REUSABLE PREGNANCY TEST KIT

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

December 2006

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Zunaidah binti Mat Daud

ABSTRACT

The Reusable Pregnancy Test Kit is a device that is can be used to detect early pregnancy. Nowadays, the existing pregnancy test kits that available in market are disposable and must discarded after one time of usage. The purpose of this project is to invent a reusable pregnancy test kit regarding to overcome that limitation. One method to validate the pregnancy by the presence of one hormone in the urine or blood called Human Chorionic Gonadotropin (hCG). Two lines will appear on the kit for the positive result and one line for the other negative result. The characteristic of the chemical sensor is not reusable. However there is no electronics sensor that can be used to detect that hormone directly from the urine like the chemical sensor's function. But to make the kit to works for several time, this project proposed a sensor that can detect the pH of urine and can be used for several times. The pH value of the pregnancy urine is quite difference with the normal urine. The aim of using sensor is to produce electrical signal being proportional to the pH of the urine. After detecting the different level of pH, the sensor will give the output based on the pH value that differentiates the pregnancy urine with the normal urine.

ACKNOWLEDGEMENT

First and foremost, thanks to The Most Gracious and The Most Merciful, as without His guidance and blessing, the author would not be able to finish this project.

This dissertation could not have been written without Pn Salina bt Mohmad who not only served as my supervisor but also encouraged and challenged me throughout my academic program as well as this project. She patiently guided me through the dissertation process, never accepting less than my best efforts.

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LIST OF ABBREVIATIONS

hCG	Human Chorionic Gonadotrophin
mIU/ml	milli-international units per milliliter
PCB	Printed Circuit Board
LH	Luteinizing Hormone
TSH	Thyroid-stimulating Hormone
ISFET	Ion Sensitive Field Effect Transistor
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
ISE	Ion Selective Electrode

CHAPTER 1

INTRODUCTION

1.1 Background of study

When a woman becomes pregnant, the pregnancy hormone Human Chorionic Gonadotrophin, (hCG) is produced. Home pregnancy tests kit can detect the presence of this hormone in a woman's urine. Many type of home pregnancy test kit are available at the market.

There are two types of home pregnancy tests which are mid-stream tests and those with urine well. The mid-stream tests are basically sticks that the patient holds in her hand at one end and at the same time urinates on the other end. The test units with a urine well contain a urine collection cup and require the woman to collect urine in this cup. After collection, the patient utilizes a dropper to place the sample into urine well on the test unit [1].

The home pregnancy test detects the presence of the pregnancy hormone in urine which is hCG. This hormone is produced by the fertilized ovum in pregnant women. During early stages of pregnancy the fertilized ovum secretes the hormone hCG. This hormone appears in a pregnant woman's urine and increases with the development of the pregnancy.[1]

The major difference between all test kits is the degree of sensitivity to hCG. Most urine tests allow the detection of pregnancy as early as 14 days after conception in most circumstances. Basically the home pregnant tests have a sensitivity threshold of 25 milli-international units per milliliter (mIU/ml) [1].

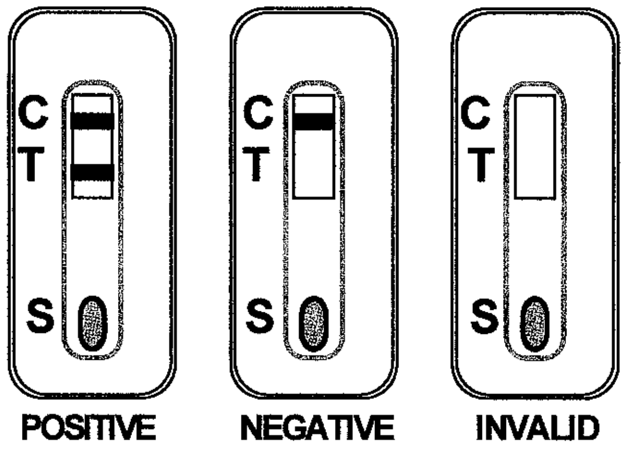


Figure 1: Pregnancy test result using Home Pregnancy Test

1. **Positive** (pregnancy). Two pink-rose bands appear: one in the test region (T) and in the control region (C). A positive result indicates presence of HCG at ≥25 mIU/ml.
2. **Negative** One rose-pink band appears in the control region (C), with no band in the test region (T). A negative result indicates that concentration of HCG is below the detection level.
3. **Invalid** There is no distinct color band visible both in the test region and in the control region, or there is a visible band only in the test region and not in the control region. The result is invalid due to deterioration of the test or improper test procedure [2]

This project is done to overcome the limitation of the home pregnancy test kits which are not reusable. Biosensor is used to replace the chemical indicator for the detection of the presence of hCG. The aim of using a biosensor rather than the other sensor is to produce electrical signal that will detect the presence of hCG and the sensor is reusable.

1.2 Problem Statement

1.2.1 Problem Identification

To invent this type of the pregnancy test kit, several problems will be encountered based on the existing test kit that use chemical indicator which is disposable after one time usage only. The chemical indicator also has limitation in testing duration for which it soaked in the urine longer that required, the result may be invalid. This project is carried out to overcome the limitation of the existing pregnancy test kits.

1.2.2 Significant of the project

The significance of this project is that the user can reuse the test kit for several times. This will save cost for testing pregnancy for long term benefits. This project will improve the accuracy of the test result without taking in account of the time duration needed for the kit to be soaked in the urine. Beside that, the environment factor such as temperature does not effect the testing due to biosensor does not react with the surrounding molecules.

1.3 Objectives:

The objectives of this project are:

- To understand the operation of the bio sensor working principle based on the electronics device such as transducer
- To invent a reusable pregnancy test kit that consists of biosensor(s) that can be used at least 10 times.
- To justify the best technique and application to real case study.

1.4 Scope of study:

This project is going to be implemented within two semesters consist of two main phases. For the first phase of the project based research on chemical properties of hCG hormones and types of sensors that are compatible for the detection on that hCG is carried out. The second phase will be implemented on second semester based on simulation on suitable software and construction of the biosensor on breadboard. After operation of the circuit works, the product lastly will be fabricated on the Printed Circuit Board (PCB).

CHAPTER 2

LITERATURE REVIEW

2.1 Composition of normal urine

To produce a sensor, the first thing that should be identified is the physical and chemical properties of the samples which is the hCG hormone presence in the urine [3]. Urine is made up of a watery solution of metabolic wastes (such as urea), dissolved salts and organic materials. The composition of urine is adjusted in the process of reabsorption when essential molecules needed by the body, such as glucose, are reabsorbed back into the blood stream via carrier molecules. The remaining fluid contains high concentrations of urea and other excess or potentially toxic substances that will be released from the body [3].

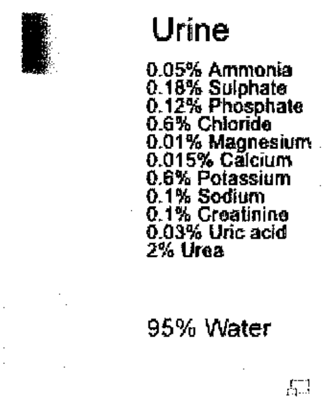


Figure 2: Composition of normal urine [2]

The difference between the pregnant woman and non pregnant woman is the composition of one hormone that is HCG that. In the normal urine, the concentration of hCG is lower than pregnant woman.

2.2 Human Chorionic Gonatropin (hCG)

Relatively tests for plasma or urinary hCG, which give positive results at one or two weeks after the first missed menstrual period, are most commonly use to diagnose pregnancy.

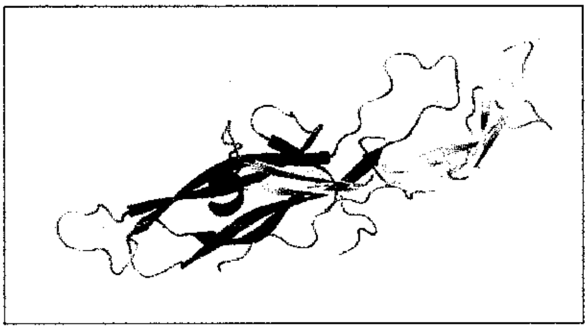


Figure 3: Structure of hCG [3]

The hCG is a glycoprotein composed of 244 amino acids with a molecular mass of 36.7 kDa. It is heterodimeric, with an α (alpha) subunit identical to that of luteinizing hormone (LH), follicle-stimulating hormone (FSH), and thyroid-stimulating hormone (TSH) and β (beta) subunit that is unique to hCG. βhCG is encoded by six highly homologous genes which are arranged in tandem and inverted pairs on chromosome (contain genes)[4].

Human Chorionic Gonadotropin (hCG) is composed of two dissimilar subunits, namely α- and β-subunits. The subunits are held together primarily by hydrophobic bonding. The molecular weight of intact hCG, αhCG and βhCG are approximately 36.7, 14.5 and 22.2kDa, respectively. It has been estimated that 30% of the total weight of HCG is contributed by the carbohydrate content which accounts for the heterogeneity property of hCG [4].

There are a total of 8 carbohydrate attachment sites in a hCG molecule, two are at the αhCG and the rest are at the βhCG. The carbohydrate content of hCG is composed of 10-11% of **neutral sugar**, 10-11% **amino sugar** and 8-9% of **sialic acids** or also known as N-acetylneuraminic acids . The sialic acid which resides at the terminal portion of carbohydrate side chain varies most among different preparations of hCG, and appears to be closely correlated with the biological activity of the hormone but not affecting its immunological activity [4].

The pI values give an indication of the sialic acid content in the molecules; the greater number of sialic acid on the hCG leads to a greater ionization constant and hence lower the pI value. The variable electrophoretic mobility of hCG attributed to the different degree of desialylation of the hCG[4].

A major portion of the hCG immuno reactivity detectable in pregnancy urine is derived from a fragment of hCG beta. This lacks the COOH- terminal portion of hCG beta, but retains immuno reactivity with most antibodies raised against the beta-subunit of hCG[4].

It also differs from the beta-subunit of hCG in its carbohydrate structure, lacking sialic acid and having a low but variable amount of galactose. A beta-fragment containing the same two NH2-terminal sequences was also isolated from a single pregnant woman's urine. The intrinsic characteristic of the beta-fragment is the formation of a variable amount of dimmer in solutions of neutral pH [4].

Those are reference ranges of hCG that contained in the urine of pregnant woman based on gestarional age. For non-pregnant woman or man which is negative, hCG < 5 mIU/mL

Table 1: References ranges of HCG for pregnancy [5]:

Gestational age	Range (mIU/mL)
0-1 Week	0-50
1-2 Weeks	40-300
2-3 Weeks	100-1,000
3-4 Weeks	500-6,000
1-2 Months	5,000-200,000
2-3 Months	10,000-100,000
2nd Trimester	3,000-50,000
3rd Trimester	1,000-50,000

As mention before the concentration of hCG in pregnancy urine that can be detected by the home pregnancy test kit is 25 mIU/ml.

2.3 Biosensor

A biosensor is an intelligent, material-based high technology device incorporating of a biological sensing element either closely connected to, or integrated within, a transducer system. Normally the usual aim for using a biosensor rather than any other sensor is to produce an electrical signal that being proportional to the concentration of a specific chemical.

