Design of a Pressure Controller for a Thermal Evaporation System

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Abstract - This project describes the method of designing a pressure controller for vacuum pressure control system well suit for evaporation and deposition of amorphous silicon thin film. The constant total pressure or pressure not less than 10^{-5} torr is required during the conditioning of the vacuum to control impurity in high temperature. The pressure controller was designed to maintain the constant total gas pressure inside vacuum chamber. This controller consist of pressure sensor circuit and relay switching which The pressure inside the chamber will detect by using the vacuum sensor. The sensor also as the transducer gives the signal to the pressure sensor circuit. The pressure sensor circuit will provide the signal that used by relay switching circuit to switch off the pump operation. The circuit was designed and simulated by using OrCAD Pspice software. After analysis and simulation, the circuits are successful to makes combination with the vacuum sensor to control the pressure inside the vacuum chamber.

Keywords : Pressure controller, pressure sensor circuit

I. INTRODUCTION

Vacuum is a pressure lower than atmospheric. Except in outer space, vacuum only occurs in closed system. In the simplest terms, any reduction in atmospheric pressure in a closed system may be called a partial vacuum [1]. A compatible vacuum pressure control system is vital for the successful operation of and evaporator for material fabrication process. The process of evaporation is a high voltage analysis which the process was involving the solid breakdown of silicon material. The process must be intended to be in vacuum chamber at pressure of 10^{-5} torr or less. The process also required a high current supply to heat the boat. The temperature of boat at 10^{-5} torr was identified to be greater than melting point of Silicon at pressure not less than 10^{-5} torr. Vacuum pressure control system includes a vacuum chamber, a vacuum pump for sucking gas from the vacuum chamber, a pressure controller for controlling vacuum pressure in the vacuum chamber. The combination of Rotary vane and Turbo pumps are use in fabricating the amorphous silicon. Beside that the Series 345 Pirani Sensor and Cold Cathode Sensor are use and its output voltage range is 200mV-600mV DC voltage and the measurement range pressure not less than 10^{-5} torr. The constant total pressure also require during the conditioning of the vacuum to control impurity in high temperature. The vacuum condition inside the chamber that required can be controlled by using the pressure controller.

The signals from the sensor are in the DC voltage form. The sensor functioning as a transducer gives the signal to sensor circuit. The output voltage of pressure sensor range is 200m-600m volt. The pressure sensor circuit is using the amplifier TL084. This amplifier is one of the most useful of linear (not digital) circuits. It is normally a fairly low power device (15 volts 10 ma or less) that can amplify, clip, and offset. This amplifier is used to amplifying weak signals from pressure sensors to a more useful level [5].. For pressure sensor circuit may deliver 5 volt, where 5 volts are required for the switching circuit to switch off the pump operation or analog to digital circuit for PIC. Figure 1 shows the vacuum pressure control system for material processing. In the vacuum pressure control system, a suitable apparatus and appropriate method to design the pressure controller are very important to maintain the stable vacuum levels inside a vacuum chamber.

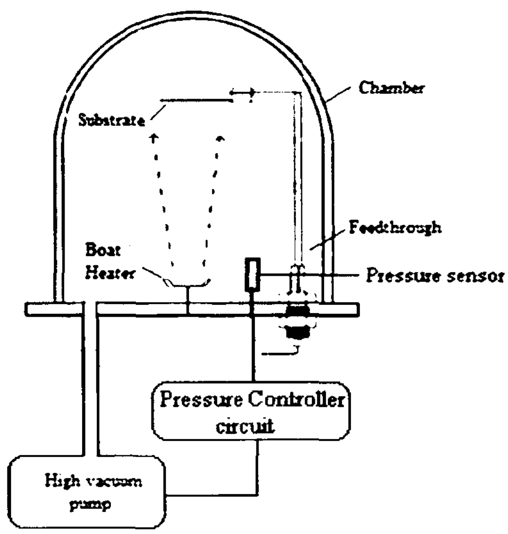

Figure 1: Vacuum Pressure Control System

II. PROBLEM STATEMENT

The problem in this project is to design the pressure sensor circuit using amplifier Tl084 to provide the output voltage at 5volt range which the circuit will interface between sensor and the relay switching circuit.

