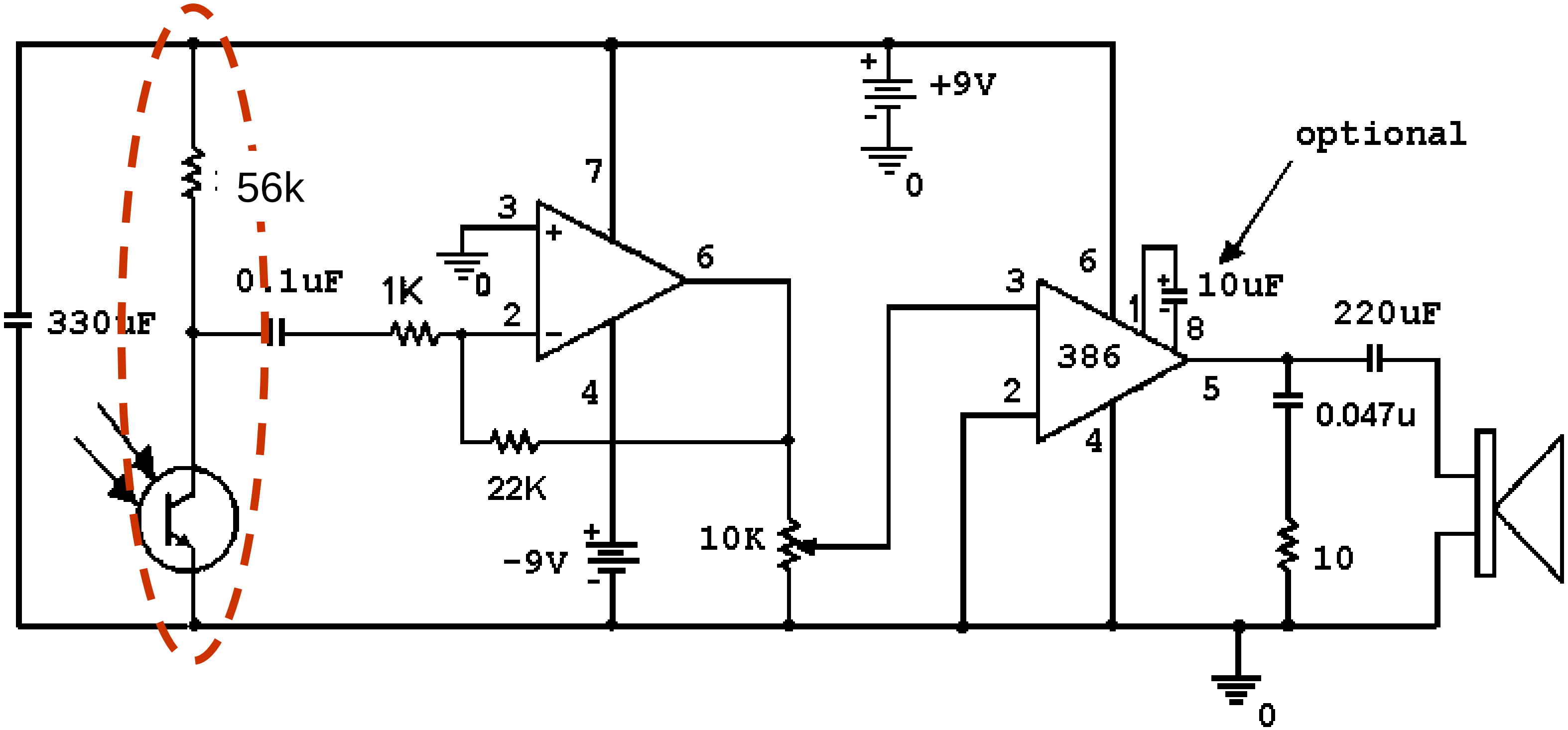
- The pot (used as a variable resistor) controls your sampling frequency
- Input frequency in audible range
  - max range (20 - 20kHz)
  - representative range (500 - 4kHz)
- Sampling frequency should be between 8kHz and 48kHz to reconstruct sound
- Input amplitude should not exceed 2Vp-p
  - Function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

