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Programmable OP-AMP Configurations

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Abstract - *The op-amp is widely used in various modes such as inverting, non-inverting and voltage follower. To use each of the mode different circuital configuration is required. The resistor values need to be altered in order to change the gain of the op-amp. This requires considerable soldering efforts and is a tedious and time consuming job. This project aims at designing a circuit which can be controlled using microcontroller to operate the op-amp in the above three modes. It uses Analog switches to switch the op-amp in different modes. It also uses digital potentiometers in place of the resistors which can be controlled by microcontroller. Hence the theoretical gain of the op-amp can be changed without actually having to change the resistors in the circuit.*

Key Words: Analog switch, microcontroller, digital potentiometer, op-amp, inverting, non-inverting, voltage follower, programmable gain.

1. INTRODUCTION

Operational amplifier or op-amp for short, finds daily usage in a large variety of electronic applications. It also provides a new element to use in building circuits, and another opportunity to test out our developing analytical skills. Many application require the op-amp in more than one mode of operation (inverting, non-inverting, voltage follower) or needs the variable gain. For such applications "programmable op-amp" is helpful. It uses a microcontroller to digitally switch between three modes of operation. Hence we can easily alter between inverting, non-inverting and voltage follower mode. The gain is varied by changing the value of digital potentiometer. It can be used in testing the optimum electronic functionality of op-amp and applications requiring variable gain of op-amp.

2. DESIGN OF SYSTEM

The block diagram of the system is as shown in Fig. 1. It shows the basic building blocks of the system.

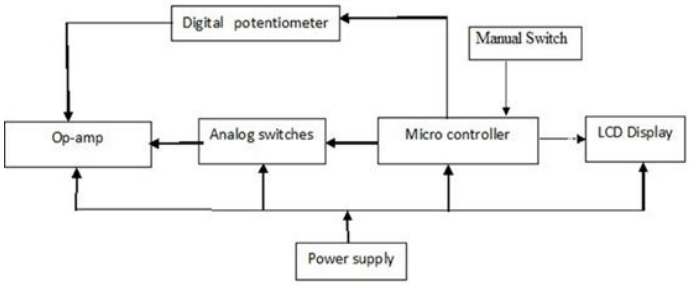

Fig -1: Block diagram of Programmable op-amp

3. WORKING

The basic circuit of the programmable op-amp is as shown in the Fig. 2.

The programmable op-amp circuit consists of arrangement of analog switches S1, S2, S3, S4, S5, S6 and digital potentiometers R1, R2, RF. The digital potentiometers are interfaced with microcontroller with I^2C or Serial Peripheral Interface Bus. The switch S7 and S8 which are manually controlled are used to set the modes of the op-amp. Depending on the position of the switches the op-amp is operated in the inverting, non-inverting and voltage follower. The switches that are used are analog switches which are controlled by microcontroller.

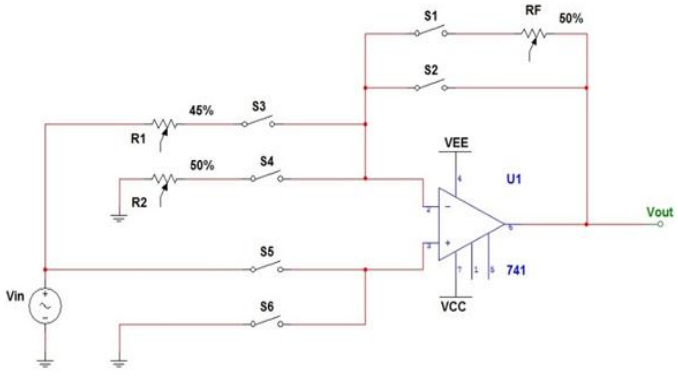

Fig -2: Basic circuit of the system

3.1 Inverting mode

By closing the switches S3, S6, S1 the programmable op-amp can be configured in inverting mode. The circuit shown in Fig. 3 acts as inverting amplifier. Let current I flows through both the resistors R1 and RF.

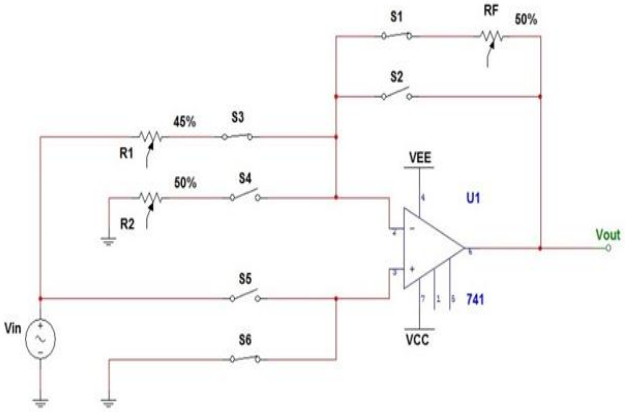

Fig -3: Programmable op-amp in inverting mode

By applying KVL,

Vin + R1*I + Vout = 0

Which can be rearranged to get

Vout = Vin – (R1+RF) * I……equation1.