III. OBJECTIVE

To design a pressure controller for the vacuum pressure control system to make successful operation of and evaporator for material fabrication process.

IV. METHODOLOGY

In order to design the pressure controller, it involves the analysis and simulation circuit.

There is two parts has been considered:

A. Pressure Sensor Circuit

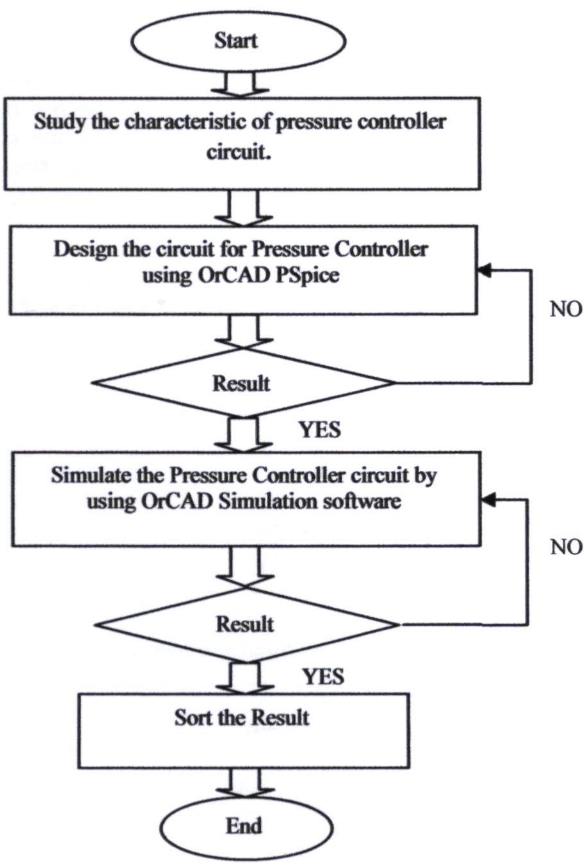

Figure 2: Flow Chart of Design Procedures

The pressure controller includes a pressure sensor circuit or amplifier circuit as the main part of the pressure controller in this project. The circuit was used Amplifier TL084 as the amplifier circuit. This op-amp has been high speed J–FET input quad operational amplifiers incorporating well matched, high voltage J–FET and bipolar transistors in a monolithic integrated circuit. The op-amp also have a high slew rates, low input bias and offset currents, output short-circuit protection, low total harmonic, low power consumption and low offset voltage temperature coefficient. The output voltage of the circuit will connect to relay switching circuit. The circuit were designed by using unity-follower and non-inverting circuit to provide 5 volt from output transducer at 200mV to 600mV DC voltage range.

Figure below shows the schematic diagram of the multistage op-amp circuit designing for the sensor circuit.

