VIVEKANAND EDUCATION SOCIETY'S INSTITUTE OF TECHNOLOGY

CHEMBUR, MUMBAI 400074

DESIGN WITH LINEAR INTEGRATED CIRCUITS (ELX 504)

COURSE PROJECT

"ARDUINO CONTROLLED VARIABLE GAIN AMPLIFIER"

SUBMITTED BY

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CERTIFICATE OF APPROVAL OF COURSE PROJECT

THIS IS TO CERTIFY THAT
REETI KOTHARI, ATIQUE KUDCHI, AARYAA PADHYEGURJAR AND **GIRISH PAWAR** OF THIRD YEAR "ELECTRONICS ENGINEERING" STUDYING UNDER THE UNIVERSITY OF MUMBAI HAVE SATISFACTORILY PRESENTED THE PROJECT ON "**ARDUINO CONTROLLED VARIABLE GAIN AMPLIFIER**" AS A PART OF THE COURSE WORK OF COURSE PROJECT FOR SEMESTER V IN THE ACADEMIC YEAR 2018-19.

DATE:

INTERNAL EXAMINER

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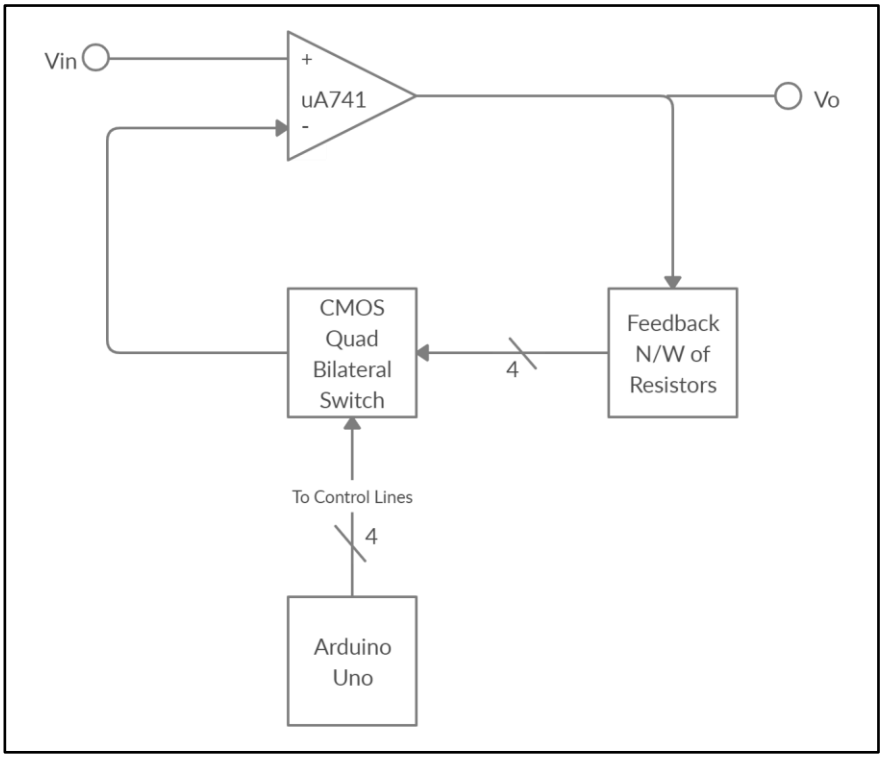
I. Introduction