# Receiver Circuit



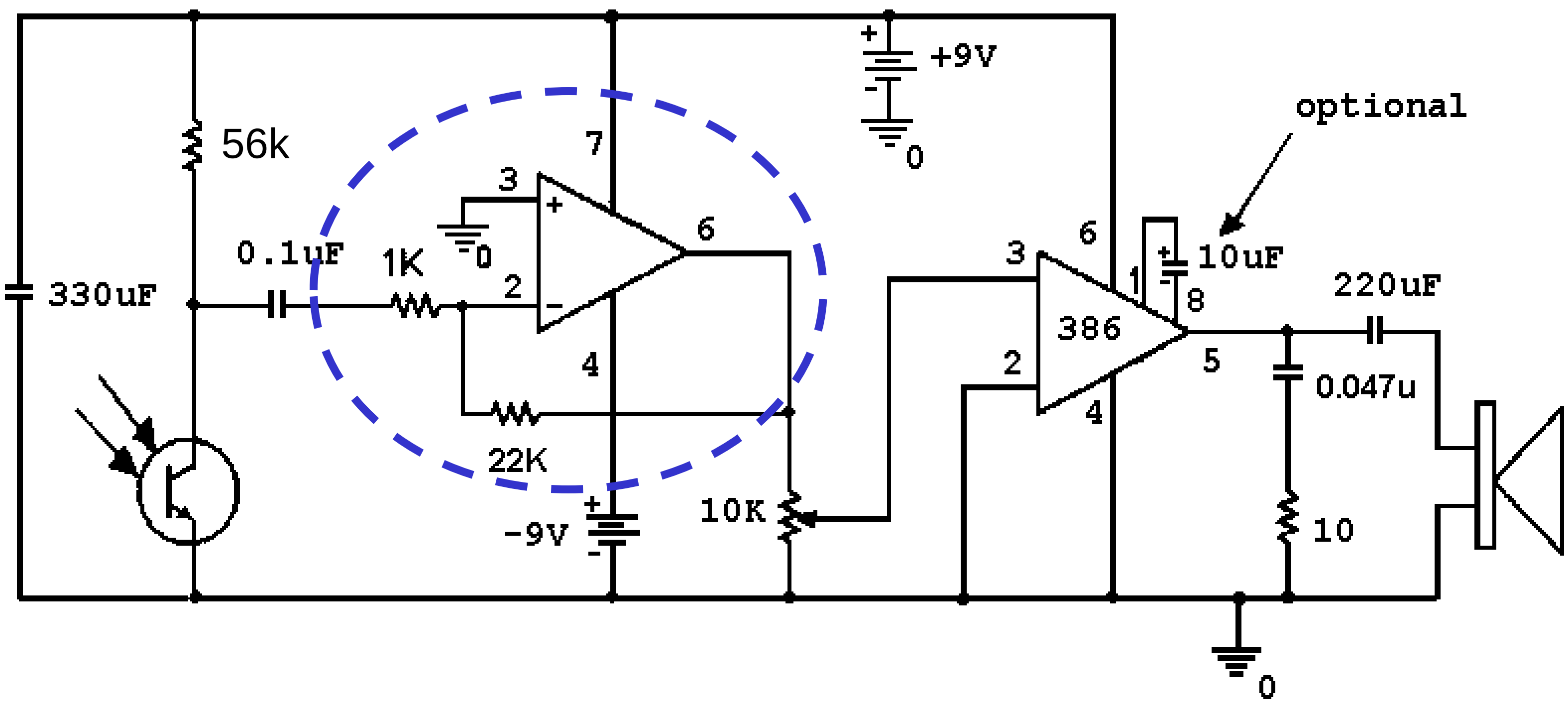

Add a 100 Ohm resistor in series with the speaker to avoid failures.

# *Receive Light Signal*



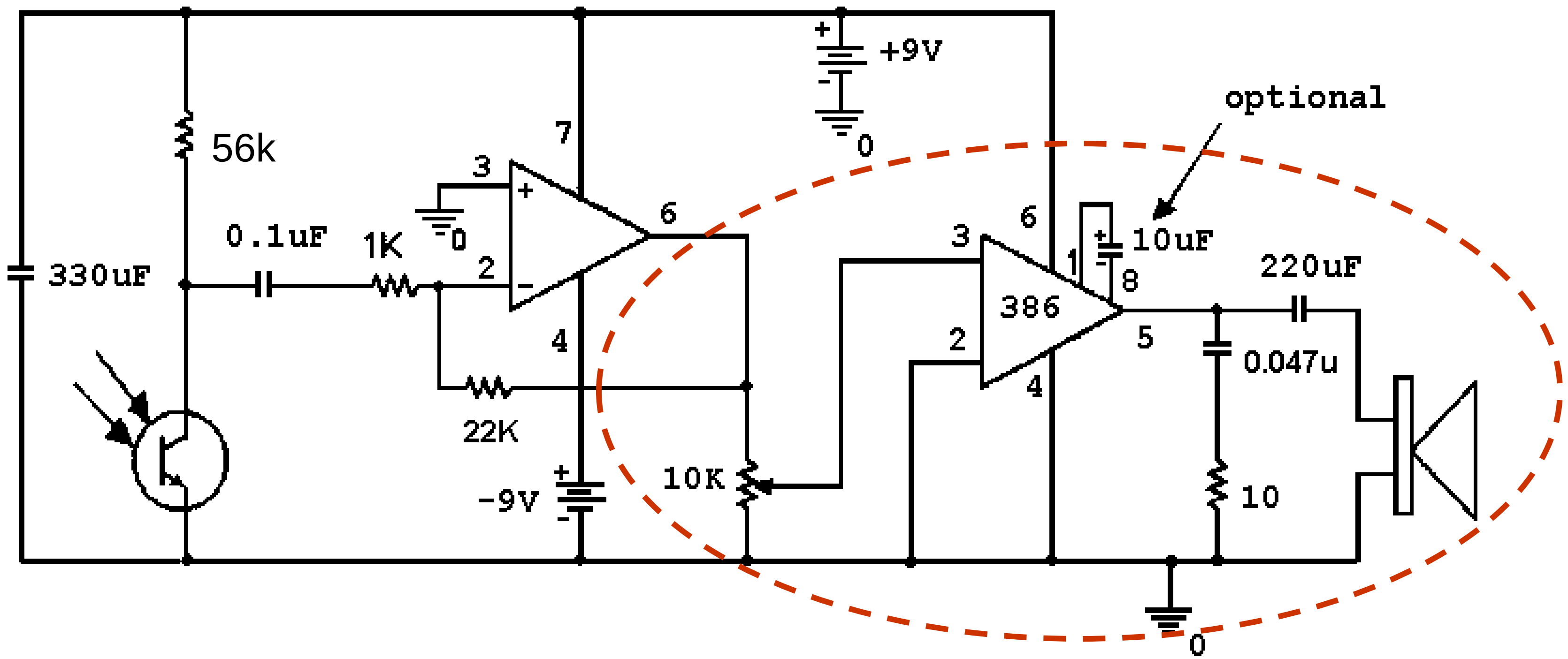

Add a 100 Ohm resistor in series with the speaker to avoid failures.