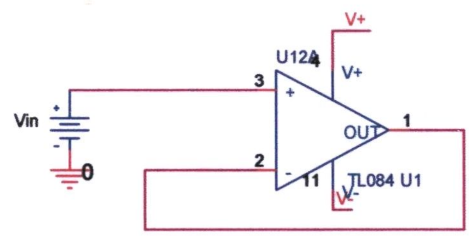

Figure 3: Unity –follower Circuit at stage 1

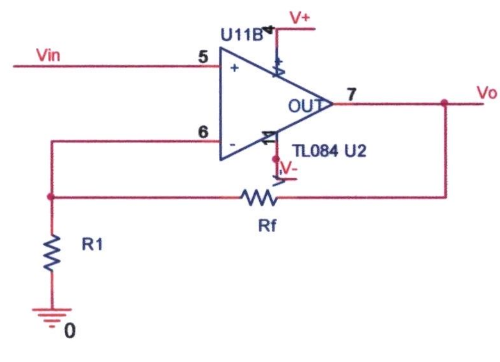

Figure 4: Non-inverting Amplifier Circuit at stage 2

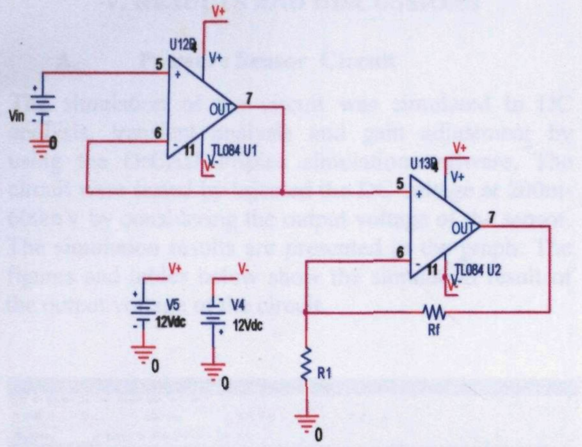

Figure 5: Schematic Diagram of Sensor Amplifier Circuit

To allow the pressure sensor output 200mv-600mV range to achieve 5 volt, let R1 as a constant. Feedback through a resistor network is used to adjust final gain. The feedback resistors Rf will be adjusted to get the gain of the amplifier to provide the output voltage that required. This circuit will provide a true approximately 5 volt output for be fed directly to relay switching or to a number of A/D converters for future development design. The gains of the amplifier are expressed as follows:

Gain of Unity Follower .... (1)

$$A = \frac{Vo}{Vi}$$

$$A = 1$$

$$\frac{Vo}{Vi} = 1$$

Gain of Non-inverting amplifier .... (2)

$$A = 1 + \frac{Rf}{R1}$$

$$\frac{Vo}{Vi} = 1 + \frac{Rf}{R1}$$

B. Relay Switching Circuit

It is often desirable or essential to isolate one circuit electrically from another, while still allowing the first circuit (pressure sensor circuit) to control the second (pump switching circuit). It is function to switch off n switch on the operation circuit. In this project, the relay switching circuit is connected to the pressure sensor circuit that has been used to switch off the vacuum pump operation.

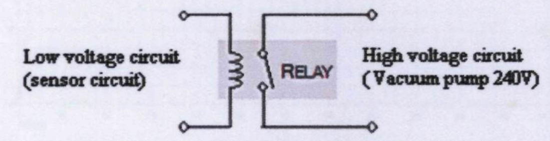

Figure 6: Relay Switching Concept

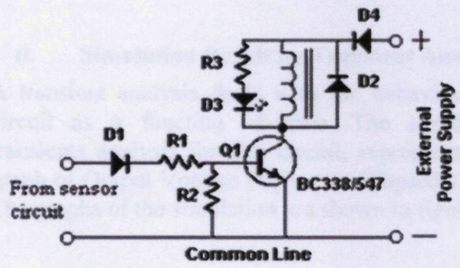

Figure 7: Schematic Diagram of Relay Switching Circuit

I. Circuit Operations

When one of the lines is taken HIGH (by a command from sensor circuit output voltage) 5 volts appears at the base of the transistor Q1. This switches on the transistor will allowing a larger current to flow through the coil of relay RL1, turning it on. Diode D1 prevents any 'reverse' potential from entering the sensor circuit and causing damage. Resistor R1 limits the current flowing into the base of Q1. Resistor R2 sets up the correct 'bias' for the transistor. Diode D2 eliminates any 'back emf' spikes that may be produced as the relay coil's magnetic field collapses. Diode D3 (the LED) and R3 provide visual confirmation that the relay has switched on. D4 will prevent the circuit from damage if the power supply is accidentally connected in a wrong way around. After received the voltage signal from the pressure sensor circuit, relay switching circuit will stop the operation of the vacuum pump (240 volt). It is occurs because the relay switching is operated in Normally Close (N.C), which the concept of Normally Close is to switch off the circuit operation.