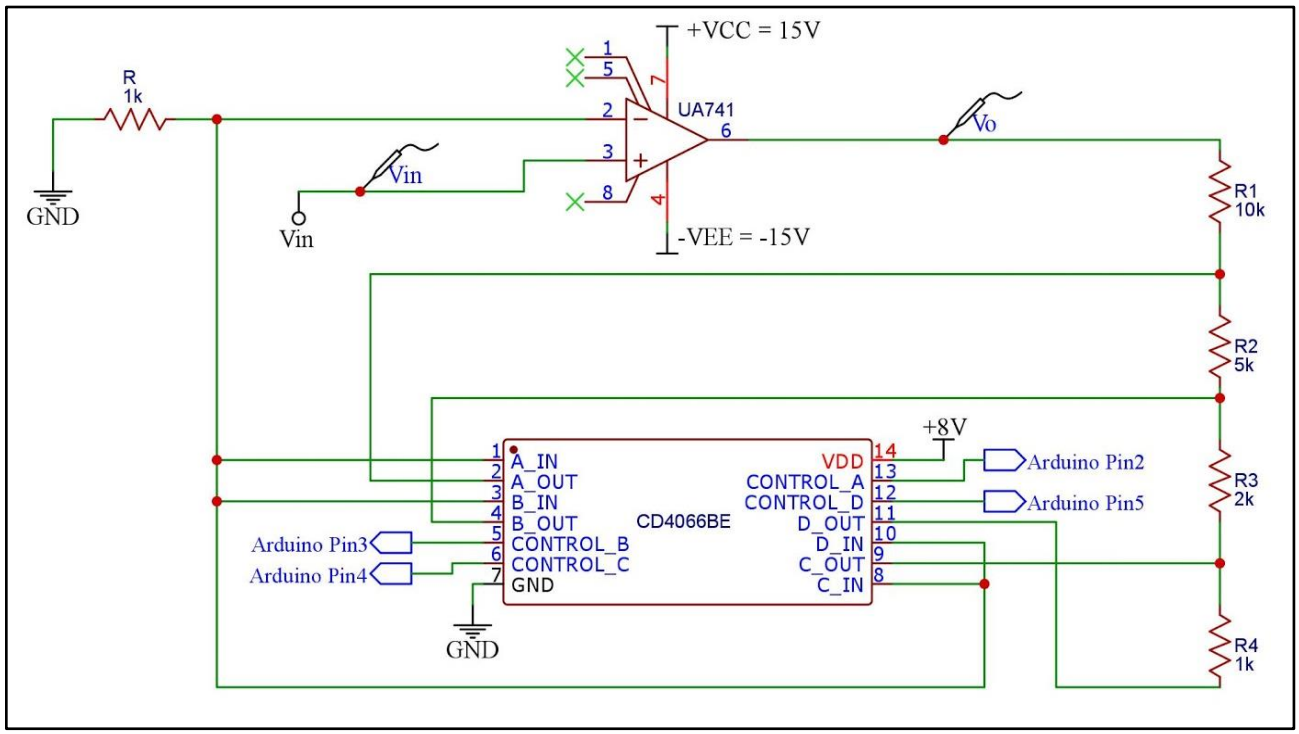
There are many instances when a variable gain op-amp circuit may be required. Although it is possible to place a potentiometer on the output of a circuit, there are more elegant ways in which this can be achieved, maintaining levels of impedance more accurately. Such a circuit is the Variable Gain Amplifier (VGA).

Variable gain amplifiers (VGAs) are signal-conditioning amplifiers with electronically settable voltage gain. A simple VGA consists of a few resistors with different values, an operational amplifier and components that switch between these resistors. In our project, we have used a CMOS Quad Bilateral Switch (CD4016BE) to perform this function. It has 4 switches with individual controls, which are controlled using the Arduino board.

II. Block Diagram



III. Circuit Diagram



IV. Components

Sr. no	Name	Values/ Number	Quantity
1	Op-Amp IC	uA 741 (± 15V)	1
2	CMOS Quad Bilateral Switch IC	CD4016BE (Max +10V input)	1
3	Microcontroller	Arduino Uno & IDE	1
4	Resistors	1 kΩ 2kΩ 5 kΩ 10 kΩ	2 1 1 1

V. Working

1. The circuit works on the simple principle of changing the feedback resistor values to vary the gain accordingly.
2. The digital pins 2,3,4,5 from the Arduino are set to output mode, subsequently giving a digital output of 5V (HIGH) and 0V (LOW) whenever specified by the code.
3. These outputs are connected to feedback resistors in the circuit.
4. Whenever we input any number from 0 to 9 into the software, the 4 pins represent a binary number. For Example, if we input number 5 as a command on the Arduino Serial Monitor, the output of the Arduino will be (2,3,4,5) = (1010).
5. The pins which are HIGH (1) will provide an active high control signal to the control pins of the respective switches of CD4016BE Switch IC. Each of these switches is connected to the resistor feedback network, thus giving us a different feedback value for each input.
6. We can thus easily change the gain value to a desirable point with only 2 key presses.

