IC 741 and IC AMP02FP Based Signal Conditioning Circuit for Electrostatic Sensor using Multisim

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Abstract: The Electrostatic sensors are extensively used in military, radar and electronic applications which can sense the electric charge from the moving charged motes. The signal conditioning circuit for an electrostatic sensor is a voltage amplifier that can intensify a small input signal. This paper proposal is to design a low noise signal conditioning circuit using Multisim and to study the performance of its gain, bandwidth and noise properties.

Keywords: Electrostatic sensors, Signal conditioning circuit, Multisim and Instrumentation amplifier.

I. INTRODUCTION

In measuring system, sensor plays a key role for detecting the physical parameters. The electrostatic sensor is simple, low power and fast response device which work on the principle of electrostatic induction. In practical, the design of electrostatic sensor is still inexplicable [1]. Electrostatic device applications are measuring dry particle mass flow rate, velocity and absorption in a conveyor. The electrostatic sensor has two components sensor electrode and signal conditioning circuit. The sensor electrode detects the electric charge and the signal conditioning circuit exaggerates the signal detected by the electrode. The design of signal conditioning circuit is to collect and amplify the electrostatic noise from the sensor electrode. The simulation process of signal conditioning circuit is done by using multisim. The sensor electrodes will available in different shapes including ring, pin and plate electrodes [2]. In this article, a ring electrode is employed to determine the bandwidth and electric charge in a pipe line. The ring electrode was analyzed by Gajewski [3]. The circuit for signal conditioning the electro static amplifier receives the small signal and amplifies to the desired level and also detects the static noise. The output signal is highly inclined to be disfigured by intrinsic or extrinsic noise.

II. BASIC NOISE DETECTOR

Figure 1 Basic Noise Detector circuit

Figure 1 shows a capacitive and a resistive load noise detector circuit. The basic principle behind the noise detector is when charged particles reach near to a ring electrode it inducts some amount of charge into the electrode. The accumulated charge (electrostatic noise) is collected using a capacitor or a resistor [4].

For capacitor

\[ V = \frac{q}{C} \]

For resistor

\[ V = IR \]

III. GAJEWSKI MODEL OF ELECTROSTATIC SENSOR

For gas-solid flow measurement a ring shaped electrostatic sensors are used and it was designed by Gajewski in 1999. The circuit replica was designed as the electrodes for the sensor to be used in propose and circuit examination. To protect the electrode from environment a metal earthed screen is used [5].

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Figure 2 Gajewski model of electrostatic sensor
The value of resistance between node 1 and ground potential should be very large to make the resistance as open circuit. The current generator is connected between node 2 and ground potential. The resultant circuit with current generator is shown in figure 3.

Figure 3 Equivalent model of electrode
The capacitance $C_{12}$ is the series combination of $C_1$ and $C_2$ and the resistances are neglected due to high resistance i.e., open circuit.

IV. SIGNAL CONDITIONING CIRCUIT
Signal conditioning circuit is a voltage amplifier circuit which will enhance the quality of the sensor signal.

Figure 4 Basic signal conditioning circuit for electrostatic sensor
In this $R_f$ and $C_f$ are used in parallel combination to control the gain and bandwidth. The cutoff frequency of the circuit is

$$f_c = \frac{1}{2\pi R_f C_f}$$

The $R_f$ is used for biasing the amplifier and the capacitor $C_f$ will be open under low frequencies. At high frequency $C_f$ reacts and reduces the output gain. The values of $R_f$ and $C_f$ will affect the gain and bandwidth of the amplifier.

V. TWO STAGE SIGNAL CONDITIONING CIRCUIT
The two-stage Signal conditioning circuit comprises of sensor electrode, amplifier and an instrumentation amplifier. The instrumentation amplifier furnishes low noise, high input impedance and high CMRR. For wider range of noise detection applications instrumentation amplifiers are used [6]. The gain of the two-stage signal conditioning circuit is given by

$$Gain = \left(1 + \frac{2R_1}{R_g}\right) R_f$$

VI. AMP02FP INSTRUMENTATION AMPLIFIER
The AMP02PF is an instrumentation amplifier available in 8 lead and 16 lead packages. The gain of AMP02PF is set by an external resistor $R_g$ and that can vary from 1 to 10,000. The bandwidth is very high and the slew rate is above $4V/\mu S$ [7]. It has a reference pin which allows the output to an external dc level and we can use this pin for offset correction or shifting the level as per our requirement. In this 8-lead package, the term sense is within associated to the output.

Figure 5 Two stage Signal conditioning circuit
Figure 6 AMP02FP Instrumentation Amplifiers
VII. SIGNAL CONDITIONING CIRCUIT SIMULATION

Figure 7 signal conditioning circuit in Multisim simulator

The AMP02FP is a high gain instrumentation amplifier with low offset voltage. The gain equation of the amplifier is

\[ \text{Gain} = \frac{V_{out}}{\left(\frac{50k\Omega}{R_g}\right)} + 1 \]

An 800Ω resistor is used to avoid the output voltage from saturation. Here \( R_g = R_1 = 800 \ \Omega \) and the total gain is 63.5. The frequency bandwidth is determined from \( \frac{f_c}{2\piR_fC_f} \) equals to 1.59 KHz for electrostatic sensor.

VIII. AC ANALYSIS AND NOISE SPECTRAL DENSITY

Figure 8 AC analysis and Noise spectral Curve

Using Multisim the frequency response is analysed using AC analysis. The output voltage swings between ± 10 V. By adjusting the gain we can control the electrostatic noise when output voltage leads to saturation level. At frequency 1.59 KHz the gain is 151 dB and noise is -507 V2/Hz or A2/Hz.

IX. CONCLUSION

In this review, according to the prerequisites of a ring type electrostatic sensor a signal conditioning circuit was designed using IC 741 and IC AMP02PF and studied its gain, bandwidth and noise characteristics.

REFERENCES


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