EFFECT OF NOISE DISTURBANCES ON THE RESPONSE OF MEASURING DEVICES

Dr. G. M. Alwan **K. T. Rashed**
Lecturer **Lecturer**
Chem. Eng. Dept. –University of Technology

ABSTRACT

The present work studies the effect of noise on the dynamic response of pH, conductivity and thermocouple sensors which used into several industrial processes.

Thermocouple would be proven had more stability against noise than conductivity and pH meter. The effect of noise on process signals could be condensate as low as possible by using suitable model of filter especially when the sensors were implemented to a digital computer.

KEY WORDS: pH, conductivity, thermocouple, dynamic, noise.

NOMENCLATURE

C: conductivity (ms / cm)

G: Transfer function (-).

k_m: Steady state gain of measuring device (-).

pH: Indication of acidity (-).

poH: Indication of basicity (-).

s: Laplace transform (sec^{-1}).

T: Temperature (C).

t: Time (sec).

Greek letters:

τ_m: Time constant of measuring device (sec).

INTRODUCTION

The efficiency of any control system is directly depends on the measuring of controlled variable so that the important problem in the design of control loops are the specifications of sensors to get a good measurements for controlled process variables.

The main variables of any chemical process are; temperature, pressure, concentration, …… etc, some of these variables can be measured directly such as temperature and pressure where another variables cannot be measured directly such as concentration due to the limiting of it's availability and with expensive cost. However it is necessary to estimate it by using the simulated relations with another measured variable (Thomson, 1997).

Dynamic characteristics of the sensors are the important guides for selecting the suitable measuring devices of any chemical processes. The signals of measurements can be contaminated by several upsets (disturbances), one of these is noise.

Noise means disturbances, either periodic or random depends upon the nature of the process. There are many source of noise such as; mixing, electrical power fluctuation, neighboring electrical equipments ….. etc.

Different techniques were used to overcome the noise problem which are, improving the process design and selecting the stable location for sensor and also by using suitable filter noise (Jim, 2003).Several types of filters must be commonly used to reject spurious signals such as; low and high pass filters, band-pass and band rejection filters. Filters may take many physical forms ,however the electrical form is most common and highly developed with regard to both theory and practical realization(Doebelin,1975).

pH – meter

A pH – meter is an electronic instrument used to measure the acidity or basicity of liquids. A typical pH sensor consists of a special measuring probe (glass electrode) connected to an electronic meter to display the pH readings.

$$pH = -Log\left[H^{+}\right] \quad \text{……………….(1)}$$

$$poH = -Log\left[oH^{-}\right] \quad \text{……………….(2)}$$

$$pH + poH = 14 \quad \text{……………….(3)}$$

Where $[H^{+}]$ and $[oH^{-}]$ represent the activity (concentration) of hydrogen and hydroxide ions respectively (Thomason, 1997).

Conductivity meter

Conductivity is the ability of materials to conduct electric current. The principle by which instrument measure conductivity is simple, two plates are placed in the sample, a potential is applied across the plates, and the current that passes through the solution is measured (μ).

Conductivity is the inverse of resistively. The conductivity sensors are suitable for use with most portable meters. The basic measurement unit is the siemens (s) which widely expressed in specific conductivity unit (s/cm).

In the present work the effect of temperature would be considered in the collection of experimental data for pH and conductivity of solutions.

Thermocouple

A thermocouple is a sensor for measuring temperature which consist of two dissimilar metals joined together at end. When the junction of two metals is heated or cooled a voltage is produced that can be correlated to the temperature. The thermocouples always are commonly available as wire. The four most common used are J, K, T and E type each one has different temperature range and environment. The thermocouple is adapted with digital meter to display the measurements.

The experimental rig(figure 1)was designed and constructed into the best way to simulate the real process and to collect the desirable data.

Dynamic Model of Detectors

The measuring devices (pH, conductivity and thermocouple) could be considered as a first order lag system (Smith, 1979 and Stephanopauls, 1984) which represented by the following transfer function:

$$G_m(s) = \frac{K_m}{\tau_m s + 1} \qquad (4)$$

In the present work, the dynamic models of pH, conductivity meter and thermocouple were derived experimentally by process reaction curve method at the same operating conditions.