By using the concept of virtual ground it can be proved that

I = Vin / R1 ……..equation2.

Vout = -RF * Vin / R1…….....from equation 2 and 1.

3.2 Non-inverting mode

By closing the switches S4, S5, S1 the programmable op-amp is configured in non-inverting mode. The circuit shown in Fig. 4 shows the operation of programmable op-amp in non-inverting mode.

Expression for Vout in terms of Vin R1 and RF is given as

Vout = (1+ (RF / R1)) * Vin.

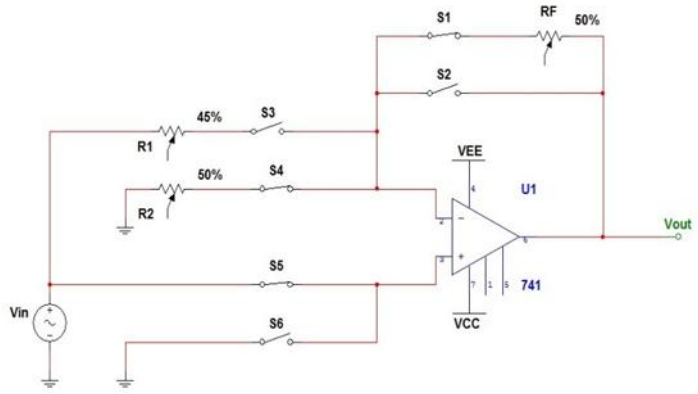

Fig -4: Programmable op-amp in non-inverting mode

3.3 Voltage Follower mode

By closing the switches S5, S2, the programmable op-amp can be configured in voltage follower mode. The circuit shown in Fig. 5 is known as voltage follower amplifier.

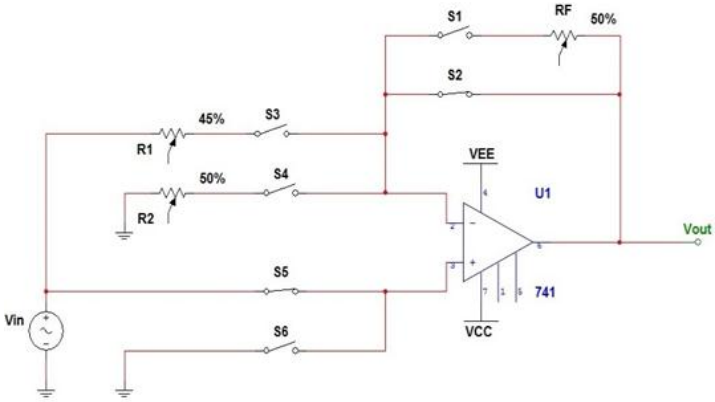

Fig -5: Programmable op-amp in voltage follower mode

Table -1: Modes with respect to switches

Hardware switch	Analog Switches ON	Operating mode of op-amp
S7=0,S8=1	S1, S3, S6	Inverting mode
S7=1,S8=0	S1, S4, S5	Non-inverting mode
S7=1,S8=1	S5,S2	Voltage follower
S7=0,S8=0	Invalid	Invalid

4. INTERFACING OF DIGITAL POTETIOMETER AND ANALOG SWITCH

4.1 Digital Potentiometer

The digital potentiometer IC MAX5413 which consist of two dual, 256 tap, and low drift potentiometer is used. A digital potentiometer resembles same functionality as analog

potentiometer. The high ends H0 & H1 and L0 & L1 are connected in between the lines. The two wiper terminal voltages are supplied to two analog channels (AN0 and AN1) of the PIC18F452. The RST, DQ, and CLK lines are driven through microcontroller port pins. Two switches, 'Up' and 'Down', are also connected to microcontroller pins. The microcontroller will send signals to the MAX5413 according to the key pressed to move the wiper position in appropriate direction. If the 'Up' key is pressed, the wiper will slide a step towards the higher end (H0 or H1). If a 'Down key' is pressed the wiper will slide down a step towards the lower end (L0 or L1). The size of the step can be set in the program. The analog voltages from the wiper terminals are converted to 10-bit digital numbers using the inbuilt ADC in PIC18F452. Hence the resistor values RF, R1 and R2 can be increased or decreased with 'Up' or 'Down' key accordingly. The microcontroller calculates the gain using the values of R1 & RF or R2 and RF. The microcontroller sends the gain to display it on LCD. The interfacing diagram with microcontroller is as shown in Fig. 6.

