Programmable Gain Amplifier

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Abstract

This experiment focuses on the design and implementation of a Programmable Gain Amplifier (PGA) using discrete components. The PGA's gain is controlled by two TTL inputs, following the gain specifications:

- **A = 0, B = 0:** Gain = 1
- **A = 0, B = 1:** Gain = 10
- **A = 1, B = 0:** Gain = 50
- **A = 1, B = 1:** Gain = 100

Instruments/Materials Required

- Breadboard x2
- Wires
- Function Generator
- Oscilloscope
- DC Power supply (+5 V, 0 V, -5 V)
- NPN Transistor 2N2222A x4
- Op-Amp UA741 x1
- Analog Switch CD4066E x1
- Zener Diode
- Resistors:
  - 8.2 kΩ x2
  - 100 kΩ x1
  - 20 kΩ x1
  - 3.3 kΩ x1
  - 4.7 kΩ x1

Introduction

A PGA amplifies an analog input signal with a gain determined by two TTL control inputs, which can be set by a programmable device such as a computer. This experiment uses an Op-Amp in a non-inverting configuration with feedback resistances connected through analog switches, controlled by the TTL inputs.

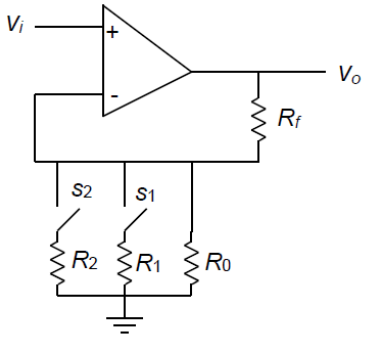

Fig. 2

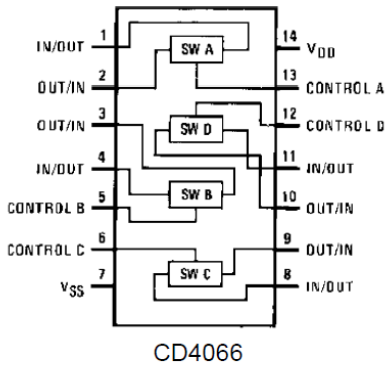

Fig. 3

Figure 1: PGA Circuit Diagram

Theory

The PGA is designed using a non-inverting Op-Amp configuration with resistances $R1$, $R2$, and $R0$. These resistances are connected through switches controlled by the TTL inputs A and B, allowing the gain to be programmed.

Gain Calculations

The gain formula for a non-inverting amplifier is:

$$\text{Av} = 1 + \frac{Rf}{R}$$

Using this formula and setting $Rf = 180\text{k}\Omega$, the required resistances are calculated as:

- $R1 = 150\Omega$
- $R2 = 3.52\text{k}\Omega$
- $R0 = 4.24\text{k}\Omega$

Practical Considerations

- The gain depends on the on-state resistance R_{on} of the analog switch CD4066, which varies with current and temperature.
- Noise is significant when the Op-Amp is used as a buffer with high resistance in the feedback path.

Level Shifter Design

A level shifter is needed to convert TTL logic levels to the bipolar control signals required by the CD4066. The design uses a 2N2222A NPN transistor and a Zener diode to achieve the required voltage levels.

Operation

- **Low TTL Input (0 V):** Transistor Q1 is off, and Q2 is on, resulting in an output of $V_{SS} \approx -5\text{V}$.
- **High TTL Input (5 V):** Q1 is on, and Q2 is off, giving an output of $V_{DD} = +5\text{V}$.

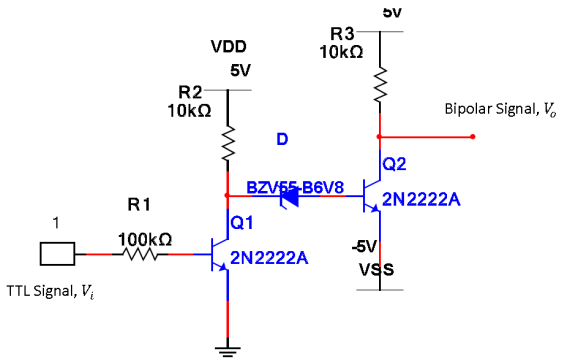

Figure 2: Level Shifter Circuit

A	B	Vi (p-p)	Vo (p-p)	Gain
0	0	1 V	1 V	1
0	1	50 mV	504 mV	10.08
1	0	50 mV	2560 mV	51.2
1	1	50 mV	5.01 V	100.2

Table 1: Experimental Observations

Observations

Conclusions

A PGA with programmable gain control was successfully designed and implemented using discrete components.