The signals are to produce a proportional in magnitude or frequency to the concentration of a chemical or biochemical to which the biological element reacts. In this process, rapid conversion of the concentration of chemical into an electrical signal is indeed very important [8].

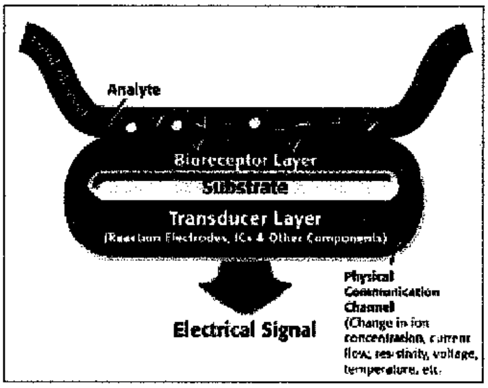


Figure 4: Representation of generic biosensor [6]

Biosensor/transducer units are referred to simply as biosensors, and they are defined as devices that do one or more of the following:

1. Detect, record, convert, process, and transmit information regarding a physiological change or process
2. Utilize biological materials to monitor the presence of various chemicals in a substance (analyte)
3. Combine an electrical interface (transducer) with the biologically sensitive and selective element [6].

Therefore, a sensor could be regarded as a transducer, which transforms one physical quantity into another. But in biosensor, this phenomenon is recognized by a bioreceptor, which is put in direct contact with the sample and forms the sensitive component of the biosensor. So, the function of a biosensor is to transform a biological event into an electrical signal [7].

When the target analyte to be monitored reaches the sensing layer, a physical or chemical signal occurs which is then converted by a transducer into an output electrical signal. The signal is treated in a processing system leading to a direct result for monitoring and interpretation [7].

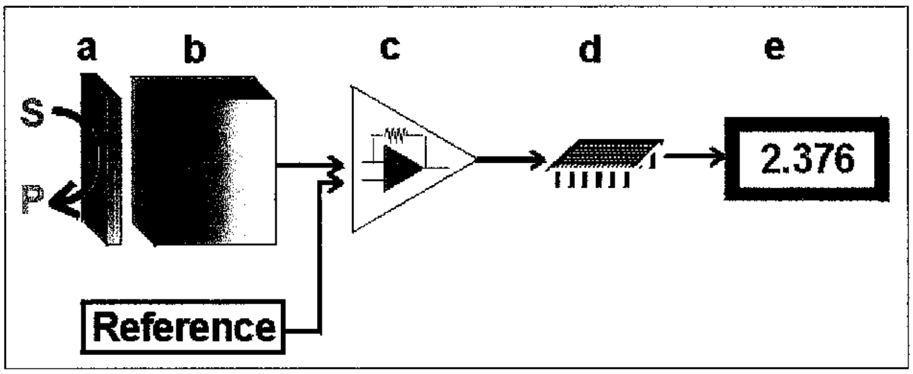


Figure 5: Schematic diagram showing the main component of a biosensor [10].

Where the biocatalyst:

(a) Converts the substrate to product.

(b) This reaction is determined by the transducer which converts it to an electrical signal.

(c) The output from the transducer is amplified

(d) Processed

(e) Displayed

To obtain a better electrical signal, these two elements, a bioreceptor and transducer have to be compatible with each other. For example electrochemical transducers couple relatively easily with enzymes because they have reasonable biocompatibility with each other. An antibody is an electrically charged protein. Its coupling with an antigen can give rise to variations in the dielectric constant which is measurable with a semiconductor sensor.

2.4 ISFET-type sensor

The Ion Sensitive Field Effect Transistor (ISFET) is an electrochemical micro sensor based on FET transducer. Ion-sensitive FET is generally selective to H^+ ions. This selectivity arises from acid/base properties of the inorganic oxide (gate material) contacting the electrolyte. Examples of the inorganic oxides used are SiO_2, Si_3N_4, Al_2O_3 and Ta_2O_5 [8].

A hybrid sensor module that is based on an identical transducer principle has been suggested. In this sensor / actuator set-up, the same ISFET can serve as both a physical and bio- / or chemical sensor. Consequently, the amount of (bio-) chemical and physical information is higher than the number of sensors that are present in the module. The "high order" ISFET module consists of two ISFET (either two ISFET or a second BioFET), an ion generator and a reference electrode (See Figure 6).

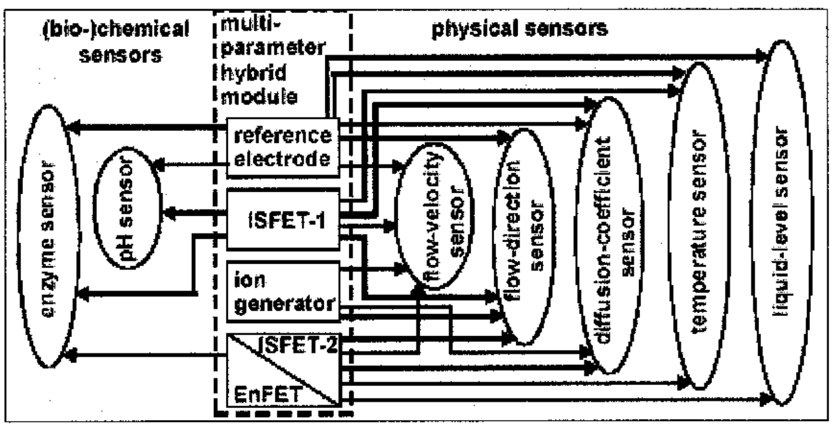


Figure 6: Possible sensor configuration for the measurement of seven bio-chemical and physical parameter using ISFET based "high order" module [8].

The multi-parameter systems allows the detection of seven chemical /biological and physical quantities such as pH, penicillin, concentration, temperature, diffusion coefficient of ions, flow direction, flow velocity and liquid level. The configuration as high lighted above from the total system [8].

An ion sensitive field effect transistor (ISFET) is the solid state analogue of the conventional ion selective electrode (most commonly the pH electrode). The device consists of an FET where the gate electrode has been replaced by an ion selective membrane, and all other parts of the FET have been covered with an encapsulant (see **Figure 7** for a schematic diagram of an ISFET, and the photograph of the ISFET chip) [9].

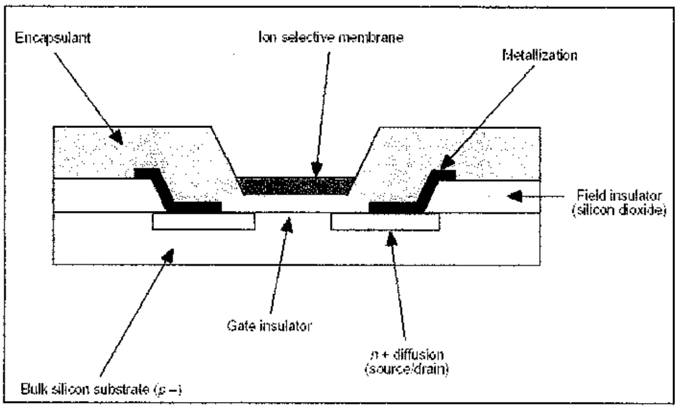


Figure 7: Schematic Diagram of an Ion Sensitive Field Effect Transistor [9]

The ion selective membrane is one that will selectively exchange a specific ion with a solution and thereby develop a charge in membrane that is dependent on the concentration of that specific ion in the test solution. The FET device can measure the amount of charge developed in the membrane and convert it to a current.

This ISFET device can therefore be used as a direct replacement of conventional ion selective electrode (ISE). The ISFET device uses the same ion selective membrane as the ISEs and, as such the chemical sensitivity and selectivity of the devices are comparable.

The ISFET device however has several distinct advantages over ISE [10]:

- A single ISFET chip can have several ion sensitive areas selective to different ions whereas the ISE can only have a single ion sensitive area.
- ISFET device have been produced having areas sensitive to pH, sodium, calcium, and potassium on a single piece of silicon.
- The ISFET device is a single solid piece of silicon and as such is very rugged and robust.

The advantages permit ISFETs to be used in this application where the ion selective electrode would be unsuitable or where size/cost constraints would make the measurement unviable.

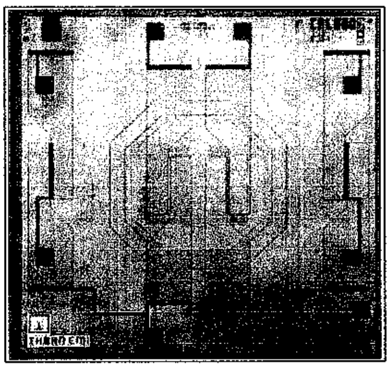


Figure 8: A Dual gate ISFET device sensitive to pH and sodium.
(Chip size 1.8mm × 1.8mm [10]).

The FETs are able to measure the conductance of a semiconductor as a function of an electrical field perpendicular to the gate oxide surface. In the simplest version, (i.e. a metal oxide semiconductor field effect transistor, n-channel Metal Oxide Semiconductor Field Effect Transistor (MOSFET), a p-type silicon substrate (bulk) contains two n-type diffusion regions (source and drain).

The structure is covered with a silicon dioxide insulating layer on top of which a metal gate electrode is deposited **(Figure 9 a).**

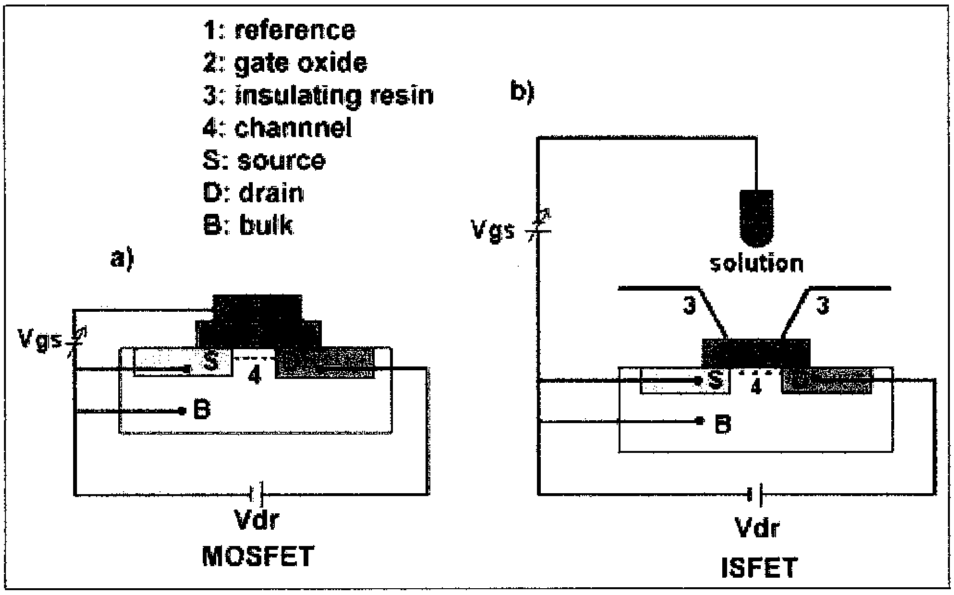


Figure 9: a) Schematic representation of a MOSFET and an **b)** ISFET structure [16].

When a positive voltage (with respect to the silicon) is applied to the gate electrode, electrons (which are the minority carriers in the substrate) are attracted to the surface of the semiconductor. Consequently, a conducting channel is created between the source and the drain, near the silicon dioxide interface [10].