The dynamic models had the form of the first order lag system which could be represented as follows:

$$G_{pH}(s) = \frac{1}{1.8\, s + 1} \qquad (5)$$

$$G_{cond}(s) = \frac{1}{2.6\, s + 1} \qquad (6)$$

$$G_{TH.}(s) = \frac{1}{3.4\, s + 1} \qquad (7)$$

The values of dynamic parameters (τ_m and k_m) were depended upon the dimensions of sensors and the physical properties of liquids. These parameters played important rule in the design of closed loop control system. The dead time did not appear as a result of bad mixing.

From above, one can conclude that the pH-meter have low time constant (fast response) than conductivity and thermocouple devices. All of these detectors had similar values of sensivity (steady state gain) which approximately equal to one.

However it was show experimentally that the inlet flow rate of process liquid must be selected as the manipulated (input) variable to control the process variables (pH, conductivity and temperature).

Condensation of Noise

It is desirable to reject or at least condensate the noise associated with the measuring signals which highly affected on the efficiency of controller and then on the final control element such as control valve. Also it was unsuitable to link noisy signals to digital computer which must be operated with stable input signals.

In the present work, the noise (fluctuation) in the measuring response of the process would be condensate by the following procedure:

1. Improving the experimental set-up and locate the sensors into stable region away from any turbulent of mixing.
2. The transmition wires between sensors and readers must be shielded to resist any out side noises from surrounding.
3. The noisecould be condensate mathematically by driven the auxiliary equation of noise filter.

However in addition to above procedure it is better to use noise filter as an instrument before implemented the measuring signals to digital computer (Jonson, 1988).

Proposed Control System

The primary element in any controlled system was the measuring device. Detectors play important rule in the control system of the chemical plants.

The accuracy of the process control depended upon the sensitivity and accuracy of the measuring device. So that to get high efficiency most of the industrial process plants were operated under supervisor of digital control system.

For examples the development of water treatment plants be required to advanced (PID) control system implemental with digital computer. The major suitable detectors used were pH and conductivity meters. The proposal interface system is shown in figure (2) can be used for input/output signals able to reject any undesirable noise. However, expert computer program can used to operate the plant at desired conditions.

RESULTS AND DISCUSSIONS

For continuous well mixed systems, the behaviors of the three measuring devices against several disturbances (upset) using strong acid (H_2SO_4), weak acid (CH_3COOH) and strong base (NaOH) which were explained as follows:

1. pH-detector :

Figures (3, 4, and 5) explained the response of pH sensor for a step change in acid and base flow rates. In spite of a high response speed and lower dead time as a result of a well-mixed condition in the case of high speed mixer (60 rpm), a high noise would be appeared in the response curve.

Then the noise would be decreased as mixer speed decreased until reached to best speed of (10 rpm). Fluctuation in response curve was appeared also as a result of bad or without mixing.

The response speed and sensivity to any disturbance or noise of the strong acid/strong base system was more explained than for the weak acid / strong base system. This was due to that the strong acid and base were highly dissociated to ions then the bulk of ions around the membrane of pH electrode was high when compared with the weak acid system. This increased the driving force between solution of bulk and layer of electrode then increased the value of pH which depended directly on this driving force.

The sensivity (steady state gain) of ions bulk around the electrode was linear function to concentration of these ions so it would be more affected by any disturbance such as the turbulent of mixing or change in flow rate of acid / base solution.

From the fluctuation (noise) in pH response, it showed (figure 6) that the minimum and maximum value of rejected filter was (-2.8) and (3.2) respectively from experimental data.

In the present work the effect of noise was condensate by design the mathematical filter model to pass the desired signals and reject spurious ones (figure 7) from the response. The equation of filtered pH response was obtained as follows:

$$pH = 6.732 - 0.0136\, t - 0.21 \times 10^{-3}\, t^2 + 0.871 \times 10^{-6}\, t^3 \quad (8)$$

with correlation coefficient of (0.99).

Conductivity Sensor

Figures (8, 9) illustrated the dynamic behavior of conductivity meter against disturbance (mixing turbulent and step change in acid flow rate).

The fluctuation in response curve was appeared as low as possible in the strong acid / strong base system figure (8) when compared to the weak acid / strong base system figure (9) and response speed higher for strong acid / strong base system. This was due to that the strong acid / strong base was polar and highly dissociated then the ionic conductivity of solution was increased.

The increasing in the speed of mixing of solution would increase the motion of electrons and the fluctuation in measurement was less appeared.

In the contrast for the weak acid / strong base system which had slow dissociation and then with low ionic conductivity and low motion of electrons. This tend that the weak solution was more affected by mixing noise.