# *Inverting Amplifier (Pre-Amp)*



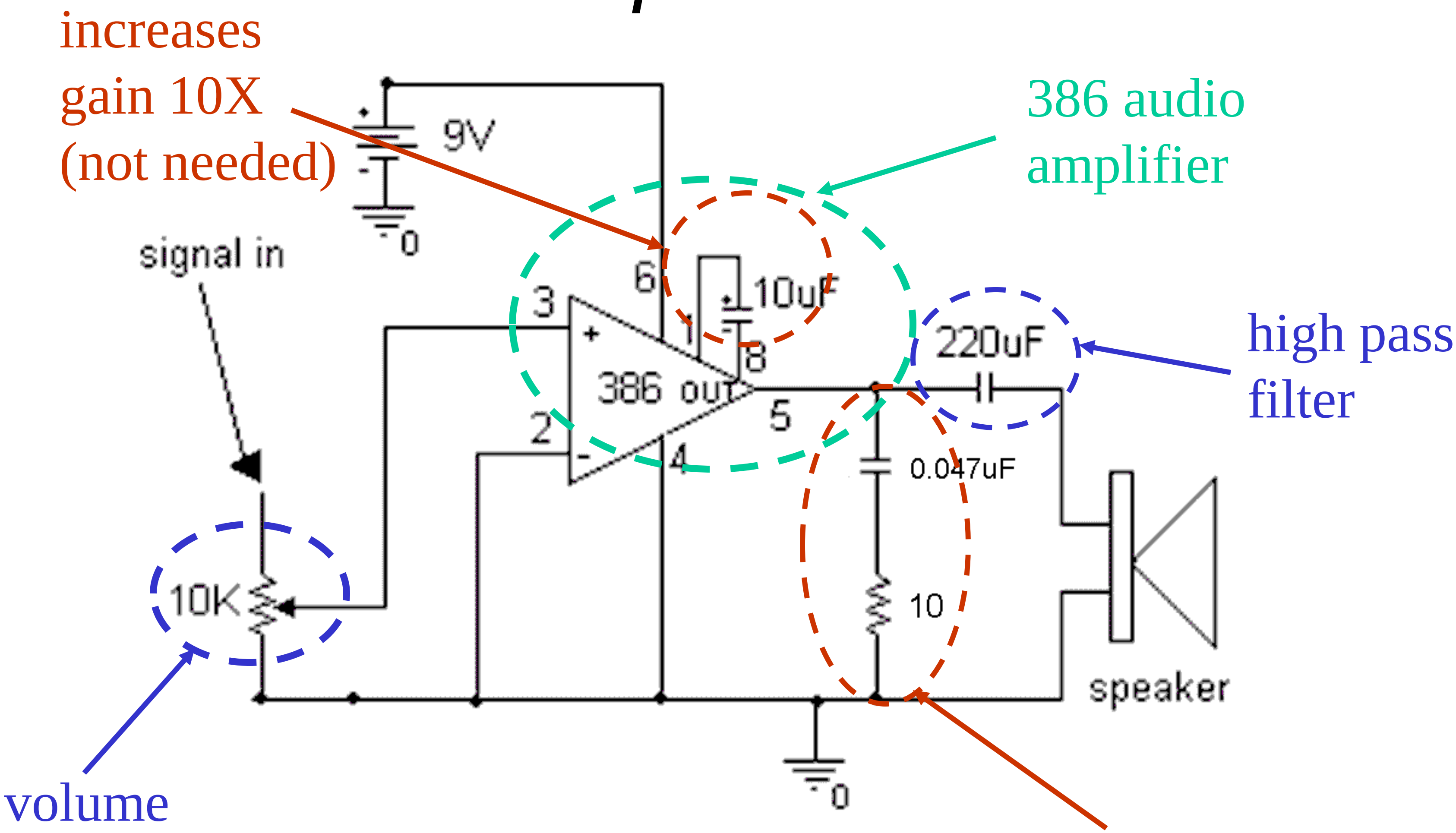

Add a 100 Ohm resistor in series with the speaker to avoid failures.