The conductivity of this channel can be modulated by adjusting the strength of electrical field between the gate electrode and the silicon, perpendicular to the substrate surface. At the same time a voltage can be applied between the drain and the source (V_{ds}), which results in a drain current (I_d) between the n-regions.

In the case of the ISFET, the gate metal electrode of the MOSFET is replaced by an electrolyte solution which is contacted by reference electrode (then the gate metal electrode of the MOSFET is replaced by an electrolyte solution which is contacted by reference electrode SiO_2 gate oxide is placed directly in an aqueous electrolyte solution,

Figure 9 b) .The metal part of reference electrode can be considered as the gate of the MOSFET.

In ISFET, electric current (I_d) flows from the source to the drain via the channel. Like in MOSFET the channel resistance depends on the electric field perpendicular to the direction of the current. Also it depends on the potential difference over the gate oxide. Therefore, the source-drain current, I_d, is influenced by the interface potential at the oxide/aqueous solution.[14]

Although the electric resistance of the channel provides a measure for the gate oxide potential, the direct measurement of this resistance gives no indication of the absolute value of this potential. However at a fixed source-drain potential (V_{ds}), changes in the gate potential can be compensated by modulation of the V_{gs}. This adjustment should be carried out in such a way that the changes in V_{gs} applied to the reference electrode are exactly opposite to the changes in the gate oxide potential.

This is automatically performed by ISFET amplifier with feedback which allows obtaining constant source-drain current. In this particular case, the gate-source potential is determined by the surface potential at the insulator/electrolyte interface. When SiO_2 is used as the insulator, the chemical nature of the interface oxide is reflected in the measured source-drain current.

The surface of the gate oxide contains OH-functionalities, which are in electrochemical equilibrium with ions in the sample solutions (H^+ and OH^-). The hydroxyl groups at the gate oxide surface can be protonated and deprotonated and thus, when the gate oxide contacts an aqueous solution, a change of pH will change the SiO_2 surface potential. A site-dissociation model describes the signal transduction as a function of the state of ionization of the amphoteric surface SiOH groups Typical pH sensitivities measured with SiO_2 ISFETs are 37-40 mV/ pH unit [11].

Ion Sensitive Field Effect Transistors (ISFET) are electronic devices, similar to MOS transistors, sensitive to pH. They are fabricated using microelectronic technologies and, thus, they have advantages like small size and low cost compared to standard pH glass electrodes. Environmental monitoring, biomedical analysis and industrial process control are attractive applications of ISFET chemical

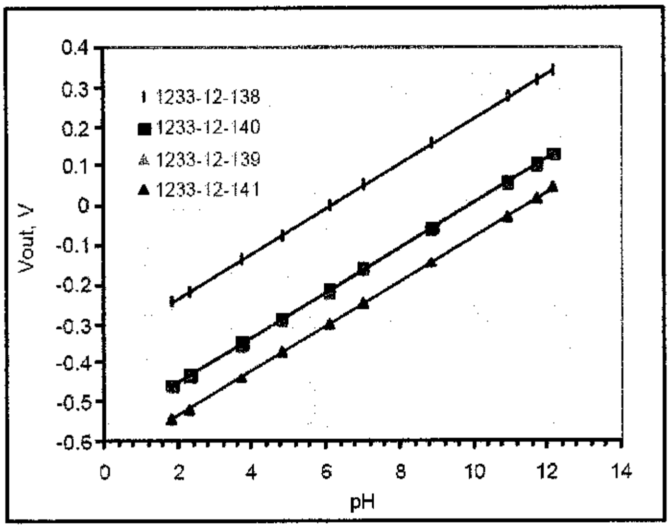


Figure 10: Graph for calibration plot for several Si3N4 pH ISFETs

The graph above shows that the relationship between pH value and voltage signal of the pH ISFET sensor is directly proportional to each other.

CHAPTER 3

METHODOLOGY

Device Selection:
Select the appropriate pH sensor

Identifying:
Identification the type of input
(Analog or Digital)

Comparator:
Since the output of the pH sensor in analog output, an IC comparator is used to allow the output is high in certain range of pH

Implementing:
Draw the schematic diagram in the PSpice and construct the circuit on the breadboard

Testing and troubleshooting
The circuit that construct on the breadboard is testing first before design on the PCB

Evaluation
- Final Report
- Oral Presentation

Figure 11: Project methodology

3.1 Basic operation of test kit

The basic operation of the system is in conjunction of the biosensor with the transducer to produce the voltage that processes the output.

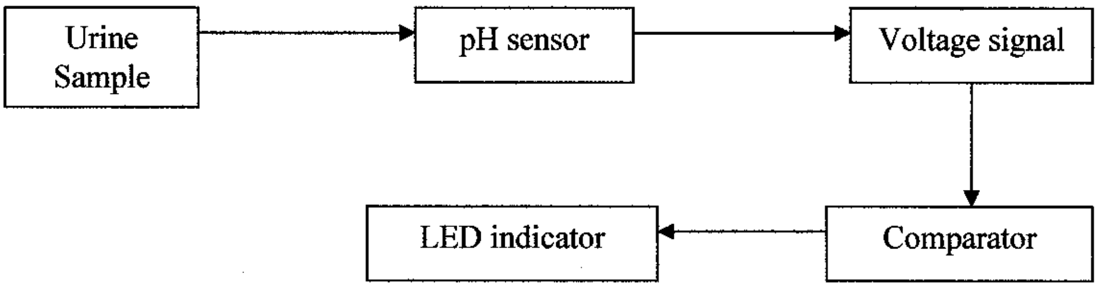


Figure 12: Basic of test kit flow chart

In this operation, the sample of urine of the pregnant woman is taken. The bioreceptor (pH sensor) is in direct contact with the sample and will form the sensitive component of the biosensor. In other word, bioreceptor has a particularly selective site that identifies the analyte. The transducer is a device that transforms the physical quantity (pH value) into another voltage signal. The pH values of urines are being proportional to the voltage signal of the pH meter. The difference of the voltage that is in the range that can be high output can be apply by using comparator circuit. The upper limit for voltage range (Comparator 1) can be calculated using voltage division as below:

$$\mathbf{Vref} = \frac{\mathbf{1k\Omega}}{\mathbf{1k\Omega + 10k\Omega}} \times (+5\mathrm{V}) = +0.4\mathrm{V}$$

While for the lower limit of the comparator circuit (Comparator 2) can be set as follows:

$$\mathbf{Vref} = \frac{\mathbf{1k\Omega}}{\mathbf{1k\Omega + 16k\Omega}} \times (+5\mathrm{V}) = +0.3\mathrm{V}$$

The overall operation is represented in the voltage window detector as shown in the figure below. The high output indicates that the input is within a voltage window of +0.305V and +0.405V (these value is being set by the reference voltage levels used).

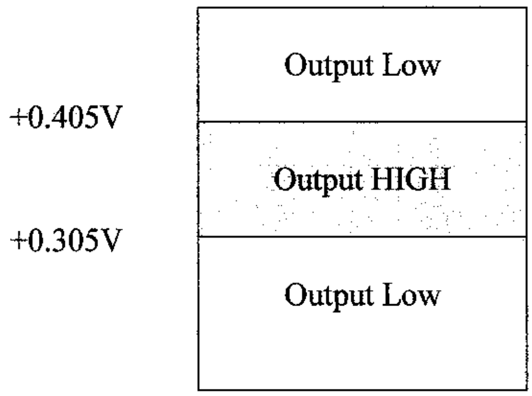


Figure 13: Operation of two comparator circuits as a window detector [12].

The test will give negative result when the voltage signal from the pH sensor is greater than 0.405V and less than 0.305V. The positive results in represent by the darker area which mark as output HIGH.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Urine pH confirmation between pregnant and non pregnant woman.

To determine acidity of two types of urine, pH indicator strips is used. The reason of choosing the pH indicator is to make the comparison with the reading of the pH meter.

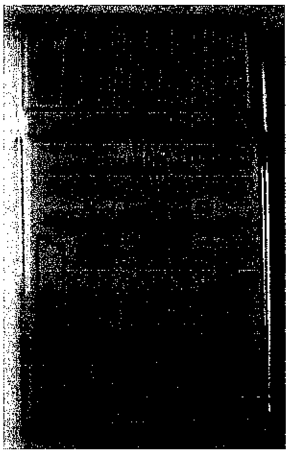
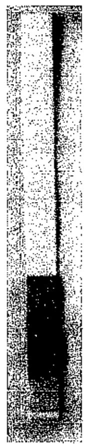


Figure 14: pH Reference

Figure 14 a): Pregnant



Fiigure 14 b): Non-pregnant

The experiment is conducted at chemical laboratory to determine the pH value of the urine between pregnant and non pregnant. The pH indicator strip is immersed for 2 minutes in the urine and the color change as figure above.The accuracy of the result using pH indicator in pH 1 tolarance. For pregnant woman, the pH value is near to pH 7 which is quite neutral. The pH value for non pregnant is about pH 5 which is quite acidic. But this test is taken from the sample of two people who are pregnant and not. For statistical analysis, to get the valid of the results and to strengthen the theory, the sample should be taken from various types of samples. But due to the availability constraints to obtain the urine sample of the pregnant woman, the authors just take the one type of sample from limited source.

The experiment is conducted with pH meter to get more accuracy. The result of the pH of the urine as follows:

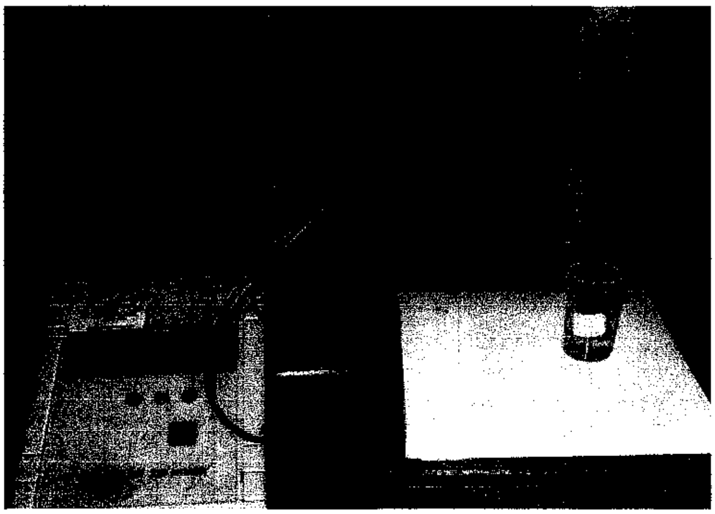


Figure 15: pH of urine determination by using pH meter

Table 2: pH value for pregnant urine and non pregnant urine

pH value	Pregnant			Non- pregnant		
	Reading 1	Reading 2	Reading 3	Reading 1	Reading 2	Reading 3
	6.82	7.13	7.42	4.78	4.79	4.8

By suing pH meter, the reading is depends on the calibration of the pH meter. If the calibration is not accurate, the uncertainty may occur to pH value that measured. Then, it's important to calibrate the pH meter before measuring is done by using the buffer solution. However the sample is taken from one types of urine of pregnant woman and the other one from non pregnant. To increase the accuracy and persistent result, the samples must be taken from various types of samples and reading must taken more frequent.

