Microcontroller-Based Micro-resonator Sensor Signal Detection Technique

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Abstract—**Microcontroller-Based Micro-Resonator Sensor Signal Detection Technique was designed to detect small Alternating Current (AC) signal from micro-resonator sensors. This project is an alternative approach to measurement technique to typically done in the laboratory that requires table top equipments such as oscilloscope and function generator. The objective of this project is to design a technique that extracts amplitude and frequency of sensor response using microcontrollers as an alternative approach to Micro Electro Mechanical System (MEMS) application. This project is implemented using two techniques. The first technique is voltage incremental comparison and the second technique is voltage differentiation. The input AC signal data read from sensor will be transmitted to microcontroller and displayed on liquid crystal display (LCD). Resonator response is artificially generated and validated against oscilloscope measurements. As for the result, the first technique is much better from the second technique and able to measure micro-resonator sensor response. It found that amplitude average of percentage accuracy is 94.35% while for frequency average of percentage accuracy is 86.35%.**

Keywords— **Micro-resonator, microcontroller, MEMs, amplitude, interfacing circuit.**

I. INTRODUCTION

Micro-electromechanical systems (MEMS) are a technology that combines computers with small mechanical devices such as sensors, valves, gears, and actuators embedded in semiconductor chips [1]. MEMS is the enabling technology for micro-resonator sensor. The micro-resonator sensor has its own frequency that will resonate with a target element at a specified vacuum level [2]. When the parameter changes it causes a shift in the resonance frequency of the structure. This shift is measured and analytically or experimentally correlated to the change of the physical parameter [3]. The micro-resonator sensor can be implemented in space and military applications for autonomous mobile sensing systems and in environmental monitoring to monitor unpleasant or hazardous agents [4].

Micro-resonator is a structure that replaces electronic resonators. It is being used in electronic filter system and it will select a particular frequency chosen amongst several ones. It is highly used in telecommunication. Micro-resonators use mechanical vibrating parts to filter signals so that the only same value frequency with own value of the structure is kept [5]. Practically, by using MEMs resonator sensor, array measurement technique to measure sensor response that only can be done in the laboratory requires table top equipments such as oscilloscope and function generator.

The objective of this project is to design a technique that extracts the amplitude and frequency of the sensor response using microcontroller. Arduino is an open source electronics prototype platform that incorporates a simple and easy to use hardware and software [6]. With 6 channel pulse width modulator (PWM) and 8 channel 10-bit analog to digital converter (ADC) [7] provides a sufficient peripherals to process and produce the desired output for the capture timing of AC signal. The closed loop electronics is designed using 8051 microcontroller to detect the change in the resonance frequency [8]. This project focus is to apply microcontroller as an alternative approach to MEMs sensor application.

II. METHODOLOGY

The overall work involved in designing this AC signal measurement is summarized in the flow chart shown in Fig. 1. The hardware in this system includes the micro resonator sensor, Arduino Duemilanove board and LCD keypad shield.

In Arduino, it also has its own software which is easy to understand. When talk about Arduino, it includes hardware and software. The software was implemented by using two techniques. The first technique uses voltage incremental comparison and second technique uses voltage differentiation. The implementation between hardware and software can be compiled easily [9]. The controller will change the analog signal to digital signal using ADC on ATMega328p AVR microcontroller embedded in Arduino duemilanove board [10]. After the design is simulated, data will be collected and analyzed.