V. RESULTS AND DISCUSSIONS

A. Pressure Sensor Circuit

The simulation of the circuit was simulated in DC analysis, transient analysis and gain adjustment by using the OrCAD PSpice simulation software. The circuit were tested by injected the DC voltage at 200m-600mV by considering the output voltage of the sensor. The simulation results are presented in the graph. The figures and tables below show the simulation result of the output voltage of the circuit.

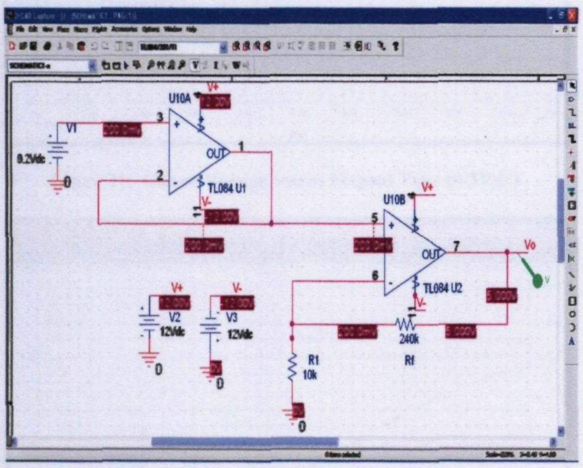

Figure 8: Circuit Diagram Simulation

I. Simulation Result by DC Analysis

In DC analysis, the operating points are also assumed to be equilibrium points. In other words, equilibrium points are constant-valued operating points and also the points do not varied with time. Based on the simulation graph, the output voltage reaches an equilibrium point at 10.5 volt. Therefore the output voltage at 5 volt can provide by the amplifier circuit.

Figure 9 shows the DC analysis output voltage reaches an equilibrium point at 10.5 volt.

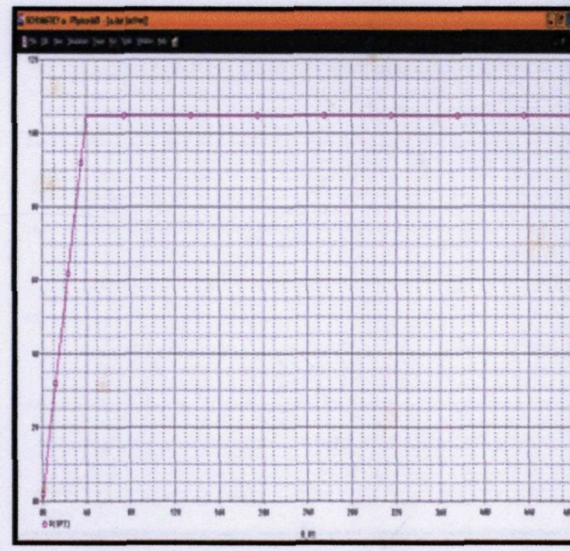

Figure 9: Output Voltage Versus Input Voltage

II. Simulation Result by Transient Analysis

A transient analysis deals with the behaviour of this circuit as a function of time. The simulation of transients analysis for this circuit, represented by the graph of Output Voltage (V) versus Elapsed Time (us). The graphs of the simulation are shown in figure below.