4.2 pH sensor

The pH sensor is extract from a water proof pH meter brand HANNA instrument (refer to Appendix I), there is no circuit diagram enclosed in the purchased item. The connections are trigger by check the diagram of the Analog to Digital Converter (ADC) that embedded in the small pocket size pH meter. A/D Converter ICL 7126CPL is used in this pH meter. The voltage is measured from IN HI which pin no 31 to negative terminal of the battery which is connected to ground.

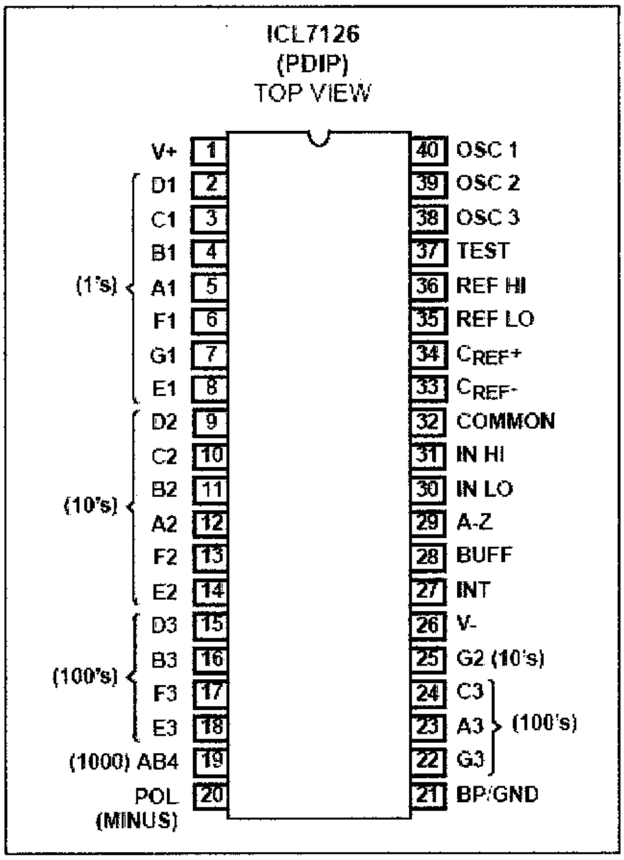


Figure 16: A/D Converter ICL7126CPL

Then after the output of the pH sensor are detected that connected to the INPUT HIGH at the ADC, the voltage are measure from the input high to the common. (Refer to Appendix II)

The voltage that relates the pH value and the value of voltage difference are taken as in the table below:

Table 3: pH value compared to Voltage reading.

pH values	Voltage reading (V)
7.4	0.405
7.1	0.397
6.8	0.350
5.3	0.240

The relationship between the pH value and the voltage output of the pH sensor is plot in the graph below.

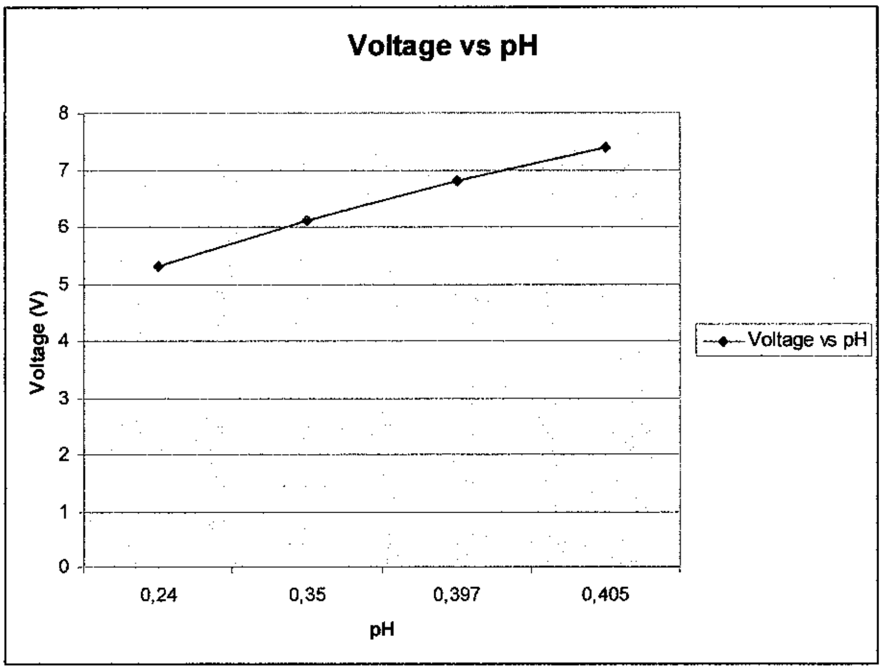


Figure 17: Graph for calibration plot for HANNA instrument pH sensor

4.3 Circuit operation and simulation

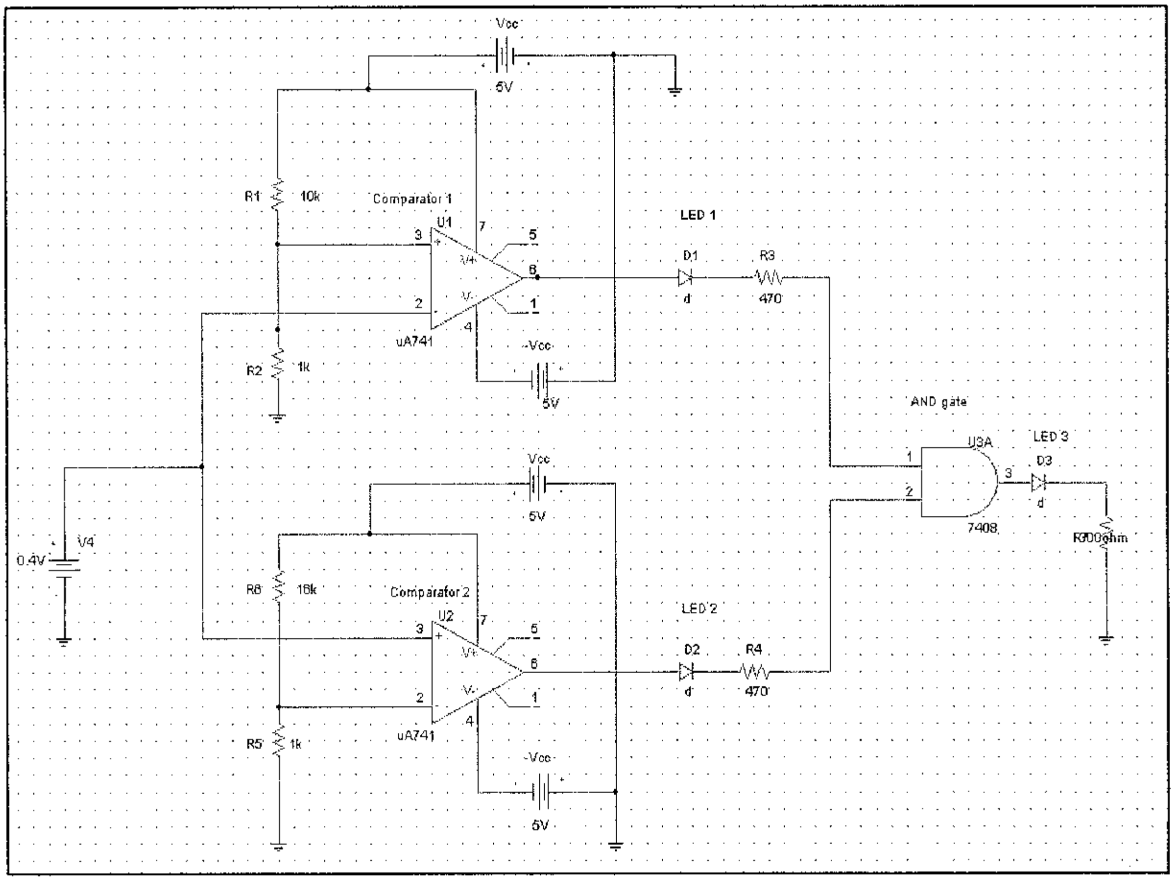


Figure 18: Comparator circuit construction in the PSpsice software

Because of the output of the pH sensor is in analog input, the circuit is decided to use comparator. The comparator that is used is combination two Omp-amp ua741. Since the output of both of these comparator circuits is output HIGH circuit will give the positive result, then output of both comparator can be wired to AND gate. Figure above shows two comparators circuited connected with common output and also with common input. Comparator 1 has a +0.405V reference voltage input connected to the non inverting input. The output will be driven low by comparator 1 when the input signal goes above +0.405V. Comparator 2 has a reference voltage of +0.305V connected to the inverting input. The output of comparator 2 will be driven low when the input signal goes below +0.305V or above 0.405V. In total, the output will go low whenever the input is below +0.305V and above +0.405V.

By using simulation in the Multisim 2001 software the circuit can be simulate to test whether it run properly or not. The voltage signal from the pH sensor can be represent by DC source that have same value of voltage signal of the pH sensor.

Simulation for Comparator 1 which has output HIGH when voltage input (V1) less than Vref (0.1V):

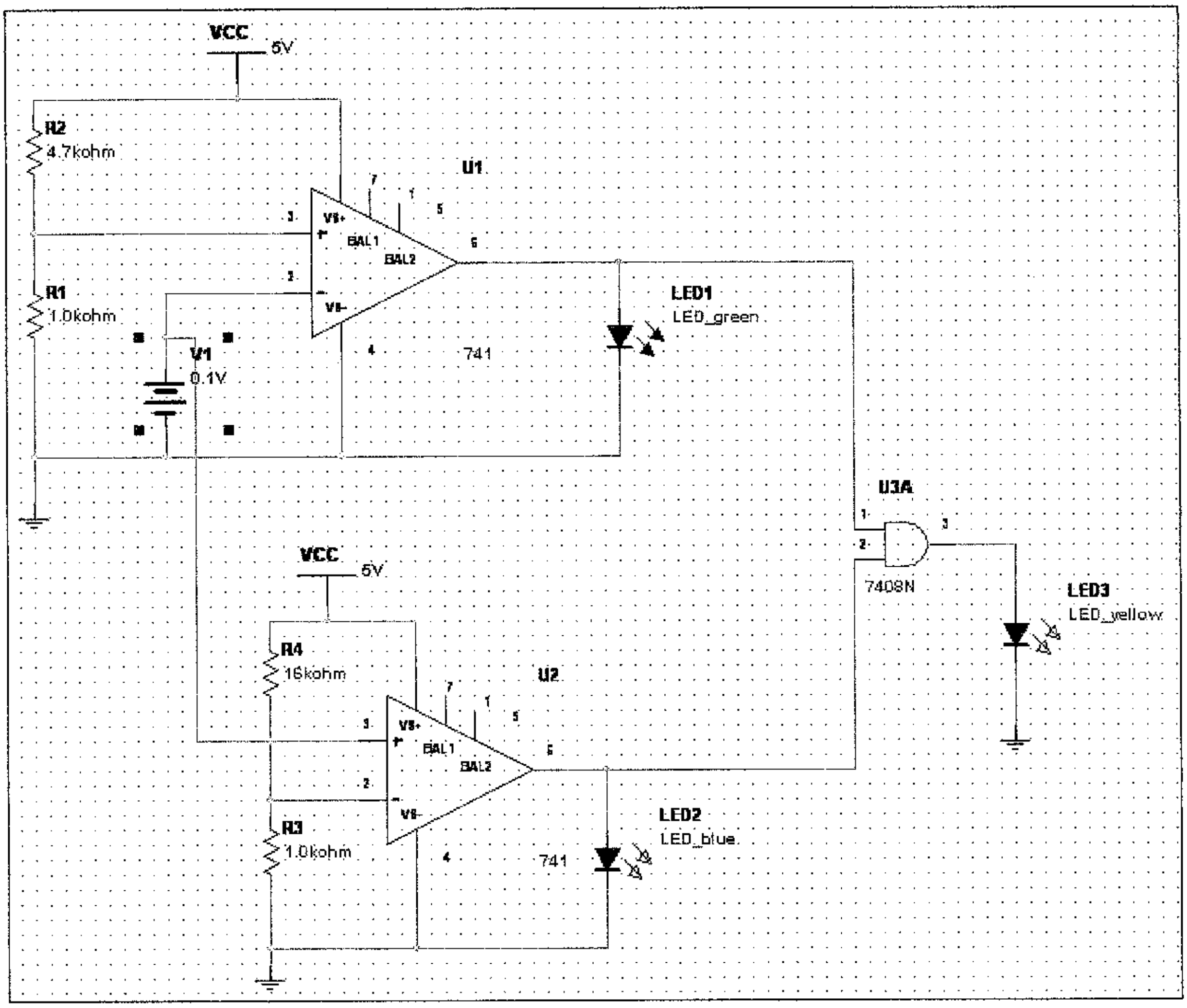


Figure 19: Simulation for Comparator 1 which is Vin (V1) less than 0.4V (Vref)