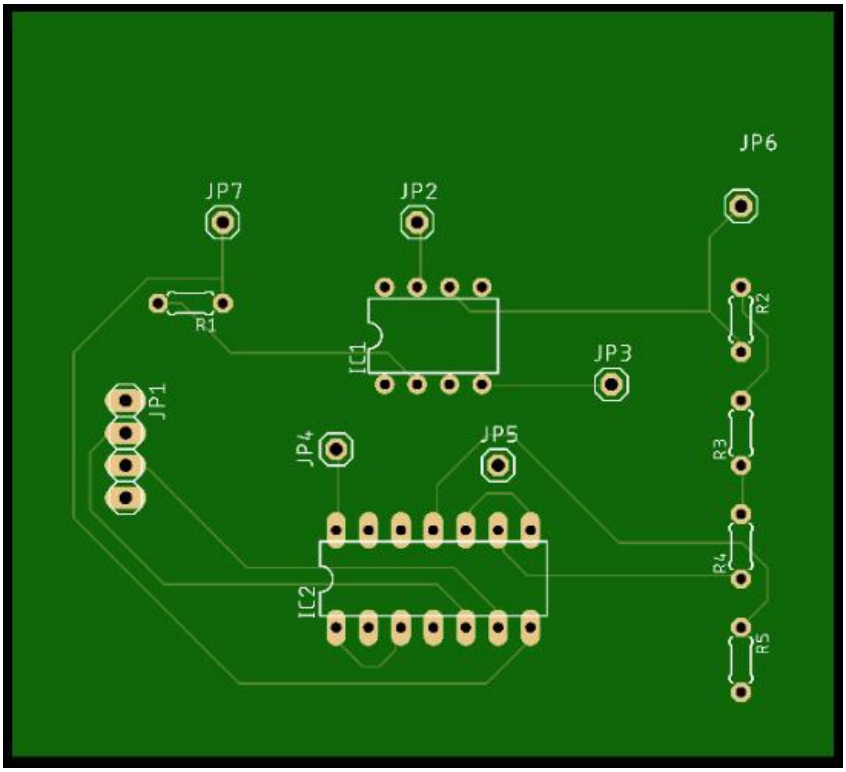
Arduino Code:

```
void setup() {
pinMode(2, OUTPUT);// to pin 13
pinMode(3, OUTPUT);// to pin 5
pinMode(4, OUTPUT);// to pin 6
pinMode(5, OUTPUT);// to pin 12
Serial.begin(9600);
}
char cmd;
void loop() {
  while (Serial.available() > 0) {
    cmd = char(Serial.read());
if (cmd == '0') {
      digitalWrite(2, 1);
      digitalWrite(3, 0);
      digitalWrite(4, 0);
      digitalWrite(5, 0);
}
if (cmd == '1') {
      digitalWrite(2, 0);
      digitalWrite(3, 1);
      digitalWrite(4, 0);
      digitalWrite(5, 0);
}
if (cmd == '2') {
      digitalWrite(2, 0);
      digitalWrite(3, 0);
      digitalWrite(4, 1);
      digitalWrite(5, 0);
}
if (cmd == '3') {
      digitalWrite(2, 0);
      digitalWrite(3, 0);
      digitalWrite(4, 0);
      digitalWrite(5, 1);
}
```

```
if (cmd == '4') {
      digitalWrite(2, 1);
      digitalWrite(3, 0);
      digitalWrite(4, 0);
      digitalWrite(5, 1);
}
if (cmd == '5') {
      digitalWrite(2, 1);
      digitalWrite(3, 0);
      digitalWrite(4, 1);
      digitalWrite(5, 0);
}
if (cmd == '6') {
      digitalWrite(2, 1);
      digitalWrite(3, 1);
      digitalWrite(4, 0);
      digitalWrite(5, 0);
}
```

```
if (cmd == '7') {
      digitalWrite(2, 0);
      digitalWrite(3, 1);
      digitalWrite(4, 0);
      digitalWrite(5, 1);
}
if (cmd == '8') {
      digitalWrite(2, 0);
      digitalWrite(3, 1);
      digitalWrite(4, 1);
      digitalWrite(5, 0);
}
    if (cmd == '9') {
      digitalWrite(2, 0);
      digitalWrite(3, 0);
      digitalWrite(4, 1);
      digitalWrite(5, 1);
}
}
}
```

VI. PCB Layout



VII. Observation Table

Practical								Theoretical	
Command on Serial Monitor of Arduino IDE	**Switch Position**				**Vin (mV)**	**Vo (V)**	**Gain = Vo/Vin**	**Rf (kΩ)**	**Gain = 1+Rf/R (R = 1 kΩ)**
	A	**B**	**C**	**D**					
0	1	0	0	0	16	0.16	10	10	11
1	0	1	0	0	16	0.22	13.75	15	16
2	0	0	1	0	16	0.25	15.625	17	18
3	0	0	0	1	16	0.27	17.5	18	19
4	1	0	0	1	16	0.16	10	10	11
5	1	0	1	0	16	0.16	10	10	11
6	1	1	0	0	16	0.16	10	10	11
7	0	1	0	1	16	0.25	15.625	15	16
8	0	1	1	0	16	0.24	15	15	16
9	0	0	1	1	16	0.29	18.125	17	18