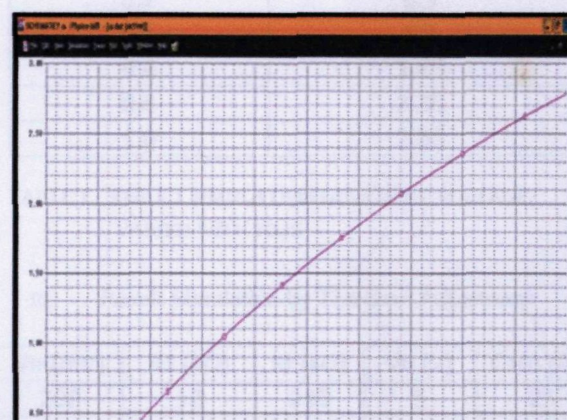

Figure 10: Output Voltage versus Elapsed Time (0.2Vdc)

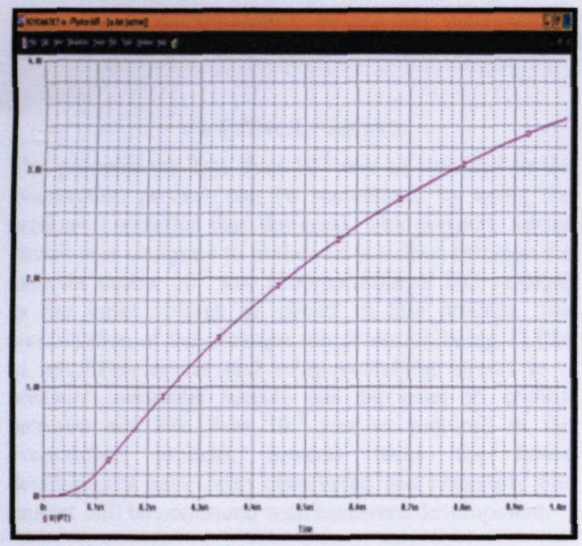

Figure 11: Output Voltage versus Elapsed Time (0.3Vdc)

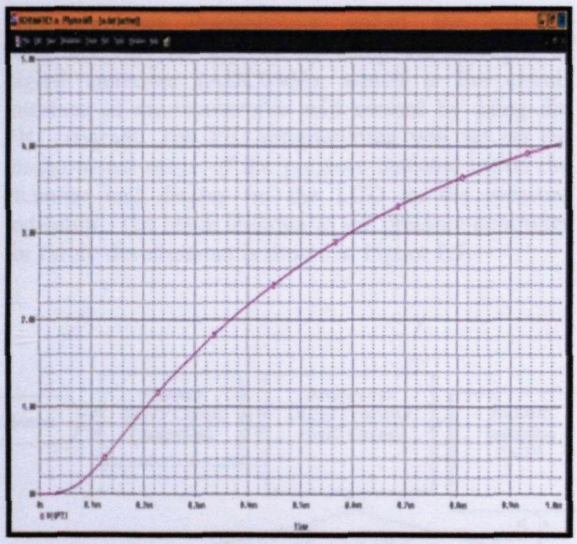

Figure 12: Output Voltage versus Elapsed Time (0.4Vdc)

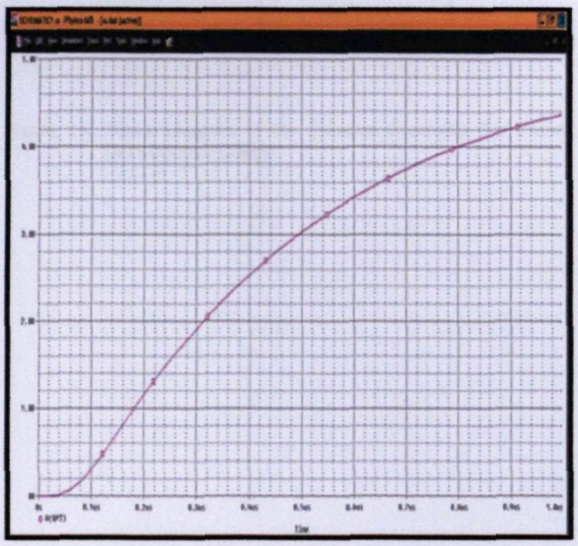

Figure 13: Output Voltage versus Elapsed Time (0.5Vdc)