However regarding to the previous reasons, one can conclude that any type of salts which dissolved in to water increased the conductivity of water, so that the conductivity meter became more suitable and effective for measuring the concentration of ions into salt solutions than pH. meter which depended only on $[H^+]$ or $[oH^-]$ concentrations into solution.

So that the applications of conductivity meters into drink water treatment plants to detect solutions are widely more then pH sensors (Zeebe, 2001).

Figure (10) illustrated the fluctuation of noise in the conductivity response which was between (- 0.45 to 0.45). The filtered response of conductivity explained in figure (11) which represented by the following equation:

$$C = 2.371 + 0.0004\,t + 3.059 \times 10^{-6}\,t^2$$

with the correlation coefficient of (0.98).

Temperature Device

For the same operating conditions, the effect of external noise on temperature response was less than for pH and conductivity meter. Figure (12) explained the fluctuation in temperature response which was between (- 0.17 to 0.18) which represented the range of operation for noise filter. This means that the thermocouple was less sensitive to upsets and had more stability compared with pH and conductivity sensors. This identical to dynamics specifications of detectors which explained previously.

Actually the composition processes were always sensitive to any disturbance than the thermal process. So that the control system for thermal process was less accurate than that of composition process.

In the present work the noise was rejected by mathematical model of noise filter from the temperature response figure (13) and the equation of filtered temperature became as follows:

$$T = 43.173 - 0.428\,t - 0.011\,t^2 \qquad (10)$$

with correlation coefficient of (0.98).

From the above responses the detectors would be still behaved as a first order lag system in spite of scattering in experimental signals due to undesirable noise.

In process control, the designer was always selected the stable sensors which had technical specifications against any external noise.

For these reasons, in several chemical process the temperature sensors were used as good inferential indicators instead of composition sensors (Stephanopauls, 1984).

CONCLUSIONS

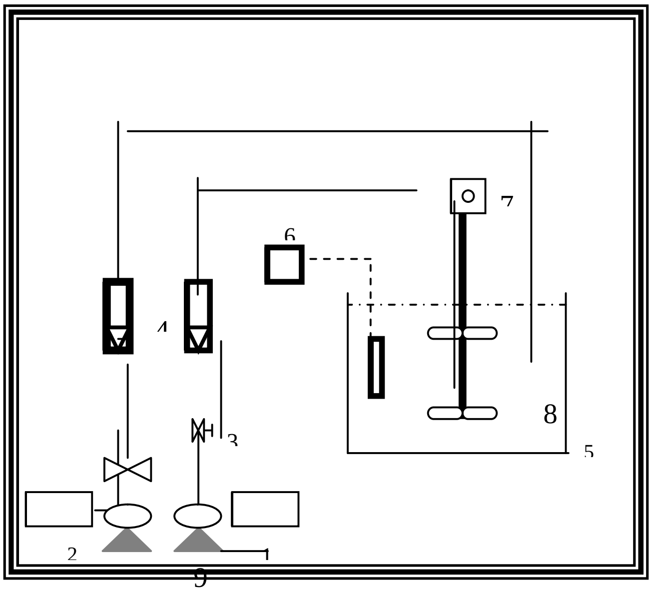
1. The efficiency of any control system was directly depended upon the dynamic characteristics of measuring devices.
2. For sufficient operation of control system, it was suitable to use conductivity meter in case of salts

solutions and use pH-meter for acid/base solutions.

3. Thermocouple detector was proven to be stable and less effected by noise disturbances than conductivity and pH-meter respectively.
4. Noise would not affect on the dynamic model of sensors in spite of instability in experimental responses.
5. Due to the previous reasons, in some cases of high cost and unavailability of composition sensor, it necessary to use low cost and available thermocouple as indicator in the inferential control loop of turbulent process to estimate the unmeasured composition variable.
6. Any type of noise in the input process signals must be condensate or rejected by suitable noise filter before implemented to digital computers.