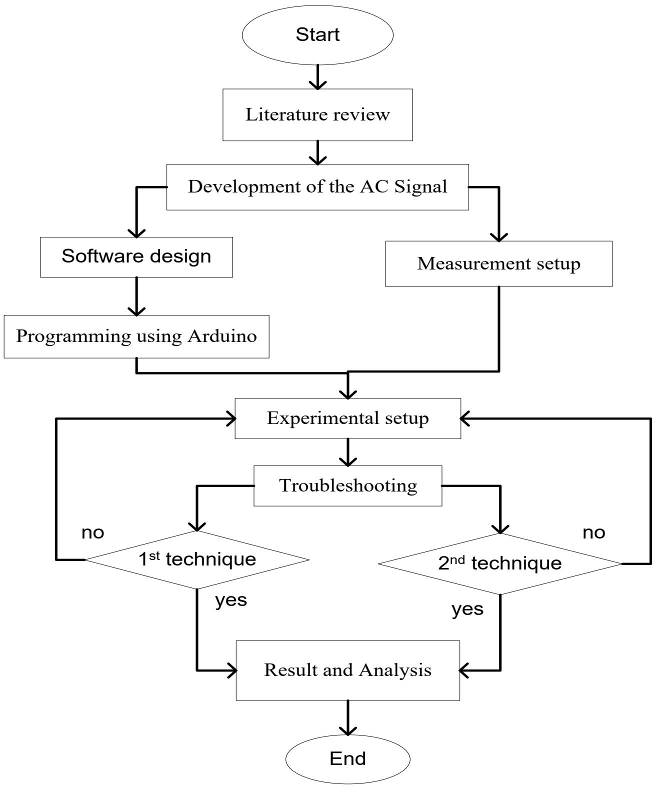

Figure 1. Overview of the project (Flowchart)

A. MEASUREMENT SETUP

The overall configuration is briefly in this section. The hardware uses physical integration of the components. Fig. 2 shows that the MEMs sensor receives AC signal and produces current to Readout interfacing circuit (ROIC). This Readout interfacing circuit will convert current to voltage. However, this circuit is replaced with artificially function generator. The Microcontroller-based reads the voltage as the input sensor response. The LCD will display the result as expected.

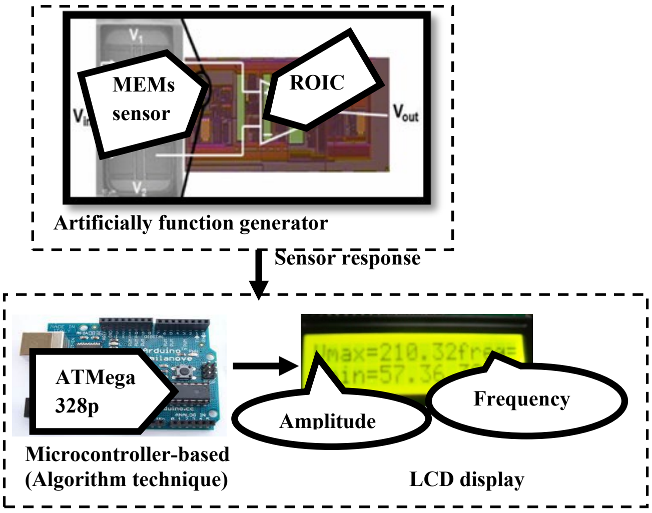

Figure 2. Microcontroller-based AC signal measurement block diagram.

The overall measurement setup is shown in Fig. 3. The function of oscilloscope is to compare whether the right value of maximum and minimum voltage was displayed on LCD.

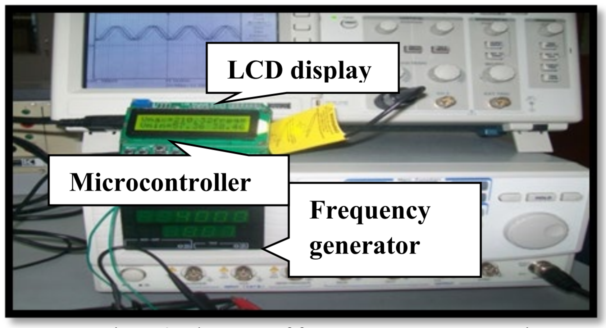

Figure 3. The setup of frequency measurement using microcontroller.

B. SOFTWARE IMPLEMENTATION

Arduino software is much easier to understand. The software is written using C language [11]. The whole software of the AC signal measurement consists of analog inputs. The analog inputs can read up to 1024 different states which are 0 until 1023. These are voltage equivalent when 5V divided by 1023. Therefore, 1 equals to 0.00488V. So basically the input is a scale from 0 to 5V in 1024 states. The input on Arduino can only read from 0 to 1023 states. However, it can change to voltage by multiplying it by 0.00488V.

The microcontroller is to read the analog input from sensor response and convert the AC signal into digital. This program is divided into two techniques.

Fig. 4 shows the flow chart of the design using voltage incremental comparison technique. The technique is to compare the first reading with second reading. This comparison will be continue until maximum voltage and minimum voltage are obtained. The time will be recorded to calculate the frequency at the peak amplitude. Meanwhile the Fig. 5 shows the voltage differentiation technique that used subtraction between the first reading and second reading. If a negative value is obtained, it shows that the signal is falling and vice versa. This step is repeated until it reached the maximum and minimum voltage. The time will be recorded to calculate the frequency at the peak amplitude.