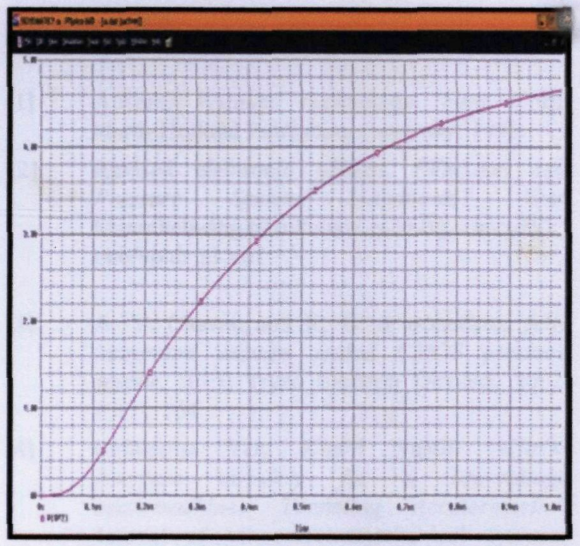

Figure 14: Output Voltage versus Elapsed Time (0.6Vdc)

Based on the simulation result, the output voltage of the circuit is varied with time (us). In this case, the circuit was already at the operating point at the starting of the transient simulation.

Table 1 shows the result simulation of output voltage varied with time at 200mV.

Time (us)	Output Voltage (V)
0.2	0.5
0.4	1.5
0.6	1.85
0.8	2.35
1.0	2.85

TABLE 1: RESULT SIMULATION OF OUTPUT VOLTAGE VARIED WITH TIME

III. Result Simulation by The Gain Adjustment

Vin(mV)	R1 (kΩ)	Rf (kΩ)	Vo (V)	Gain (Av)
200	10	240	5	25
300	10	150	4.8	16
400	10	115	5	12.5
500	10	90	5	10
600	10	75	5.1	8.5

TABLE 2: RESULT SIMULATION OF OUTPUT VOLTAGE BY GAIN ADJUSTMENT.

Table 2 shows the value of the output voltages are dependent to the value of the gain are varied. In order to yield the value of the gain, the feedback resistor Rf will be adjusted. Therefore the output voltage at 5 volt can yield by make the adjustment of Rf. The result from the simulation will occur by setting the bias point of the circuit during the simulation. Beside that, the result on the table 2, can proved by equation (1) and (2) above.

VI. CONCLUSIONS

The pressure not less than 10^{-5} torr as required in the evaporation process can be maintained by using the pressure controller that designed. The pressure sensor circuit was designed to makes an interface between the vacuum sensor 10^{-5} torr (200mV-600mV DC voltage) as the input voltage of circuit in this process. The combination of the pressure sensor circuit using TL084 as amplifier circuit and relay switching circuit as a pressure controller circuit can be used to control pressure not less than 10^{-5} torr as required in the evaporation process. Several ideas for future development have been discovered and hopefully this project will be continued with hardware development.

VII. FUTURE DEVELOPMENT

For the future development design, the pressure controller will be improve by using the analogue to digital converter (ADC0804), which is the circuit interface of microcontroller will control by using the PIC program. The PIC programming will set up the measurement range of the pressure detected inside the chamber and display on the LCD as the pressure indication. The block diagram of the pressure controller for future development is shown in Figure 1.5.

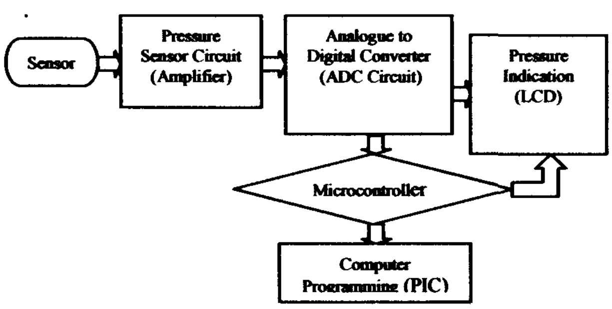

Figure 15: Block Diagram of the Pressure Controller For Future Development Design.

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