REFERENCES

1. Thomson, S. J. and Safa M. A., "development of an automated high accuracy pH-measuring instrument with full and it reporting facility", www.IEEEyplore.org, April, 1997.
2. Jim Cox and Dave Brown, "Noise of Eddy Current Instrumentation", www.usace.army.mil, October, 2003.
3. Dobelin,E.O."Measurement systems, Application and design"MacGraw-Hill,kogakusha,2nd edition,1975.
4. Smith, C. L., "Fundamentals of control theory", Chemical Engineering. Desk book Issue, October, 15, 1979.
5. Stephanopouls, G., "Chemical process Control, An Introduction to theory and partice", Prentic-Hall, New Jersey,2nd edition. (1984).
6. Jonson, D., "Process Control Instrumentation Technology", Jhon Wiley, 3rd edition, (1988).
7. Zeebe, R. E. and Wolf G. D., "Co_2 in Seawater Equilibrium Kinetic", isotopic, Elsevier Science B. V., Amsterdam, Netherlands, (2001).



Item NO.	*Details*
1	Acid solution tank
2	Base solution tank
3	Needle valve
4	Rota meter
5	Mixing tank
6	Digital indicator
7	Mixer
8	Sensor(pH,conductivity,thermocouple
9	Dosing pump

Figure (1) General layout of experimental set-up

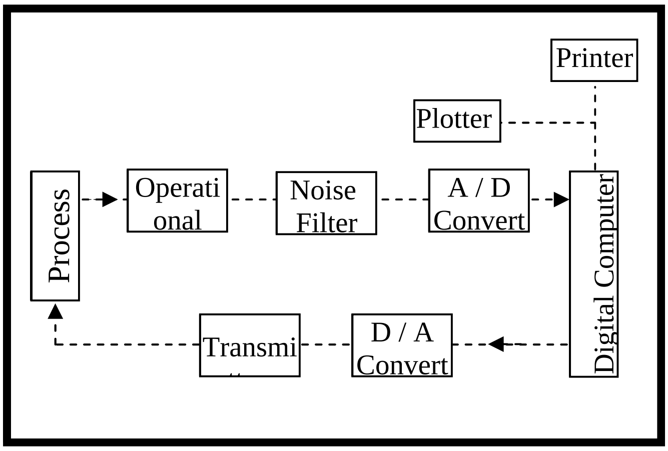


Figure (2): Diagram of digital control system

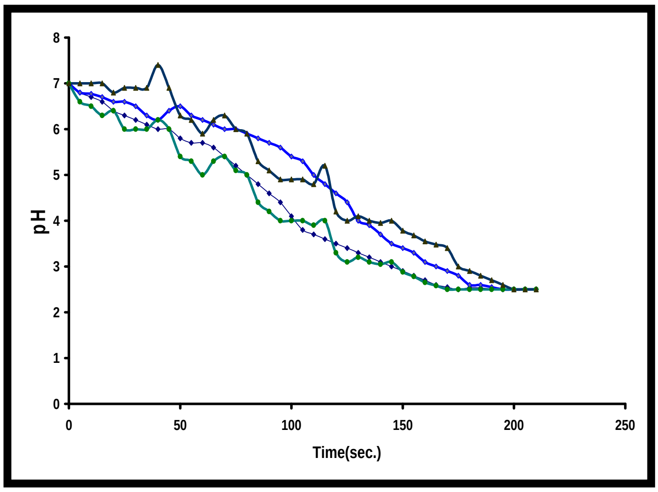


Figure (3) : pH_response for step change in acid flow rat for strong acid &base with various speed of mixing where (▲= 60 rpm, ♦ =20 rpm, ■ = 10 rpm, ⁎ = 0 rpm).