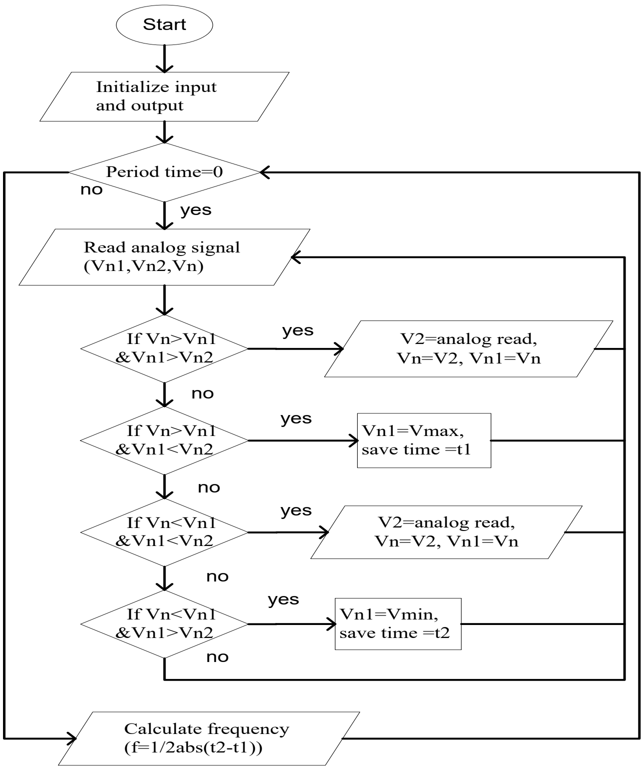

Figure 4. Flow chart of the project using voltage Incremental comparison technique

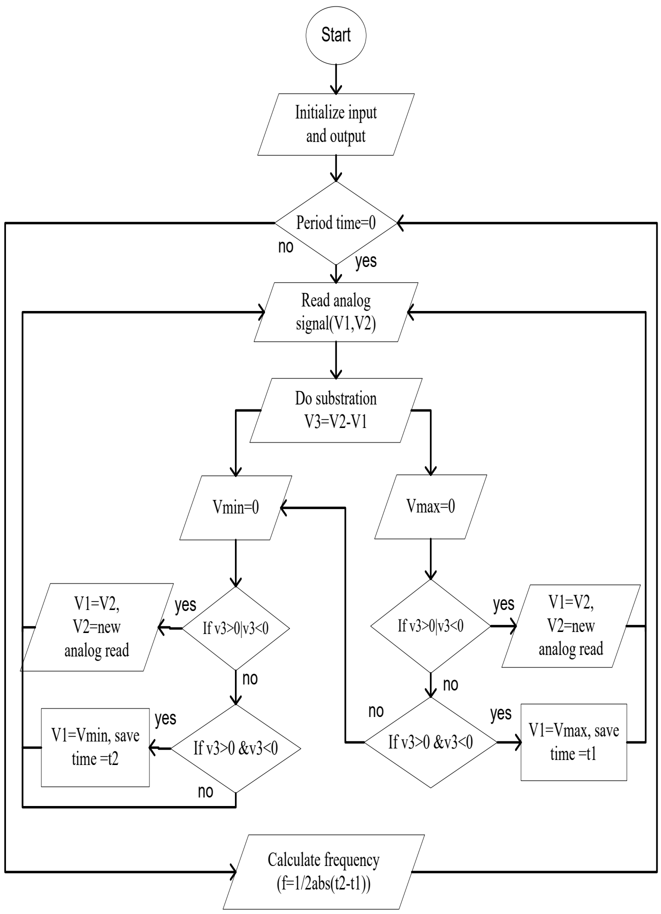

Figure 5. Flow chart of the project using voltage differentiation technique

III. RESULTS AND DISCUSSION

The experimental results for first technique were listed in the Table 1, Table 2, and Table 3. The measurement and actual value were taken from LCD display and oscilloscope respectively. The data in Table 1 and Table 2 show the percentage accuracy using incremental comparison technique at frequency of 100Hz for maximum and minimum voltage. While Table 3 shows the percentage accuracy for frequency with constant maximum and minimum voltage value.