Simulation for Comparator 2 which has output HIGH when voltage input (V1) is greater than Vref (1.2V):

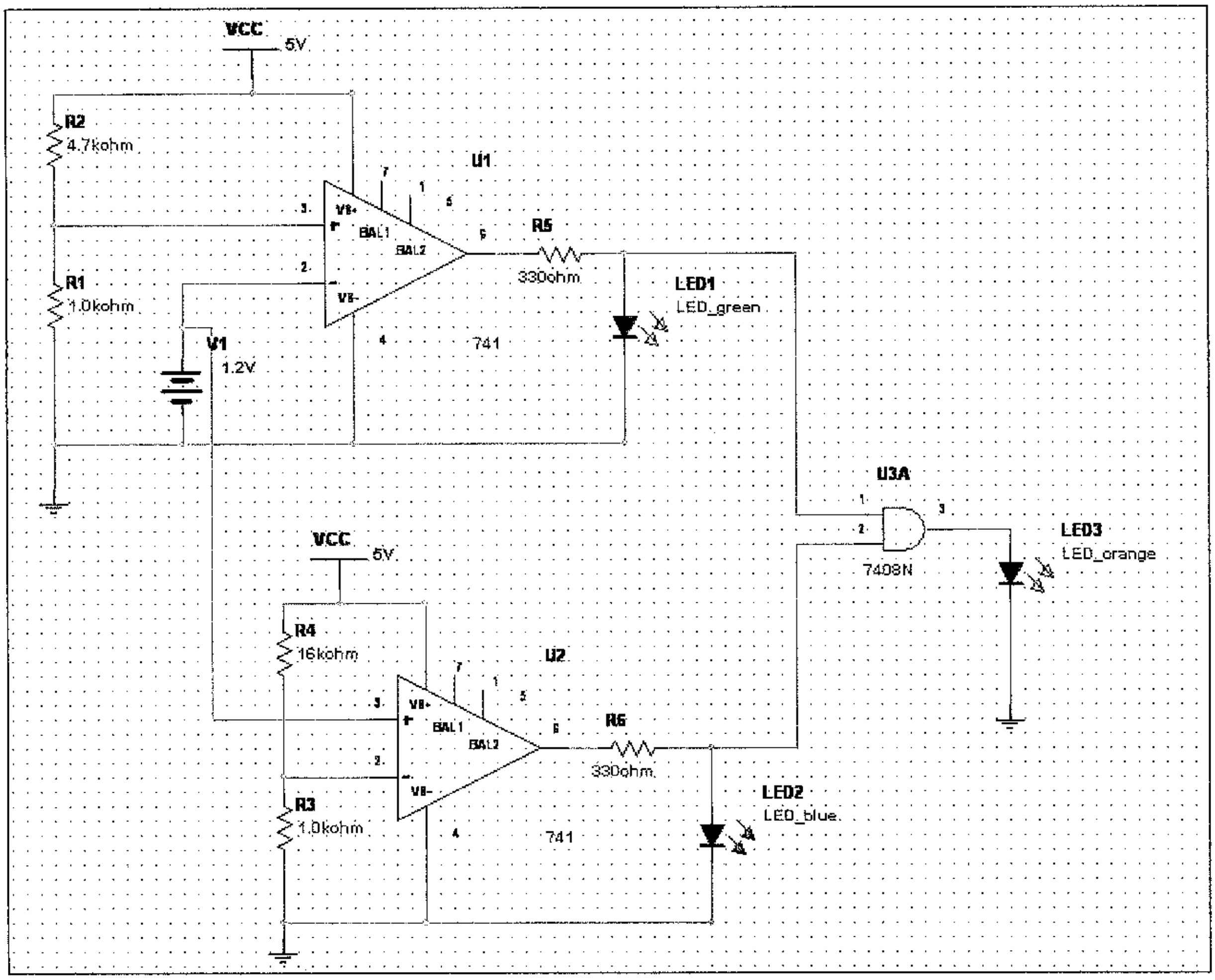


Figure 20: Simulation for Comparator 2 which is Vin (V1) greater than 0.3V (Vref)

Simulation for both Comparator 1 and Comparator 2 which have output HIGH when voltage input (V1) between Vref range (0.4>Vin>0.3V):

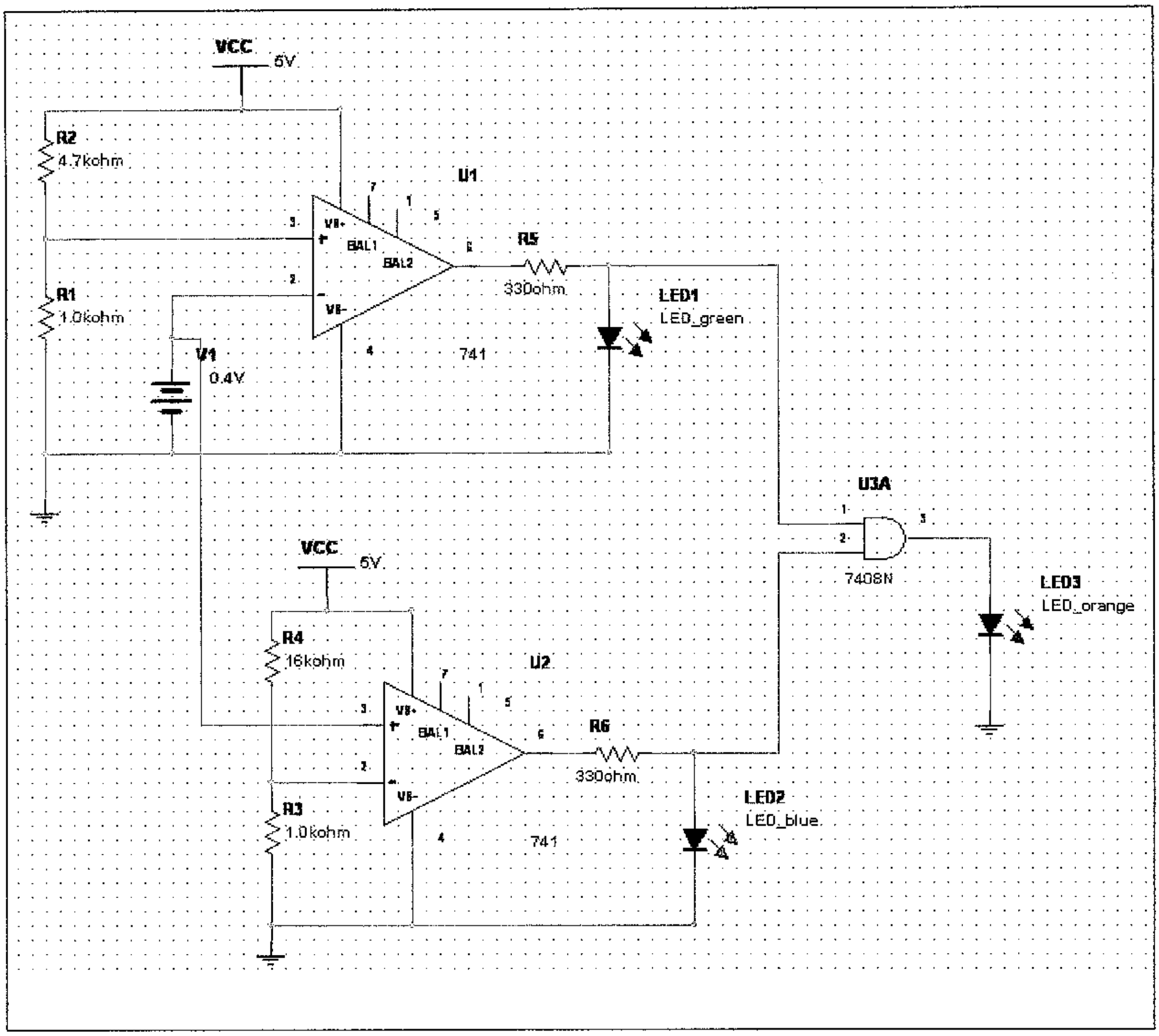


Figure 21: Simulation for both comparator which is Vin(V1) is within the range (Vref)

4.4 Circuit operation and on the Vera board construction

In the final stage of this project, the circuit is constructed on the Vera board due to problem that occurs to the PCB machine. The function of transferring of comparator circuit from breadboard to Vera board is to make it more stable and run smoothly. The negative results are indicated in the **Figure 22 a)** and **b)** which is LED in orange color is light off. The output of both comparators is wired to AND Gate for final output which represent by LED in orange color. When the voltage signal in the range of the pH of pregnant urine (positive result) the orange LED will light up as indicated in **Figure 22 c)** . The circuit construction on the Vera board gives the results as below when gives at different level of input voltages:

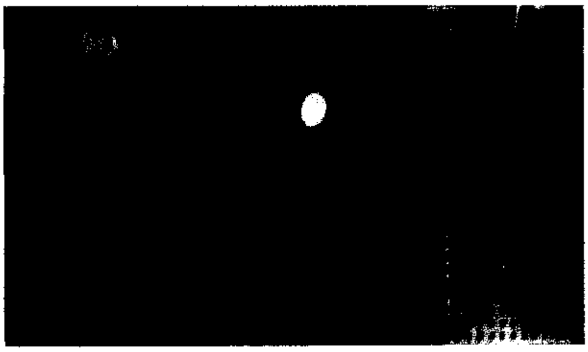


Figure 22 a): Input voltage less than 0.4V

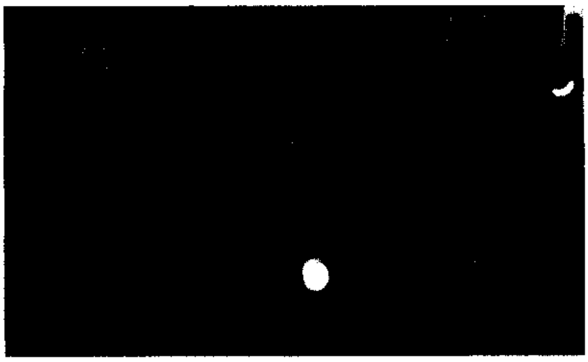


Figure 22 b): Input voltage greater than 0.3V

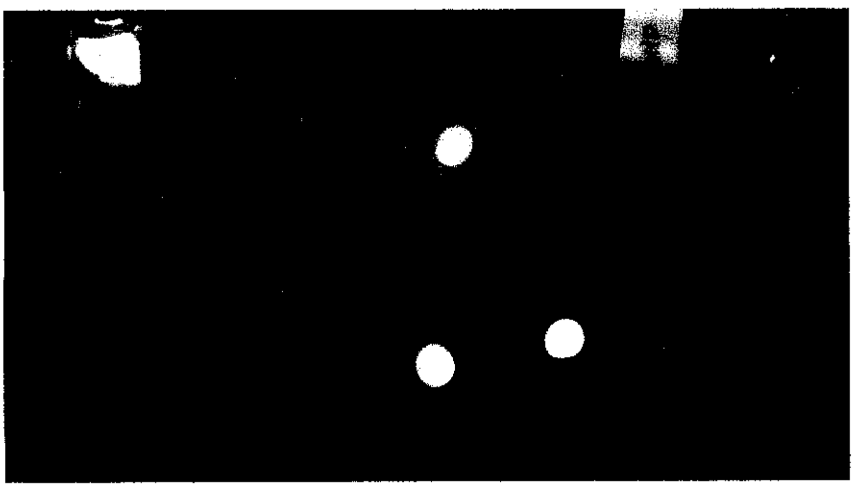


Figure 22 c): Input voltage between 0.3V and 0.4V

CHAPTER 5

RECOMMENDATION AND CONCLUSION

5.1 CONCLUSION

As chemical sensors used in pregnancy test kit are to be simpler and more widely available, we can expect to see a proliferation of uses in conjunction with electronics devices can enhance the performance of the equipments. The bio-medical engineering plays the vital role to develop the technologies in bio medical such as biosensor that integrated the biological parameters with electronic devices to produce same output but have some advantages. One of the big advantages of using the electronics sensor is reusable characteristics which is can minimize the cost of testing process for several times and save the budget for the long terms objectives.

5.2 RECOMMENDATION

There are several types of sensors that can used to measure pH of a solution as urine. This project recommended by using ISFET as the transducer to detect HCG and pH in the urine. The immunological precipitated deposited on the gate of an ISFET, the specific conductivity is even higher than surrounding buffer, caused by high concentration. ISFET is proposed to measuring the pH value of the urine of the pregnant woman. The cost of the pH sensor must be optimum as well as the sustainability.

REFERENCES

1. 1. Cortez Diagnostics, Inc. • 23961 Craftsman Rd., Suite D.Calabasas, California 91302 USA *" Home pregnancy Test Kit"*
2. http://www.babyhopes.com/pregnancytests.html
3. http://en.wikipedia.org/wiki/Human_urine
4. Lay-Harn Gam, Aishah Latiff " *SDS-PAGE Electrophoretic of Human Chorionic Gonadotropin (HCG) and it's β-subunit* " International Journal of Biological Sciences. 2005
5. S. Jacoby, A. T. Kicman, P. Laidler, and R. K. Iles *"Determination of the Glycoforms of Human Chorionic Gonadotropin {beta}-Core Fragment by Matrix-assisted Laser Desorption/Ionization Time-of-Flight Mass Spectrometry Clin. Chem*"., November 1, 2000; 46(11): 1796 - 1803.
6. E.T Powner and F. Yalcinkaya " *Intelligent Biosensor*" Volume 17. Number 2 1997 pp 107-116 - www.emaraldinsight.com
7. Jonathan Tucker, Keithley instruments, inc. *"Biosensor/transducer qualification: a critical step for homeland security*" March 2004.
8. Micheal J. Schoning " *'Playing around' with Field Effet Sensors on the Basis EIS Strucutres , LAPS and ISFETs*" Sensors 31 March 2005.
9. Wojciech Wroblewski *"Field effect transistors (FETs) as transducers in electrochemical sensors*" Chemical Sensor Research Group.
10. Joan F.Zilva, Peter R.Pannall and Philip D. Mayne " *Clinical Chemistry in Diagnosis and Treatment"* A Lloyd –Luke Pubilcation, fifth edition.
    Department of Medicine, College of Physicians and Surgeons Columbia University, New York, New York 10032.
11. Piet Bergveld, IEEE Trans on *"Bio- Med Eng, "* vol BME-19, No. 5 pp.342-351, Sept 1972. Gary R. Rechnitz, C & EN, pp.29-35, Jan, 1975.
12. Robert L. Boylestad Louis Nashelsky "Electronics *Devices and circuit Theory*" Eighth Edition, International Edition.

APPENDICES

APPENDIX I

pH-Tester "pHep"

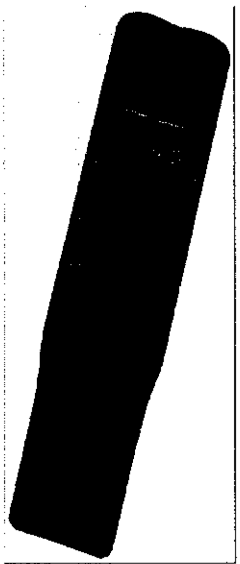
- pH Tester im ergonomischen Gehäuse mit großem Display
- pHep: Standardmodell, manuelle Zweipunktkalbrierung

technical specification

	pHep
Messbereich:	0,0 bis 14,0 pH
Auflösung:	0,1 pH
Genauigkeit:	±0,1 pH
Temperaturkompensation:	Keine
Umgebungsbedingungen:	0 bis 50°C
Batterien:	4x1,5V (mitgeliefert)
Batterielebensdauer:	ca. 1700h Betriebsstd
Abmessungen (mm):	175x41x23

Verpackungseinheit: 1 Stück

Typ	**Best.-Nr.**	**Stückpreis** *1+*
pHep 1685	**218-970**	**38,00**



pH tester

APPENDIX II

- **Short-Circuit Protection**
- **Offset-Voltage Null Capability**
- **Large Common-Mode and Differential Voltage Ranges**
- **No Frequency Compensation Required**
- **Low Power Consumption**
- **No Latch-Up**
- **Designed to Be Interchangeable With Fairchild µA741**

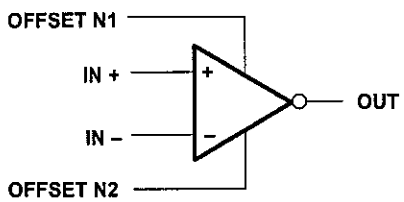
description

The µA741 is a general-purpose operational amplifier featuring offset-voltage null capability.

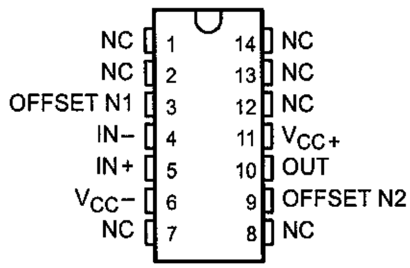
The high common-mode input voltage range and the absence of latch-up make the amplifier ideal for voltage-follower applications. The device is short-circuit protected and the internal frequency compensation ensures stability without external components. A low value potentiometer may be connected between the offset null inputs to null out the offset voltage as shown in Figure 2.

The µA741C is characterized for operation from 0°C to 70°C. The µA741I is characterized for operation from –40°C to 85°C.The µA741M is characterized for operation over the full military temperature range of –55°C to 125°C.

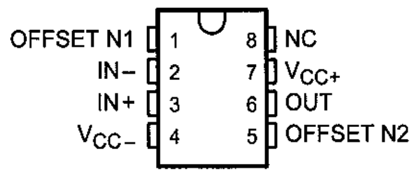
symbol



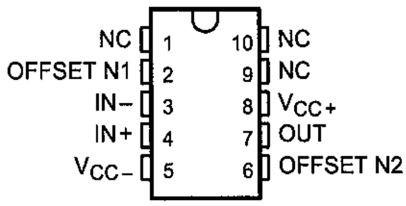
µA741M . . . J PACKAGE
(TOP VIEW)



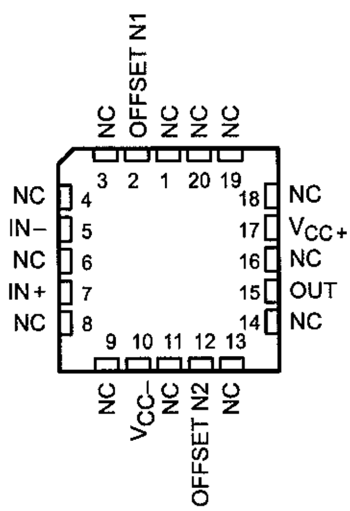
µA741M . . . JG PACKAGE
µA741C, µA741I . . . D, P, OR PW PACKAGE
(TOP VIEW)



µA741M . . . U PACKAGE
(TOP VIEW)



µA741M . . . FK PACKAGE
(TOP VIEW)



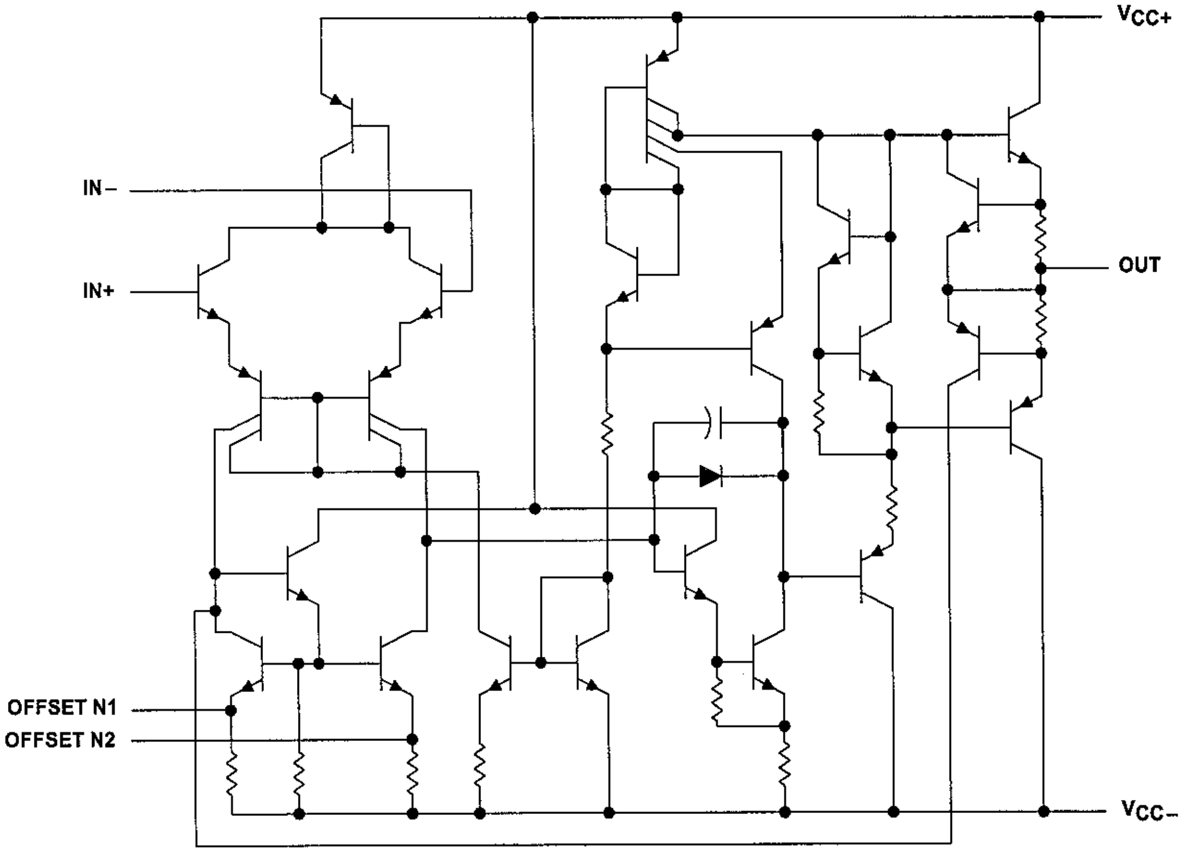
NC – No internal connection

AVAILABLE OPTIONS

T_A	PACKAGED DEVICES							CHIP FORM (Y)
	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	CERAMIC DIP (JG)	PLASTIC DIP (P)	TSSOP (PW)	FLAT PACK (U)	
0°C to 70°C	µA741CD				µA741CP	µA741CPW		µA741Y
40°C to 85°C	µA741ID				µA741IP			
55°C to 125°C		µA741MFK	µA741MJ	µA741MJG			µA741MU	

ɜ D package is available taped and reeled. Add the suffix R (e.g., µA741CDR).