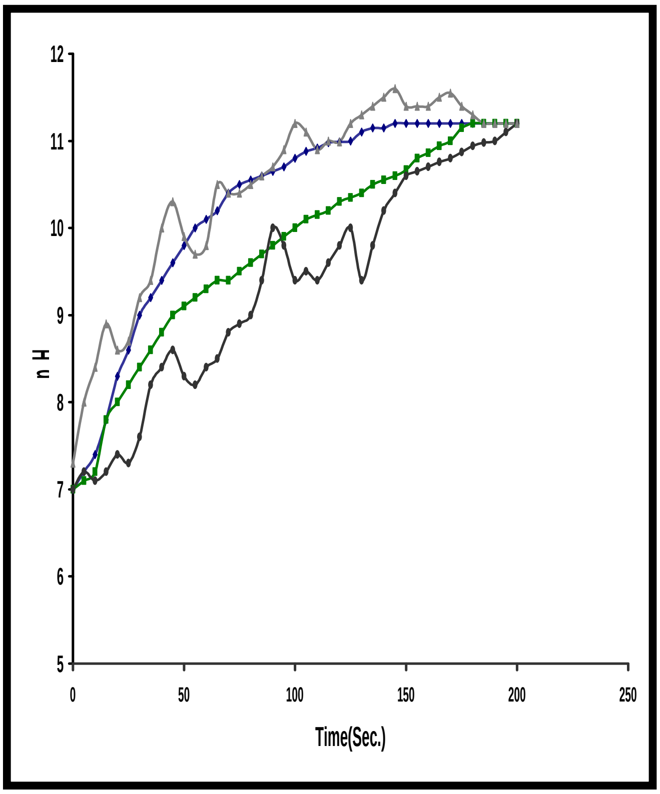


Figure (4): pH_response for step change in base flow rat for strong acid &base with various speed of mixing where (▲= 60 rpm, ♦ = 20 rpm, ■ = 10

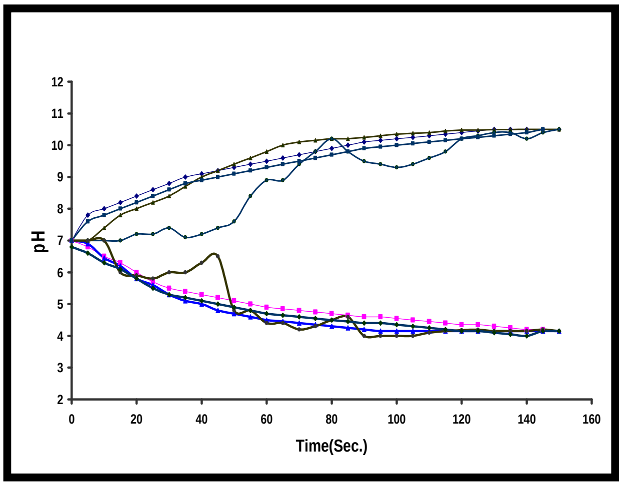


Figure (5): pH_response for step change in base and acid flow rat for weak acid & strong base with various speed of mixing where (▲=60 rpm, ♦=20 rpm,

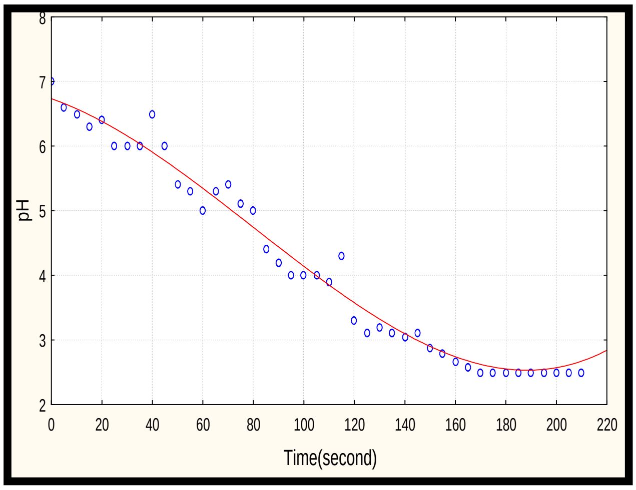


Figure (7): Filtered response of pH from noise for strong base and acid of 60 rpm.

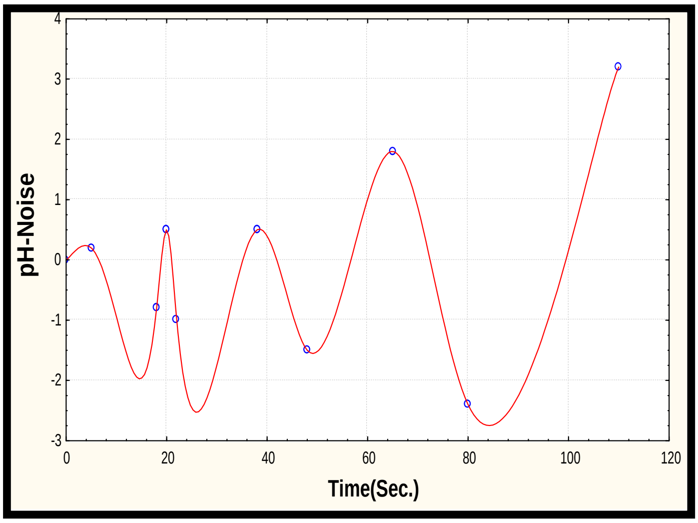


Figure (6): Fluctuation noise of pH response.