TABLE 1. MAXIMUM VOLTAGE AND PERCENTAGE ACCURACY USING VOLTAGE INCREMENTAL COMPARISON TECHNIQUE AT CONSTANT FREQUENCY (FREQUENCY =100 HZ)

Vmax actual(mV)	*Vmax1 measure(mV)*	*Percentage1 (%)*
244	215.10	88.16
264	239.00	90.5
284	262.90	92.6
304	277.24	91.2
328	305.92	93.3
344	320.26	93.1
380	358.50	94.3
400	377.62	94.4

TABLE 2. MINIMUM VOLTAGE AND PERCENTAGE ACCURACY USING VOLTAGE INCREMENTAL COMPARISON TECHNIQUE AT CONSTANT FREQUENCY (FREQUENCY =100 HZ)

Vmin actual(mV)	*Vmin1 measure(mV)*	*Percentage1 (%)*
180	172.08	95.6
204	195.98	96.1
224	219.88	98.2
244	234.22	96.0
264	253.34	96.0
284	272.46	95.9
292	277.24	94.9
312	310.7	99.6

TABLE 3. FREQUENCY VALUE AND PERCENTAGE ACCURACY USING VOLTAGE INCREMENTAL COMPARISON TECHNIQUE AT CONSTANT VALUE OF MAXIMUM VOLTAGE AND MINIMUM VOLTAGE (VMAX=205.54MV, VMIN = 148.18MV)

Frequency actual(Hz)	*Frequency1 measure(Hz)*	*Percentage1 (%)*
20	17.24	86.2
30	23.81	79.4
40	31.25	78.1
50	41.67	83.3
60	55.56	92.6
70	62.50	89.3
80	71.43	89.3
90	83.33	92.6

The experimental results for second technique were listed in the Table 4, Table 5, and Table 6. The measurement and actual value were taken from LCD display and oscilloscope respectively. The data in Table 4 and Table 5 show the percentage accuracy using incremental comparison technique at frequency of 100Hz for maximum and minimum voltage. While Table 6 shows percentage accuracy for frequency with constant maximum and minimum voltage value.

TABLE 4. MAXIMUM VOLTAGE AND PERCENTAGE ACCURACY USING VOLTAGE DIFFERENTIATION TECHNIQUE AT CONSTANT FREQUENCY (FREQUENCY =100 HZ)

Vmax actual(mV)	*Vmax2 measure(mV)*	*Percentage2 (%)*
244	216.43	88.7
264	229.42	86.9
284	238.97	84.15
304	267.67	88.05
328	293.89	89.60
344	298.94	86.90
380	342.87	90.23
400	365.52	91.38

TABLE 5. MINIMUM VOLTAGE AND PERCENTAGE ACCURACY USING VOLTAGE DIFFERENTIATION TECHNIQUE AT CONSTANT FREQUENCY (FREQUENCY =100 HZ)

Vmin actual(mV)	*Vmin2 measure(mV)*	*Percentage2 (%)*
180	86.04	47.8
204	97.51	47.8
224	152.97	68.29
244	214.84	88.05
264	236.60	89.62
284	271.50	95.6
292	265.19	90.82
312	285.85	91.62

TABLE 6. FREQUENCY VALUE AND PERCENTAGE ACCURACY USING VOLTAGE DIFFERENTIATION TECHNIQUE AT CONSTANT VALUE OF MAXIMUM VOLTAGE AND MINIMUM VOLTAGE (VMAX=205.54MV, VMIN = 148.18MV)

Frequency actual(Hz)	*Frequency2 measure(Hz)*	*Percentage2 (%)*
20	10.20	51
30	16.67	55.57
40	27.78	69.45
50	33.33	66.66
60	45.45	75.75
70	50	71.42
80	55.56	69.45
90	62.50	69.44

The graph in Fig. 6 illustrates the relationship between the maximum and minimum voltage of measured value and maximum and minimum voltage of actual value by using both techniques. With incremented value in maximum voltage, it will affect the measured value at frequency of 100Hz. Actual value linearly proportional to the measured value.

From Fig.7, the graph shows the first technique is much better than the second technique because there is no delay when executing AC signal data at each point. Meanwhile, the delay in second technique is because of the subtraction process. As the result, the maximum and minimum value in second method was far scattered. The changes frequency value is shown on Fig. 8.

The frequency percentage value is depended on the time captured at maximum and minimum voltage. The first technique value is more organized and closed to actual value compared to second technique as shown in Fig. 9.