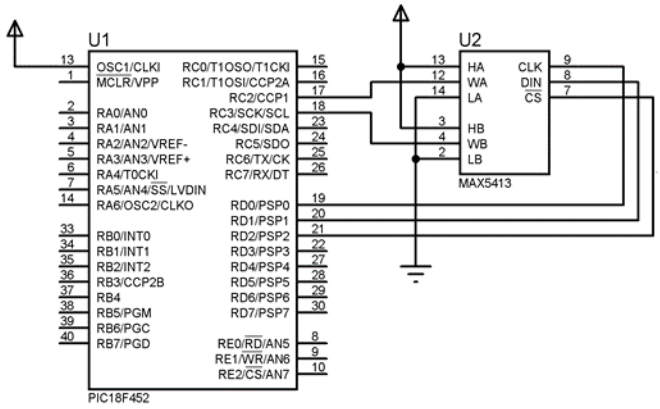

Fig -6: Interfacing of digital pot. MAX5413 with PIC18F452 microcontroller

4.2 Analog switch

Here we make use of analog switch IC MAX4066, which is quad, SPST, CMOS analog switch. The IC offers an on resistance of 45 ohm. The control lines of the analog switch IC are connected to the microcontroller. When the control line is low the switch is open and when the control line is high the switch is closed. The truth table is as given below.

Table -2: Truth table for analog switch

On/off control input	State of analog switch
L	Off
H	On

5. FLOWCHART

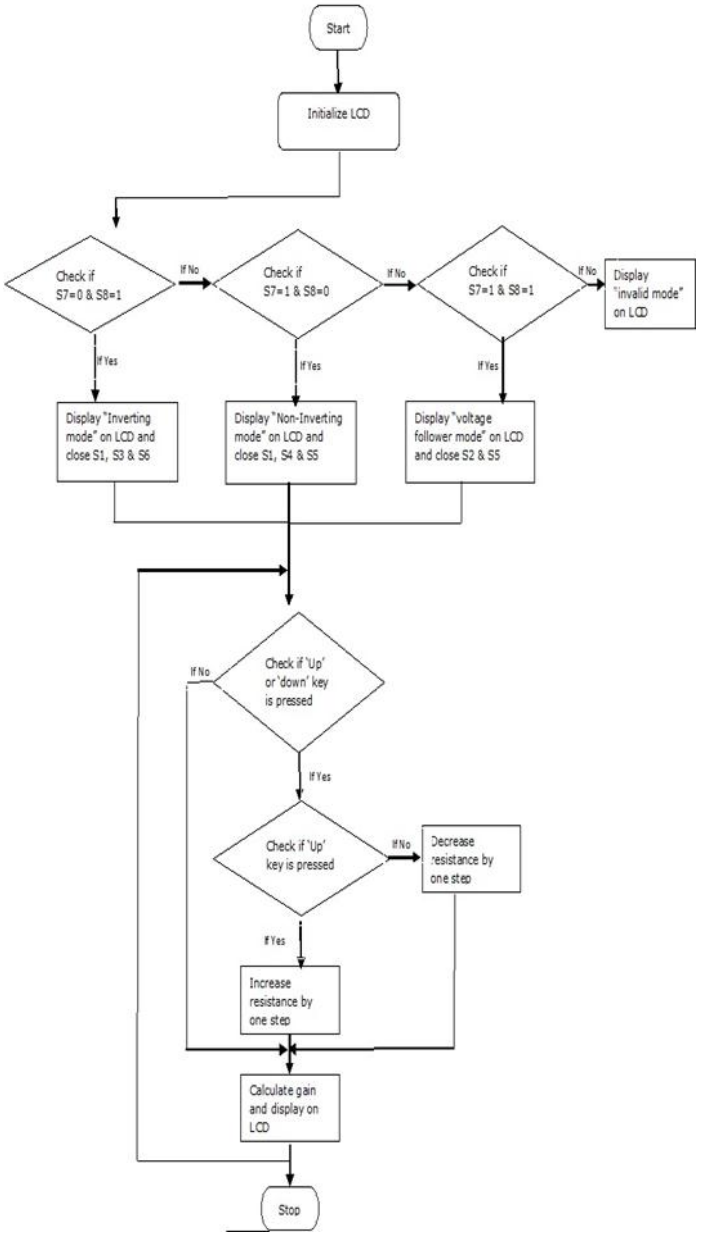

Fig -7: Flowchart

6. SOFTWARE AND HARDWARE REQUIREMENTS

MikroC or MPLAB is used for the programming of the microcontroller. Hardware requirements include PIC18F452 microcontroller, MAX4066 analog switch IC, MAX5413 digital potentiometer IC, 16x2 LCD or graphical LCD, op-amp.