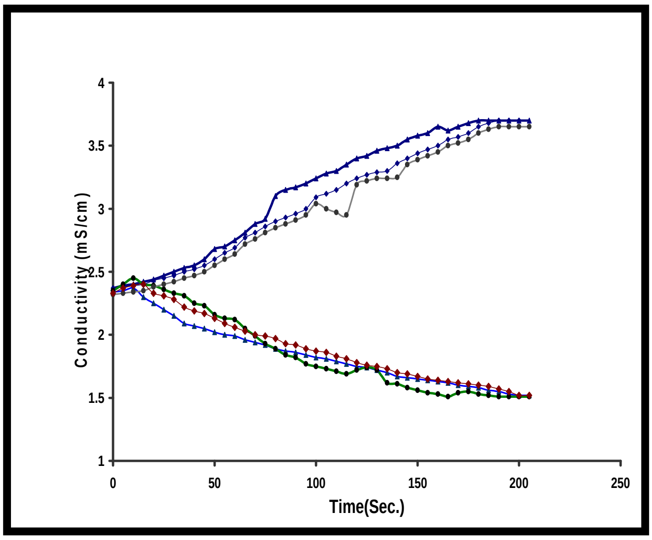


Figure (8): Conductivity response for step change in acid flow rate for strong acid & base with various speed of mixing (▲= 60 rpm, ♦ = 20 rpm, * = 0 rpm).

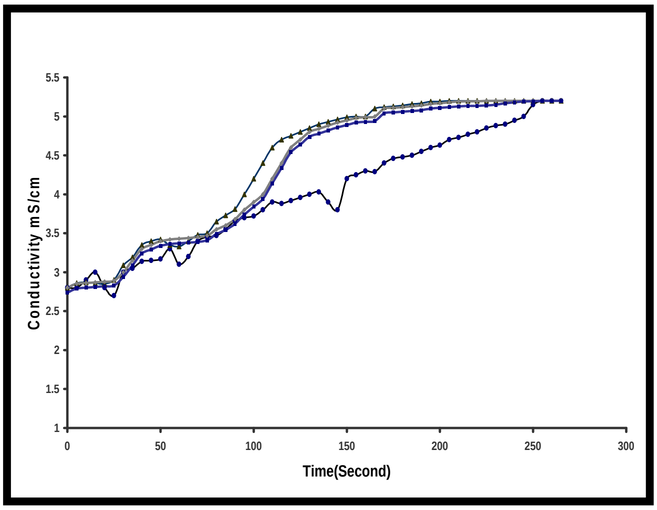


Figure (9): Conductivity response for step change in acid flow rate for weak acid & strong base with various speed of mixing (▲= 60 rpm, ♦ = 20 rpm, ⋆ = 0 rpm).