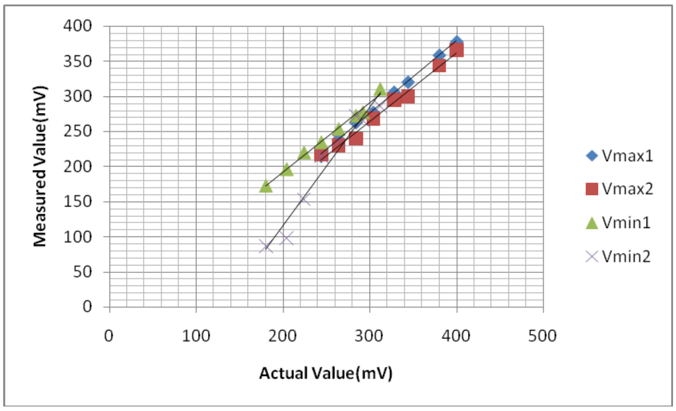

Figure 6. Maximum and minimum voltage of measured value (mV) versus maximum voltage of actual value (mV) using two different technique.

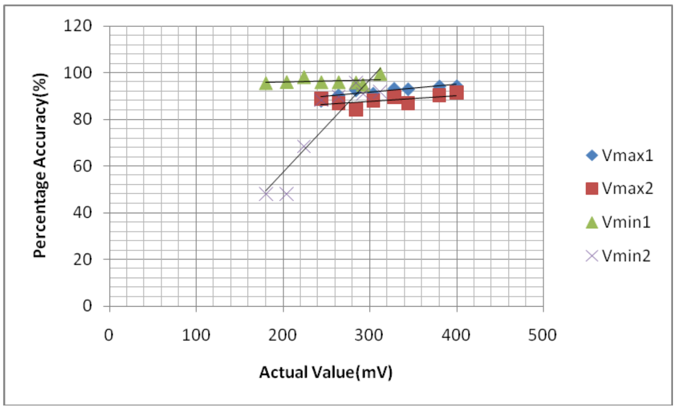

Figure 7. Percentage accuracy (%) of measured value versus maximum and minimum voltage of actual value (mV) using two different technique.

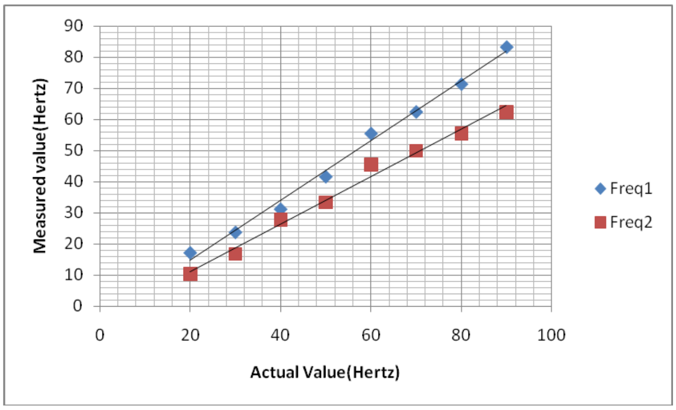

Figure 8. Frequency of measured value (mV) versus frequency of actual value (mV) using two different technique.

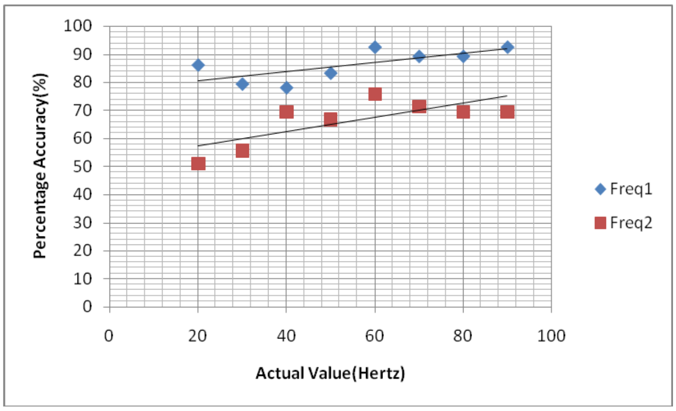

Figure 9. Percentage accuracy (%) versus frequency of actual value (mV) using two different technique.

IV. Conclusion

In conclusion, this project meets the objective of the study where the objective is to design a new technique that extracts the amplitude and frequency of the sensor response using microcontroller and also to compare both result from analysis and measurement. It can be implemented in the MEMs resonator sensor detector application. From the data analysis, the voltage incremental comparison technique is better compared to voltage differentiation techniques. The result obtained in first technique is more accurate in term of amplitude voltage and frequency AC signal.

For recommendation, this system can be upgraded by adding the transmitter and receiver so that the result can be displayed on the laptop or phone through wireless connection. Besides that, the programming also can be upgraded so that it can display the graph characteristic of sensor response with the timing of measurement. This system can applied with alarm system which is in laboratory of fabrication. It can detect the quantity of gases is not needed in laboratory and give the alarm when in dangerous situation.

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