›matic

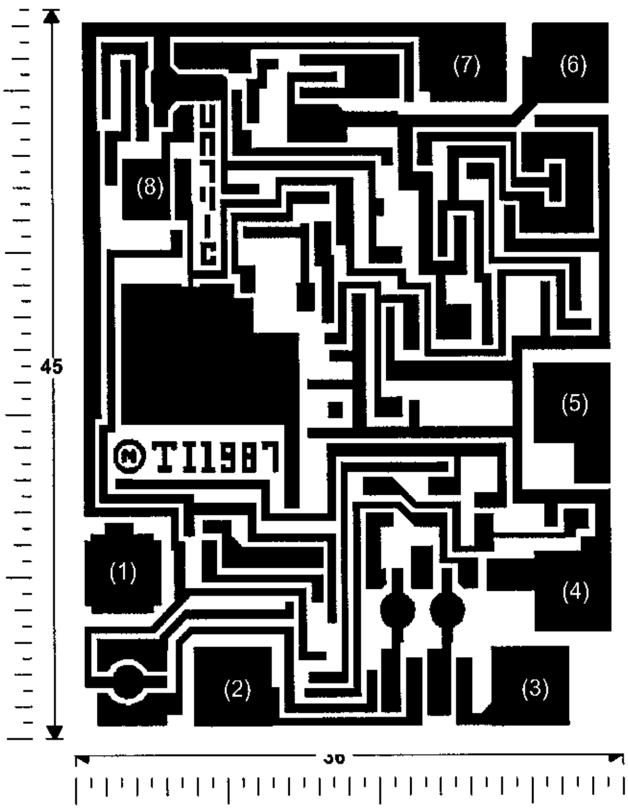


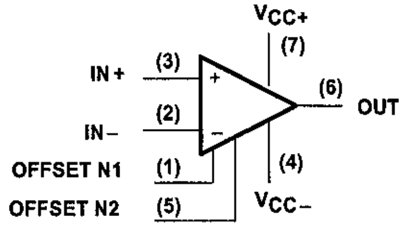
Component Count	
Transistors	22
Resistors	11
Diode	1
Capacitor	1

μA741Y chip information

This chip, when properly assembled, displays characteristics similar to the μA741C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.

BONDING PAD ASSIGNMENTS





CHIP THICKNESS: 15 TYPICAL

BONDING PADS: 4 × 4 MINIMUM

$T_J$max = 150°C.

TOLERANCES ARE ±10%.

ALL DIMENSIONS ARE IN MILS.

›lute maximum ratings over operating free-air temperature range (unless otherwise noted)†

		µA741C	µA741I	µA741M	UNIT
ly voltage, V_{CC+} (see Note 1)		18	22	22	V
ly voltage, V_{CC-} (see Note 1)		−18	−22	−22	V
ential input voltage, V_{ID} (see Note 2)		±15	±30	±30	V
voltage, V_I any input (see Notes 1 and 3)		±15	±15	±15	V
ge between offset null (either OFFSET N1 or OFFSET N2) and V_{CC-}		±15	±0.5	±0.5	V
:ion of output short circuit (see Note 4)		unlimited	unlimited	unlimited	
nuous total power dissipation		See Dissipation Rating Table			
ating free-air temperature range, T_A		0 to 70	−40 to 85	−55 to 125	°C
ge temperature range		−65 to 150	−65 to 150	−65 to 150	°C
temperature for 60 seconds	FK package			260	°C
temperature 1,6 mm (1/16 inch) from case for 60 seconds	J, JG, or U package			300	°C
temperature 1,6 mm (1/16 inch) from case for 10 seconds	D, P, or PW package	260	260		°C

ɜses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and tional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not ed. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

S: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC+} and V_{CC-}.
2. Differential voltages are at IN+ with respect to IN−.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
4. The output may be shorted to ground or either power supply. For the µA741M only, the unlimited duration of the short circuit applies at (or below) 125°C case temperature or 75°C free-air temperature.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	500 mW	5.8 mW/°C	64°C	464 mW	377 mW	N/A
FK	500 mW	11.0 mW/°C	105°C	500 mW	500 mW	275 mW
J	500 mW	11.0 mW/°C	105°C	500 mW	500 mW	275 mW
JG	500 mW	8.4 mW/°C	90°C	500 mW	500 mW	210 mW
P	500 mW	N/A	N/A	500 mW	500 mW	N/A
PW	525 mW	4.2 mW/°C	25°C	336 mW	N/A	N/A
U	500 mW	5.4 mW/°C	57°C	432 mW	351 mW	135 mW

electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ±15 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	μA741C MIN	μA741C TYP	μA741C MAX	μA741I, μA741M MIN	μA741I, μA741M TYP	μA741I, μA741M MAX	UNIT
V_{IO}	Input offset voltage	V_O = 0	25°C		1	6		1	5	mV
			Full range			7.5			6	
$\Delta V_{IO(adj)}$	Offset voltage adjust range	V_O = 0	25°C		±15			±15		mV
I_{IO}	Input offset current	V_O = 0	25°C		20	200		20	200	nA
			Full range			300			500	
I_{IB}	Input bias current	V_O = 0	25°C		80	500		80	500	nA
			Full range			800			1500	
V_{ICR}	Common-mode input voltage range		25°C	±12	±13		±12	±13		V
			Full range	±12			±12			
V_{OM}	Maximum peak output voltage swing	R_L = 10 kΩ	25°C	±12	±14		±12	±14		V
		R_L ≥ 10 kΩ	Full range	±12			±12			
		R_L = 2 kΩ	25°C	±10	±13		±10	±13		
		R_L ≥ 2 kΩ	Full range	±10			±10			
A_{VD}	Large-signal differential voltage amplification	R_L ≥ 2 kΩ	25°C	20	200		50	200		V/mV
		V_O = ±10 V	Full range	15			25			
r_i	Input resistance		25°C	0.3	2		0.3	2		MΩ
r_o	Output resistance	V_O = 0, See Note 5	25°C		75			75		Ω
C_i	Input capacitance		25°C		1.4			1.4		pF
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}min$	25°C	70	90		70	90		dB
			Full range	70			70			
k_{SVS}	Supply voltage sensitivity ($\Delta V_{IO}/\Delta V_{CC}$)	V_{CC} = ±9 V to ±15 V	25°C		30	150		30	150	μV/V
			Full range			150			150	
I_{OS}	Short-circuit output current		25°C		±25	±40		±25	±40	mA
I_{CC}	Supply current	V_O = 0, No load	25°C		1.7	2.8		1.7	2.8	mA
			Full range			3.3			3.3	
P_D	Total power dissipation	V_O = 0, No load	25°C		50	85		50	85	mW
			Full range			100			100	

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for the μA741C is 0°C to 70°C, the μA741I is –40°C to 85°C, and the μA741M is –55°C to 125°C.

NOTE 5: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

operating characteristics, $V_{CC\pm}$ = ±15 V, T_A = 25°C

PARAMETER		TEST CONDITIONS		μA741C MIN	μA741C TYP	μA741C MAX	μA741I, μA741M MIN	μA741I, μA741M TYP	μA741I, μA741M MAX	UNIT
t_r	Rise time	V_I = 20 mV,	R_L = 2 kΩ,		0.3			0.3		μs
	Overshoot factor	C_L = 100 pF,	See Figure 1		5%			5%		
SR	Slew rate at unity gain	V_I = 10 V, C_L = 100 pF,	R_L = 2 kΩ, See Figure 1		0.5			0.5		V/μs

trical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V, T_A = 25°C (unless rwise noted)

	PARAMETER	TEST CONDITIONS	µA741Y MIN	µA741Y TYP	µA741Y MAX	UNIT
	Input offset voltage	$V_O = 0$		1	6	mV
(adj)	Offset voltage adjust range	$V_O = 0$		±15		mV
	Input offset current	$V_O = 0$		20	200	nA
	Input bias current	$V_O = 0$		80	500	nA
	Common-mode input voltage range		±12	±13		V
	Maximum peak output voltage swing	R_L = 10 kΩ	±12	±14		V
		R_L = 2 kΩ	±10	±13		
	Large-signal differential voltage amplification	$R_L \geq 2$ kΩ	20	200		V/mV
	Input resistance		0.3	2		MΩ
	Output resistance	$V_O = 0$, See Note 5		75		Ω
	Input capacitance			1.4		pF
R	Common-mode rejection ratio	$V_{IC} = V_{ICR}min$	70	90		dB
;	Supply voltage sensitivity ($\Delta V_{IO}/\Delta V_{CC}$)	$V_{CC} = \pm 9$ V to ±15 V		30	150	µV/V
	Short-circuit output current			±25	±40	mA
	Supply current	$V_O = 0$, No load		1.7	2.8	mA
	Total power dissipation	$V_O = 0$, No load		50	85	mW

haracteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified.
5: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

rating characteristics, $V_{CC}\pm = \pm 15$ V, T_A = 25°C

PARAMETER	TEST CONDITIONS	µA741Y MIN	µA741Y TYP	µA741Y MAX	UNIT
Rise time	V_I = 20 mV, R_L = 2 kΩ,		0.3		µs
Overshoot factor	C_L = 100 pF, See Figure 1		5%		
Slew rate at unity gain	V_I = 10 V, R_L = 2 kΩ, C_L = 100 pF, See Figure 1		0.5		V/µs

PARAMETER MEASUREMENT INFORMATION

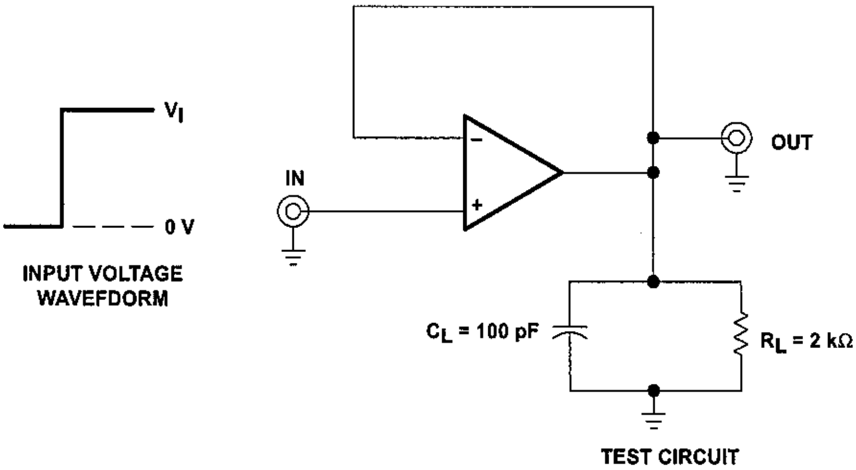


Figure 1. Rise Time, Overshoot, and Slew Rate

APPLICATION INFORMATION

Figure 2 shows a diagram for an input offset voltage null circuit.