# *Audio Amplifier*



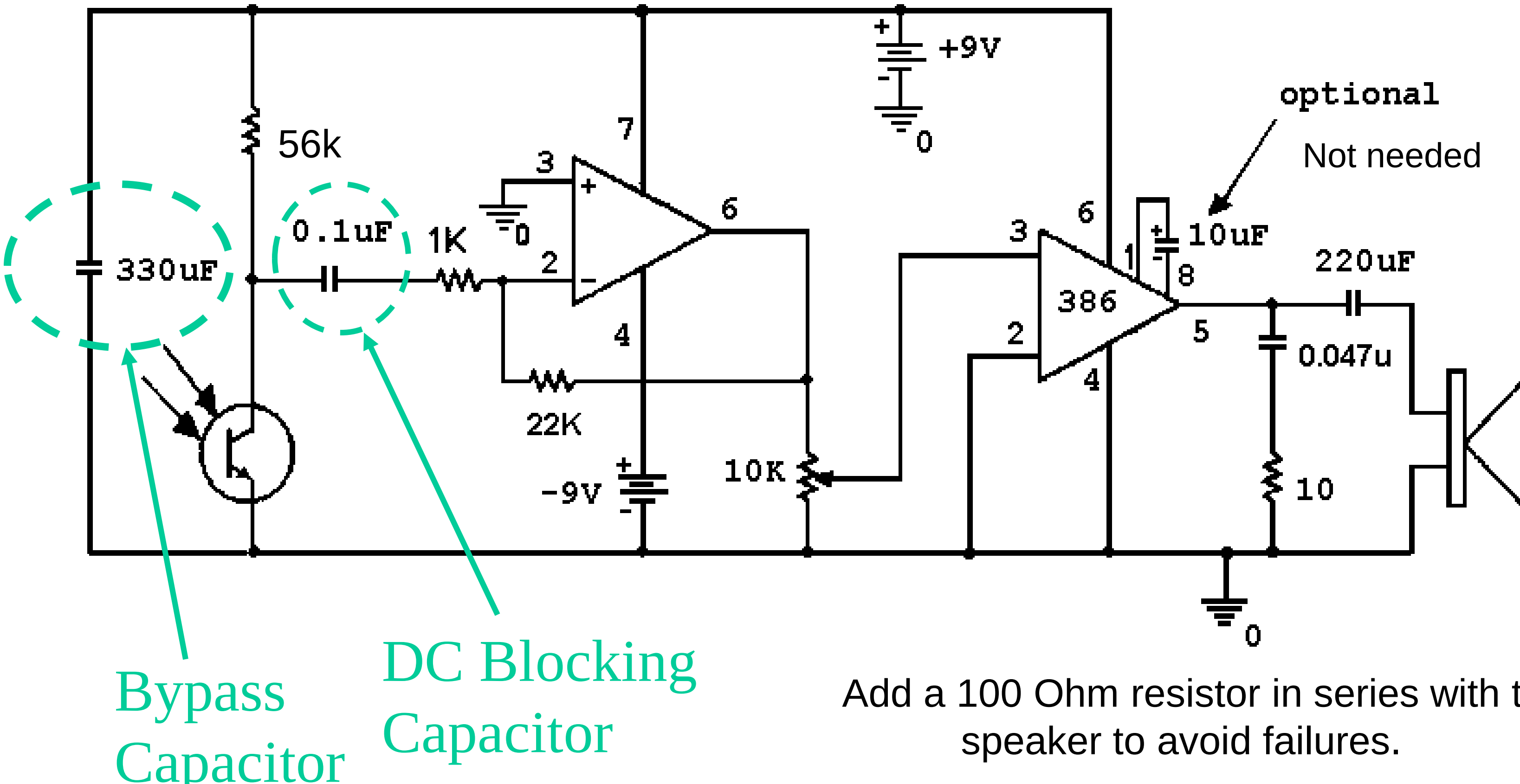

Add a 100 Ohm resistor in series with the speaker to avoid failures.

# *Audio Amplifier Details*




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

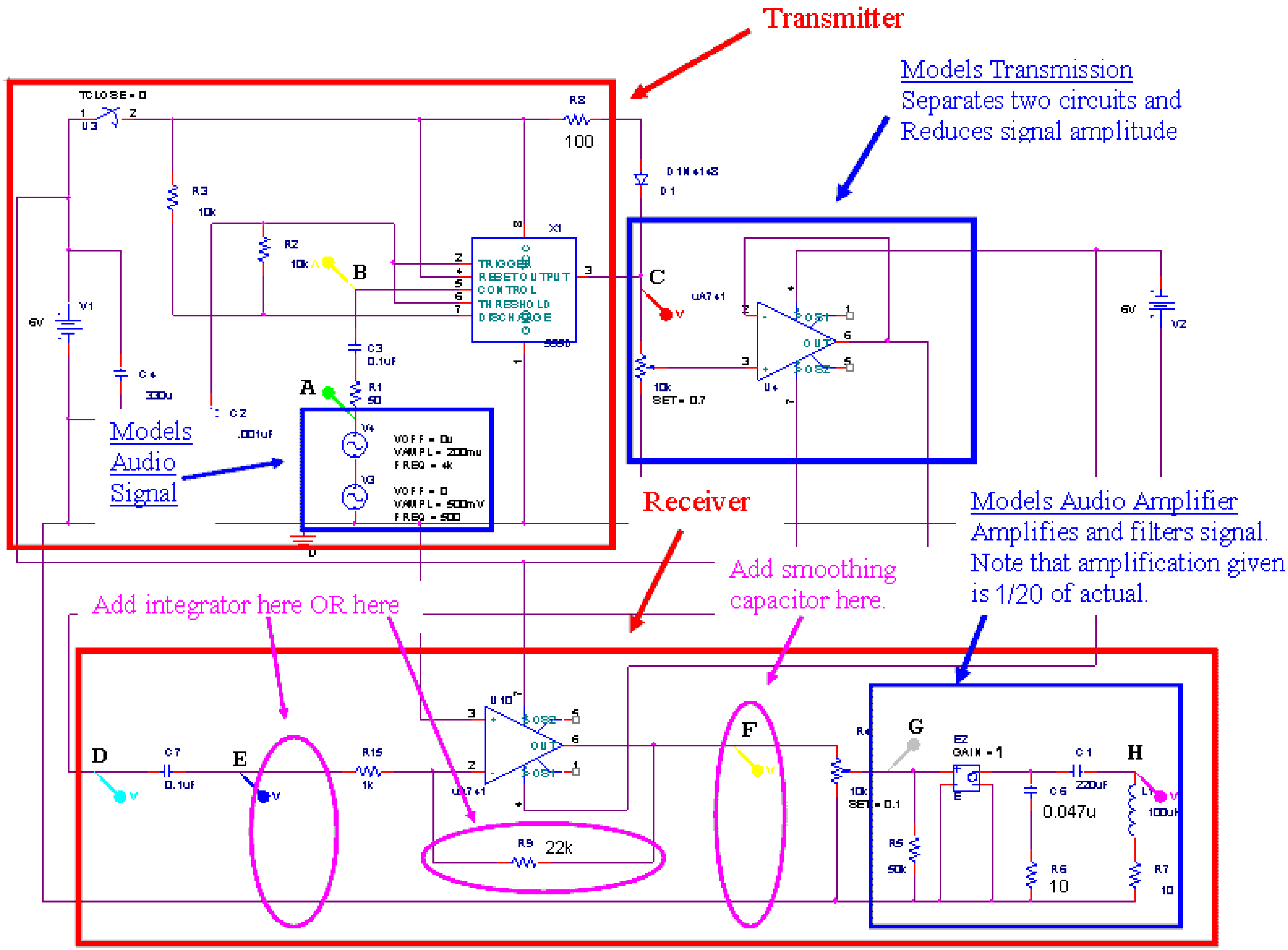
# Special Capacitors



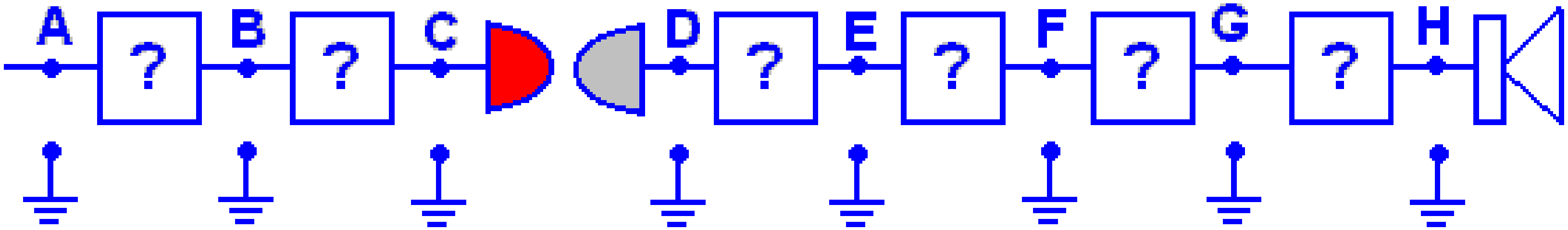

Add a 100 Ohm resistor in series with the speaker to avoid failures.