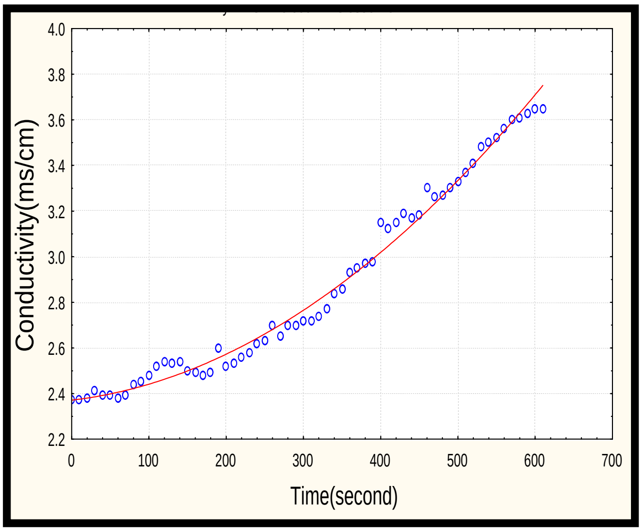


Figure (11): Filtered response of conductivitv from noise for

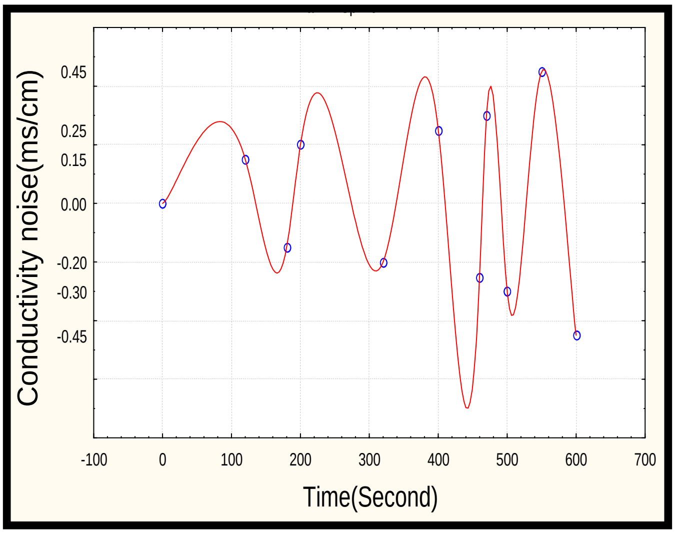


Figure (10): Fluctuation noise of conductivitv response.

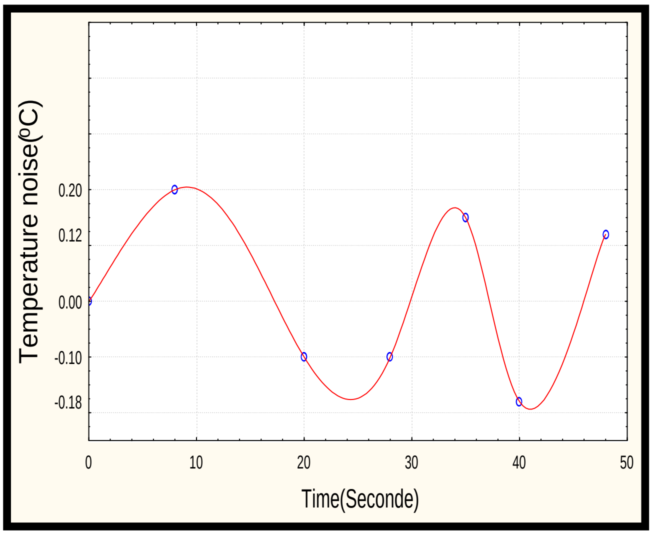


Figure (12): Fluctuation noise for temperature response

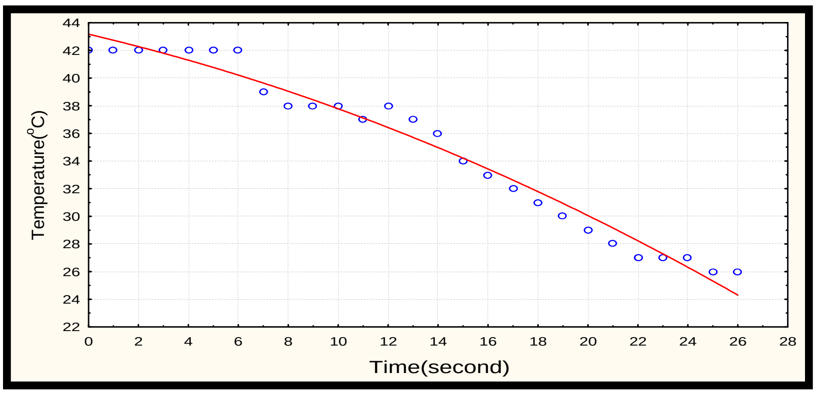


Figure (13): Filtered response of temperature from noise for 60 mm

تأثير توزيع الضوضاء على الاستجابة لأجهزة القياس

د. غانم مقبول علوان **د. خالد طه رشيد**

مدرس **مدرس**

قسم الهندسة الكيمياوية - الجامعة التكنولوجية

الخلاصة

ان البحث المقدم يدرس تأثير الضوضاء على الاستجابة الحركية لمقيـاس الدالـة الحامـضية، التوصـيلية و المتحسسات ذات المزدوج الحراري و التي تستخدم في عدد من العمليات الصناعية. وجد ان المـزدوج الحلـراري يمتلك أعلى استقرارية تجاه الضوضاء و اكثر من مقياس التوصيلية و الدالة الحامضية. ان تأثير الضوضاء علـى اشارات العملية يمكن تكثيفه الى اقصى حد باستخدام نموذج مناسب من المرشح خصوصاً عندما تدخل المتحسـسات في الحاسبة الرقمية.

الكلمات الدالة

مقياس الدالة الحامضية، التوصيلية،مزدوج حراري، حركية، ضوضاء.