7. RESULTS AND DISCUSSIONS

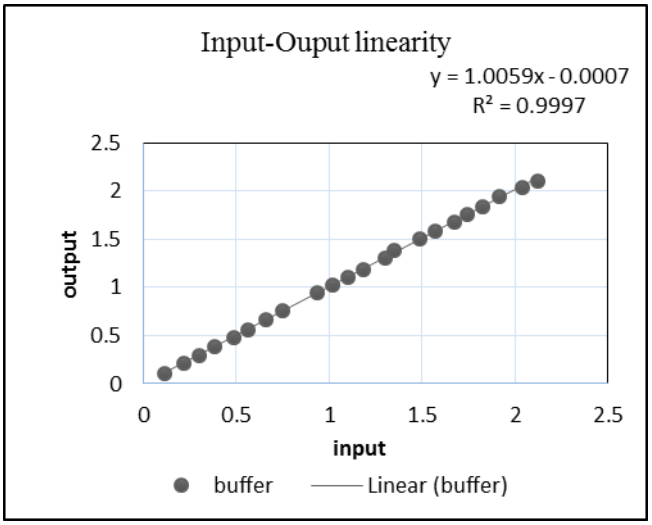

Fig -8: Linearity of the circuit

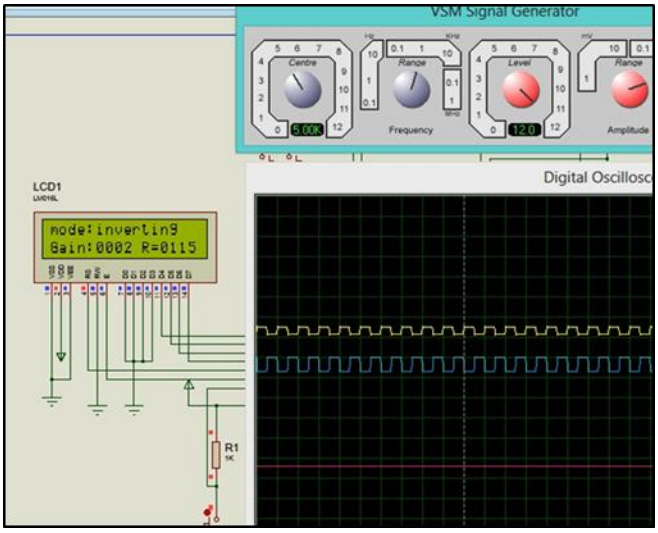

Fig -9: Simulation for inverting mode and gain = 2

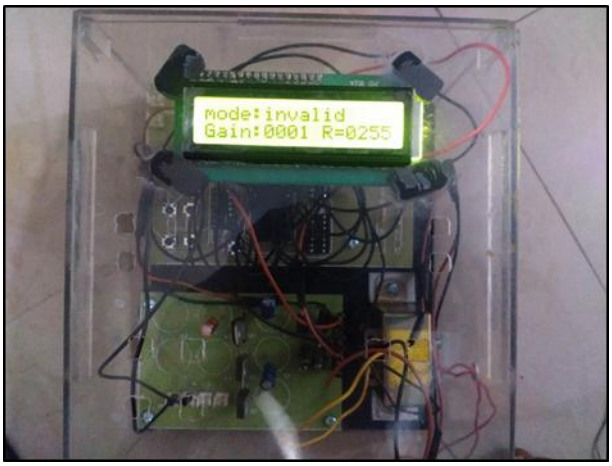

Fig -10: Actual circuit showing invalid mode (S7=1, S8=1)

8. APPLICATIONS

Various applications of "Programmable op-amp" are –
1) To test various op-amp.
2) In applications requiring variable gain.
3) In applications requiring more than one mode of operation of op-amp.
4) To reduce manual efforts of soldering for different configurations of op-amp.

9. CONCLUSION

It is a system which will prove helpful in reducing efforts of soldering. This will speed up the job of testing or using the op-amp in various operating mode.

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