# 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.

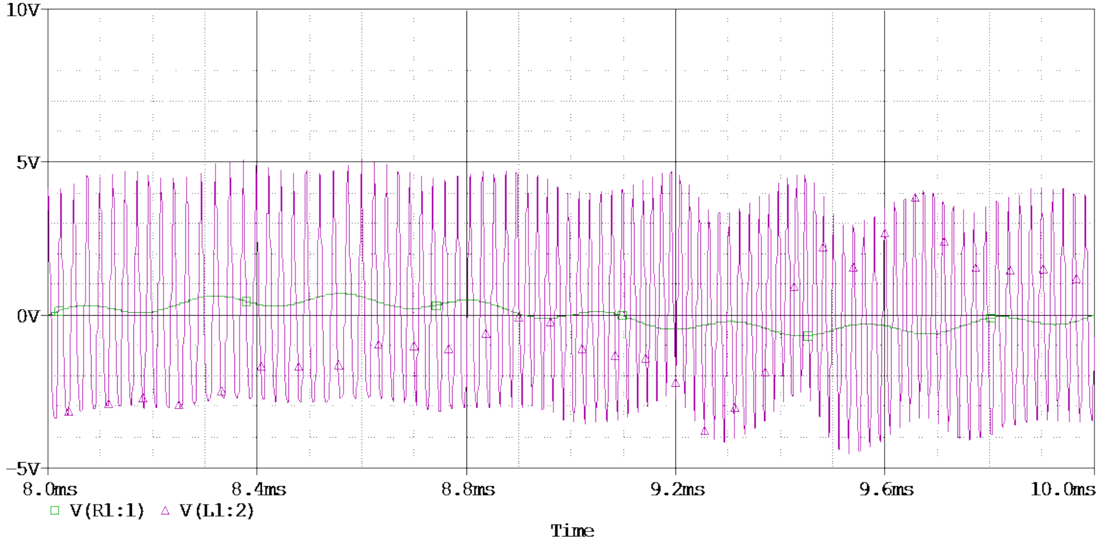

Transmitter
Models Transmission
Separates two circuits and
Reduces signal amplitude
Models Audio Signal
A
B
C
Receiver
Models Audio Amplifier
Amplifies and filters signal.
Note that amplification given
is 1/20 of actual.
Add smoothing
capacitor here.
Add integrator here OR here
D
E
F
G
H
100
22k
0.047u
10
TRIGGER
RESET
OUTPUT
CONTROL
THRESHOLD
DISCHARGE
VOFF = 0
FREQ = 500
GAIN = 1
220uF

# *Comparing Output of Blocks*



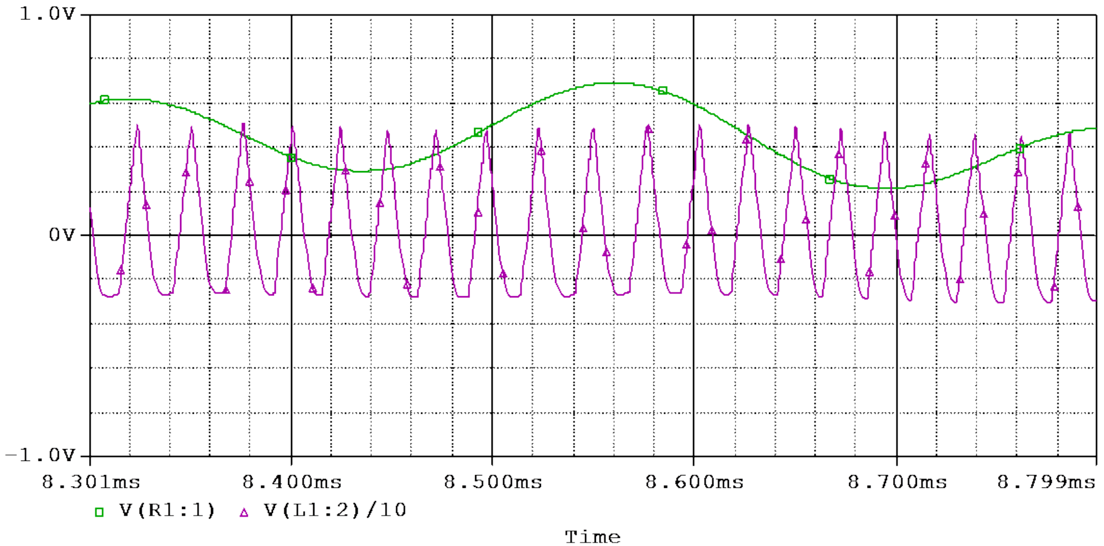

- Take pictures of the signal on each side of the circuit block.
  - A on channel 1 and B on channel 2
  - B on channel 1 and C on channel 2
- Take all measurements relative to ground
- Does the block behave as expected?
- How does it compare to the PSpice output?