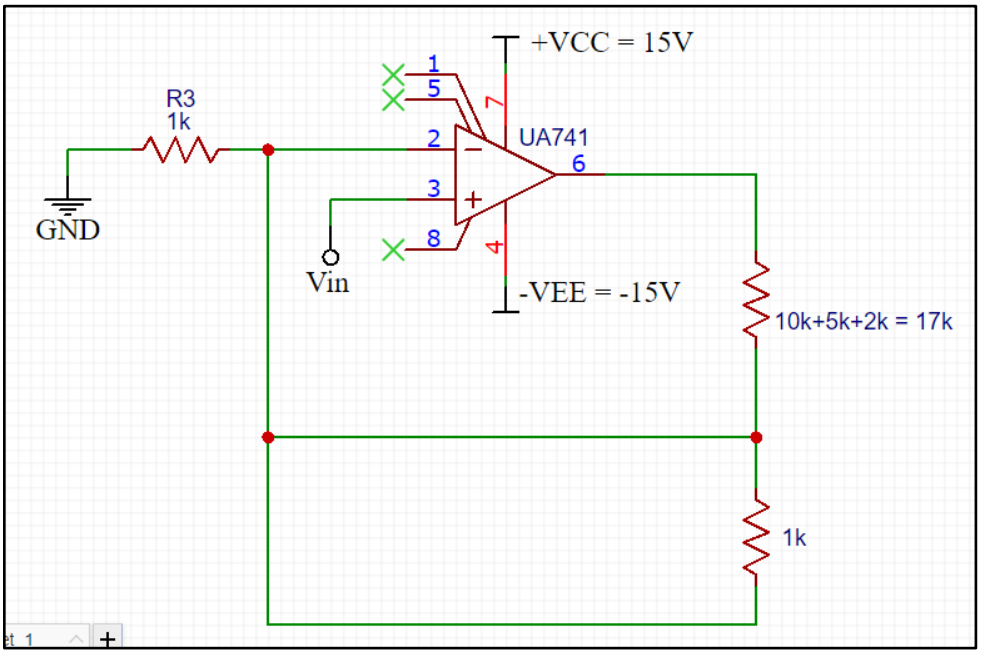
VIII. Calculation

Consider cmd = 9

This corresponds to (0011) Switch Control

Hence, switches A and B are OPEN and switches C and D are CLOSED.

According to the switch positions, the resultant circuit for this command is as follows:



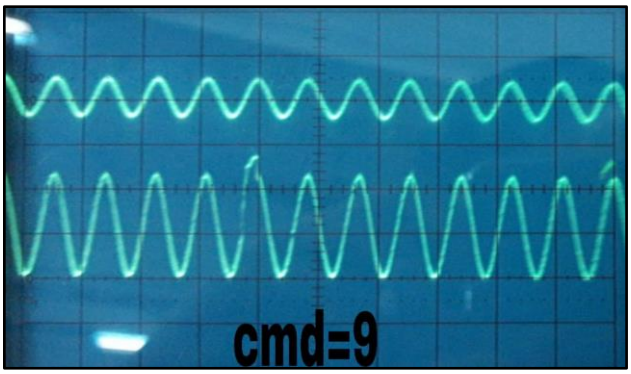
Here, 1 kΩ resistor becomes redundant, and the feedback resistor is given by

Rf = 10 kΩ + 5 kΩ + 2 kΩ = 17 kΩ

Theoretical Gain = 1 + Rf/R1, Where R1 = 1 kΩ

= 1 + 17/1

= 18



Practical Gain (Observed on CRO) = 18.125

IX. Advantages

1. Fast switching operation
2. Non-fluctuating gain values
3. Simple circuit with high-level applications
4. Cheap and easy to manufacture and code
5. Highly accessible components
6. Changing fixed gain values is easy

X. Disadvantages

1. Limited gain values
2. The circuit becomes bigger if more resistors are to be added
3. No option to gradually change between resistors values

XI. Applications

1. Speech analysis
2. Radar
3. Music Industry
4. LIDAR

XII. Conclusion

Analogue devices voltage-controlled variable gain amplifiers provide continuous gain control over a wide dynamic range for a variety of audio and optical frequency bands. VGAs improve the dynamic range of a circuit by allowing users to adjust a signal's amplitude in real-time, which is invaluable for ultrasound, speech analysis, radar, wireless communications, and instrumentation-related applications. The resulting model is a simple combination of resistors forming a feedback network whose switching action is being controlled by CMOS Quad Bilateral Switch IC CD4016BE, which in turn, can be easily manipulated by a microcontroller like the Arduino.

XIII. References

1. https://www.hackster.io/lucian_vdo/arduino-variable-gain-amplifier-c36934
2. https://www.electronicdesign.com/analog/variable-gain-amplifiers
3. Datasheet: https://www.ti.com/lit/ds/symlink/cd4066b.pdf
4. https://pdfs.semanticscholar.org/29d4/a1b85673a162486749ef7a5ec06b7a6628d1.pdf