# Comparing Output of Blocks




"wide-angle" view

- Shows overall shape and size of input and output



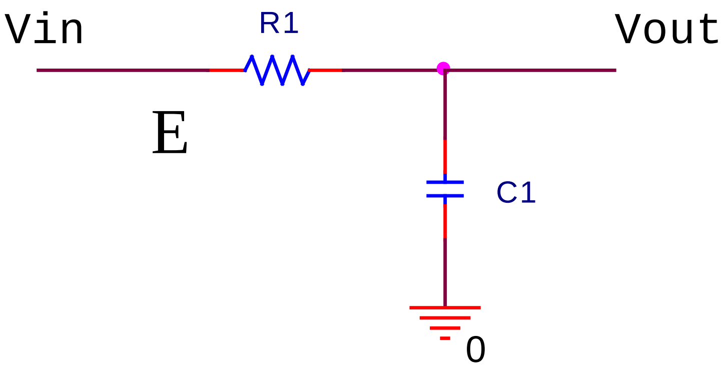

"close-up" view

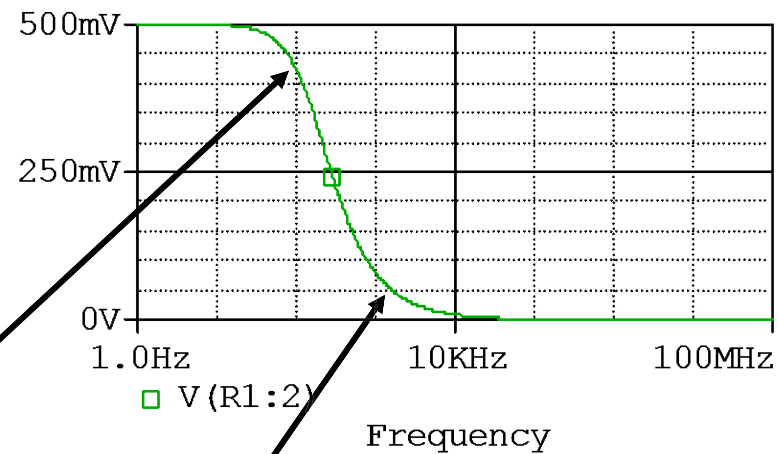
- Output divided by 10
- Shows sampling frequency
- Shows shape of samples

# 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*



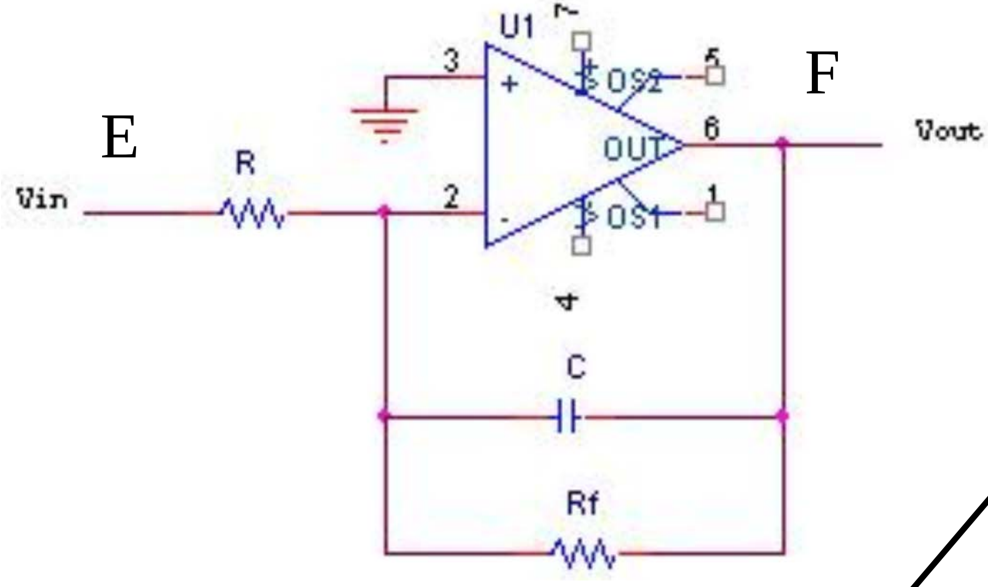



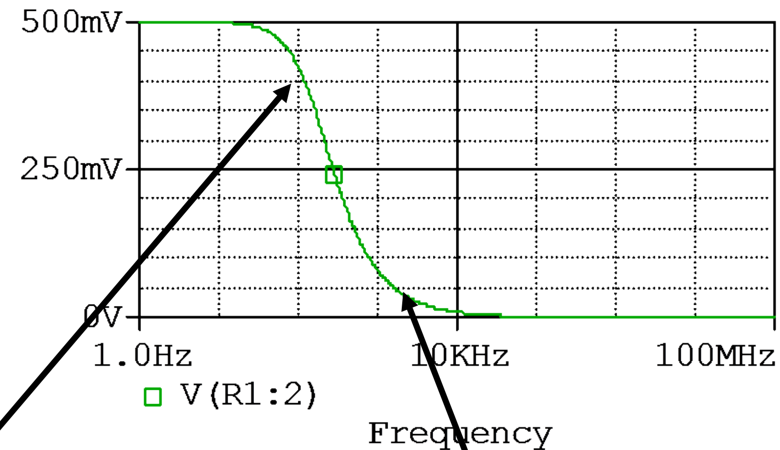

$$V_{out} = \frac{1}{RC}\int V_{in}dt$$

$$f_C = \frac{1}{2\pi RC}$$

Integration works only at high frequencies f >>fc. Unfortunately, your amplitude will also decrease.

# Active Integration



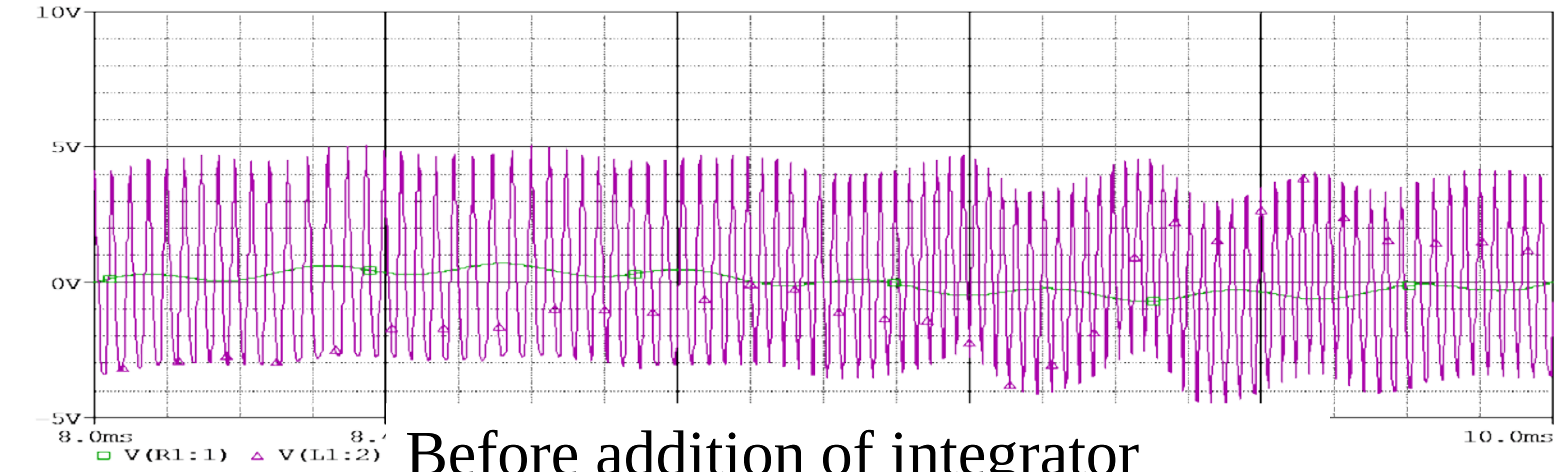




$$V_{out} = \frac{-1}{R_i C}\int V_{in}\,dt$$

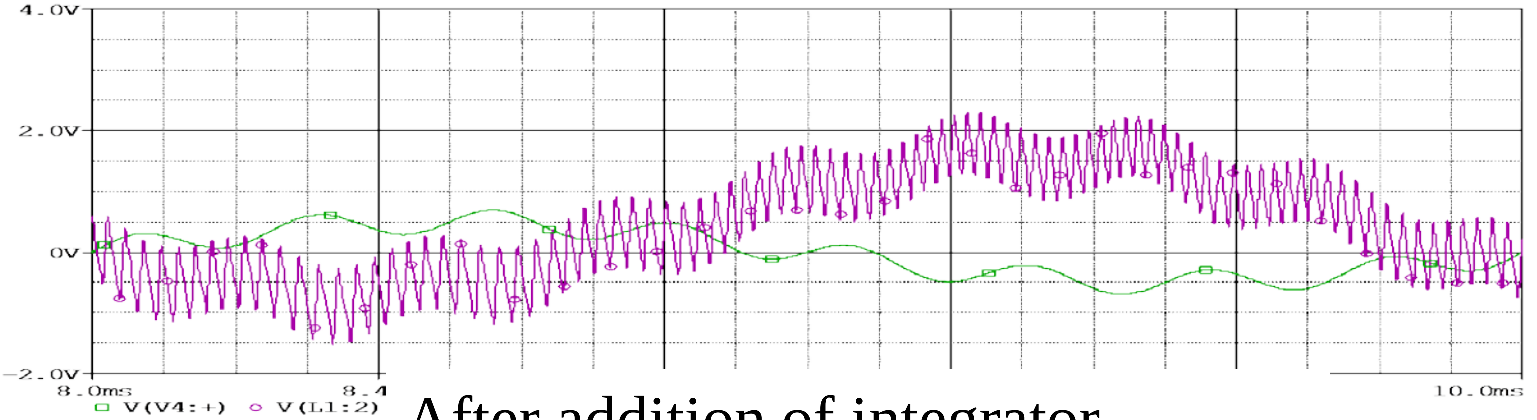
$$f_C = \frac{1}{2\pi R_f C}$$

- Integration works at f >>fc
- 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*

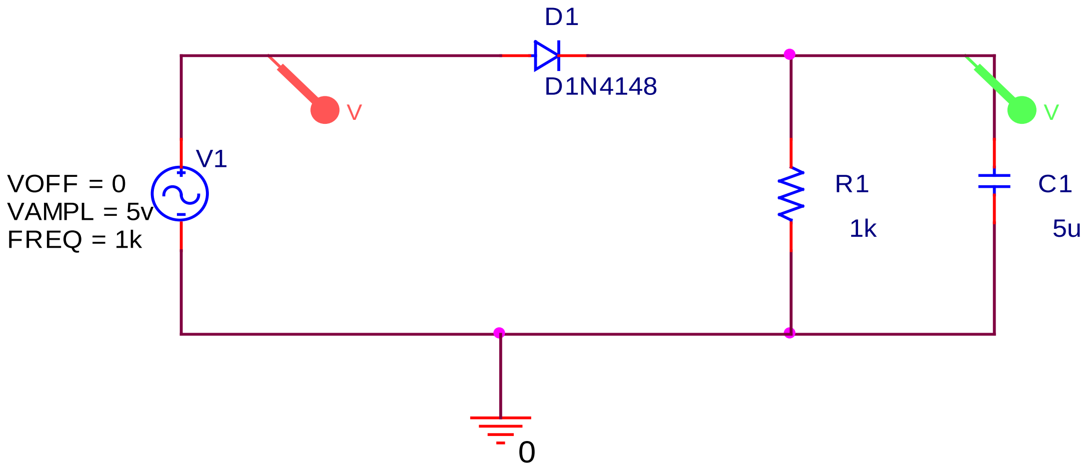


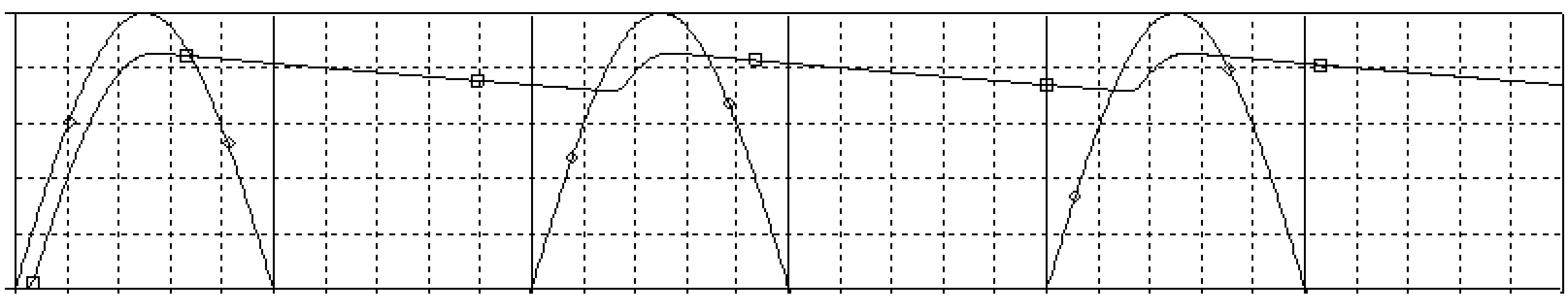

Before addition of integrator




After addition of integrator

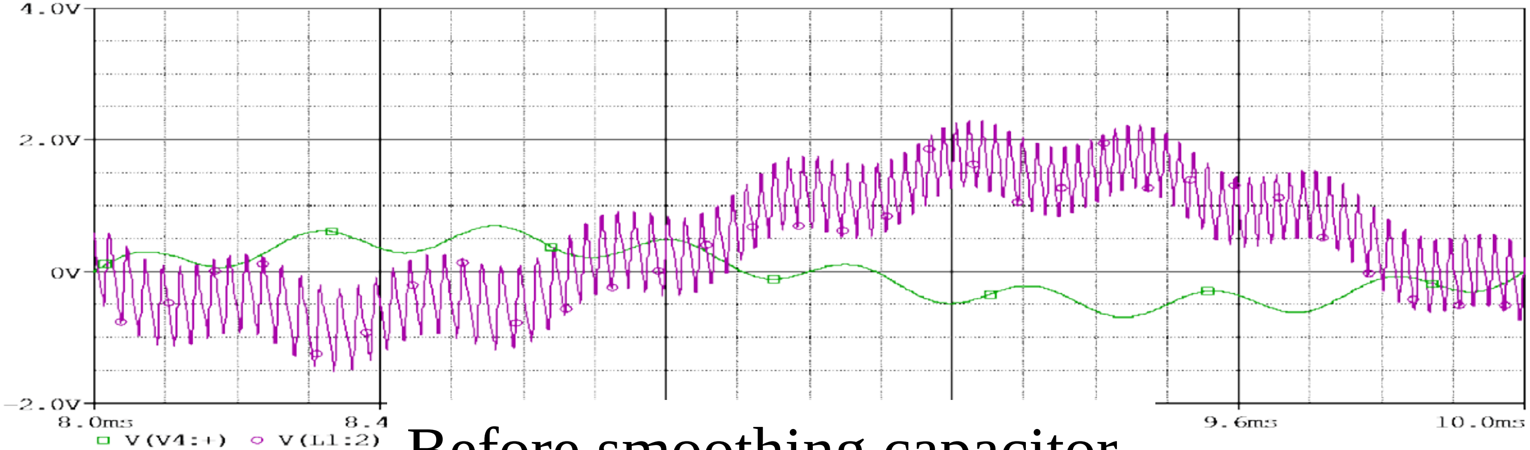
# *Effect of Smoothing Capacitor*



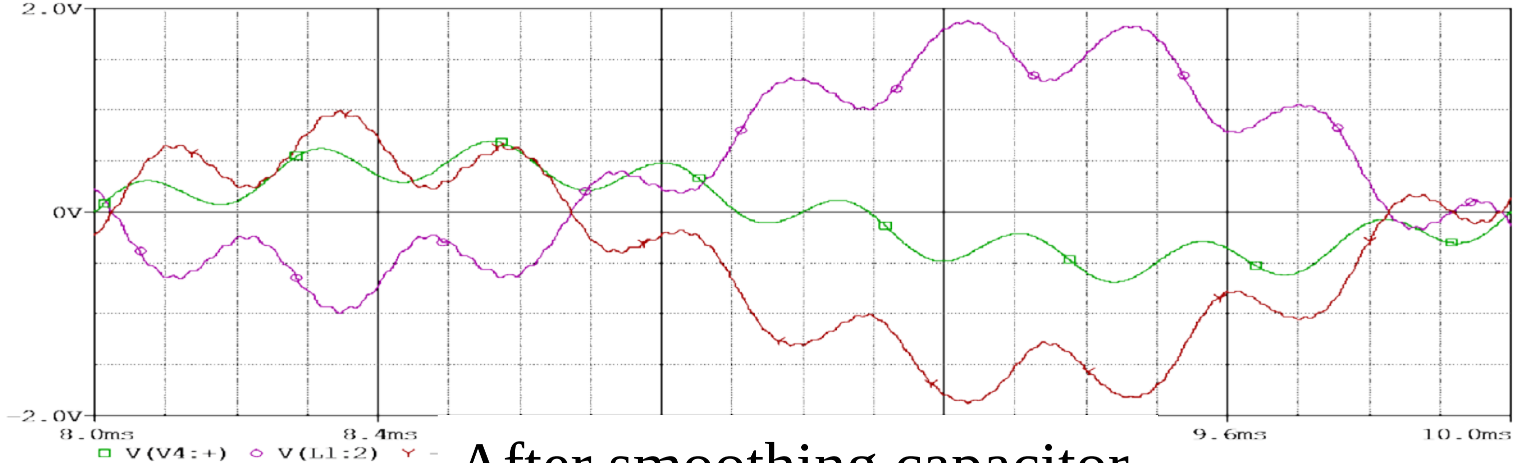



Recall what the smoothing capacitor did to the output of the half wave rectifier.

# *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
    - Blocks: A-B, A-C, A-D, A-E, A-F, A-G
    - 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.