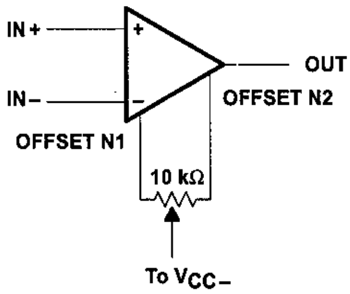


Figure 2. Input Offset Voltage Null Circuit

TYPICAL CHARACTERISTICS†

INPUT OFFSET CURRENT vs FREE-AIR TEMPERATURE

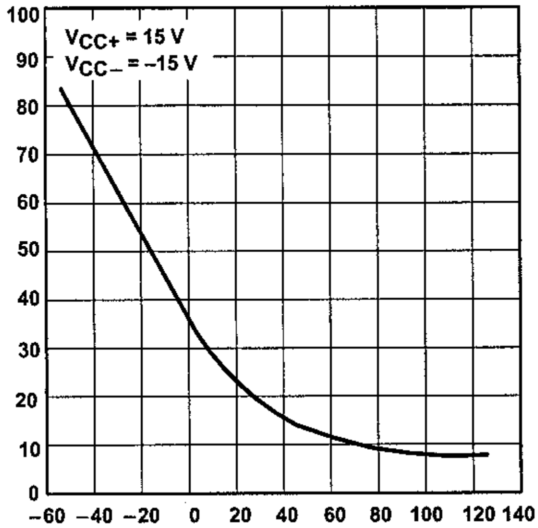


Figure 3

INPUT BIAS CURRENT vs FREE-AIR TEMPERATURE

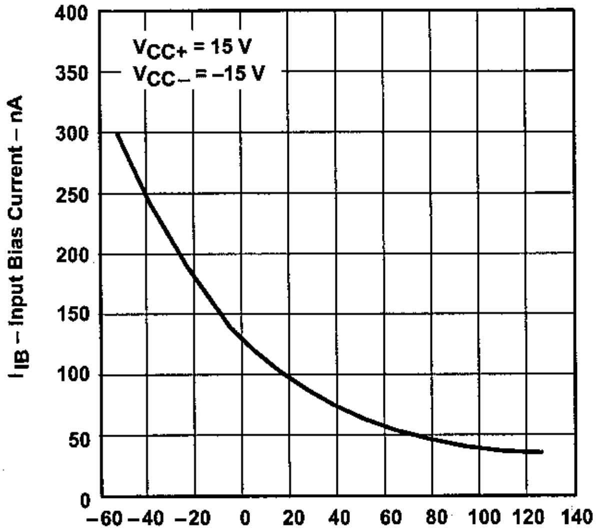


Figure 4

MAXIMUM PEAK OUTPUT VOLTAGE vs LOAD RESISTANCE

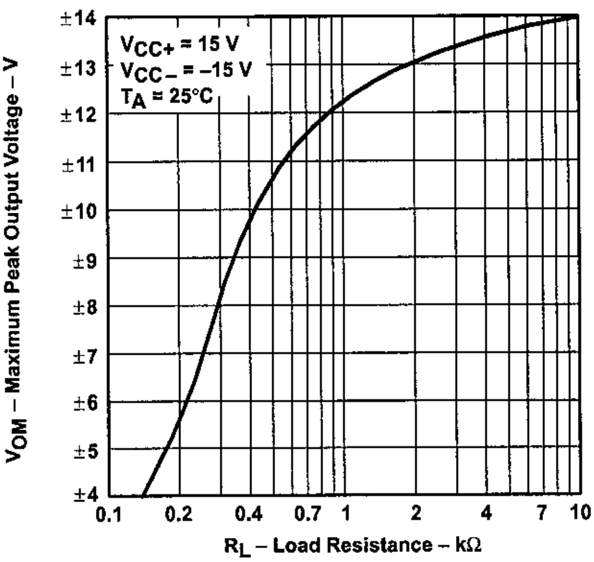


Figure 5

ta at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

MAXIMUM PEAK OUTPUT VOLTAGE
vs
FREQUENCY

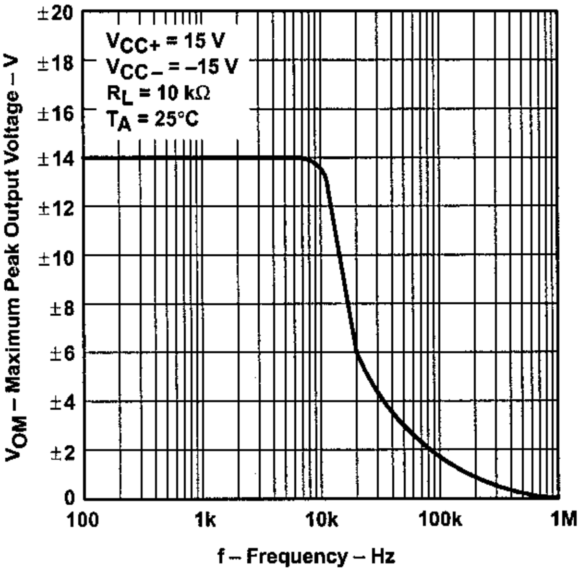


Figure 6

OPEN-LOOP SIGNAL DIFFERENTIAL
VOLTAGE AMPLIFICATION
vs
SUPPLY VOLTAGE

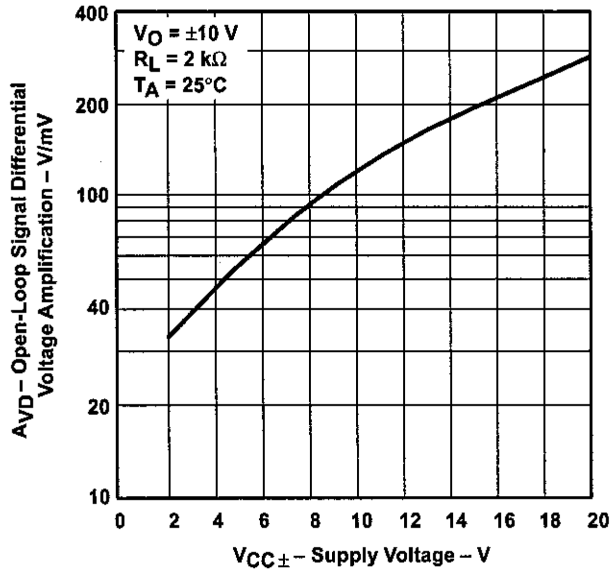
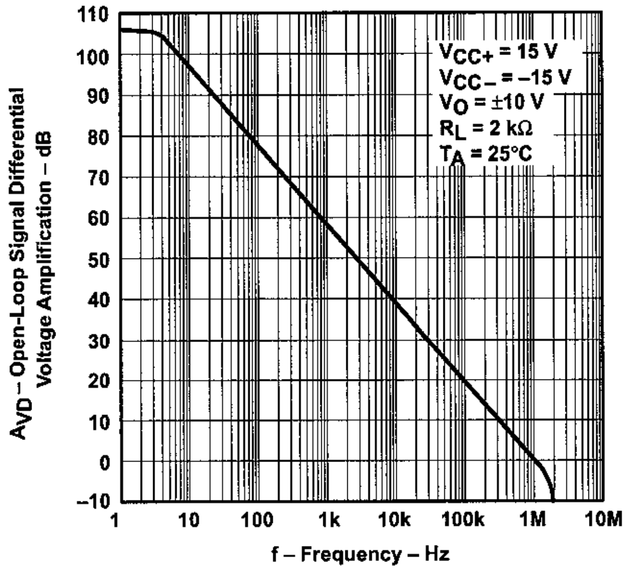


Figure 7

OPEN-LOOP LARGE-SIGNAL DIFFERENTIAL
VOLTAGE AMPLIFICATION
vs
FREQUENCY



TYPICAL CHARACTERISTICS

COMMON-MODE REJECTION RATIO
vs
FREQUENCY

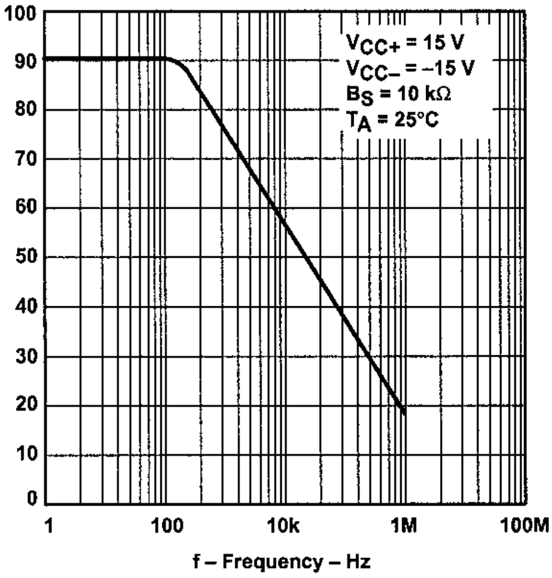


Figure 8

OUTPUT VOLTAGE
vs
ELAPSED TIME

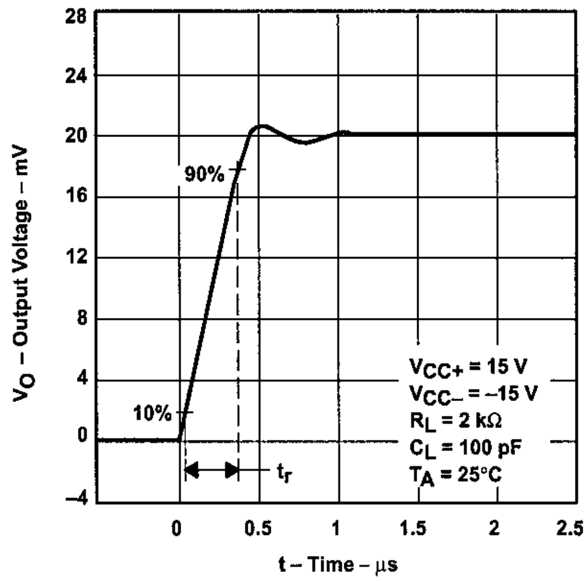


Figure 9

VOLTAGE-FOLLOWER
LARGE-SIGNAL PULSE RESPONSE

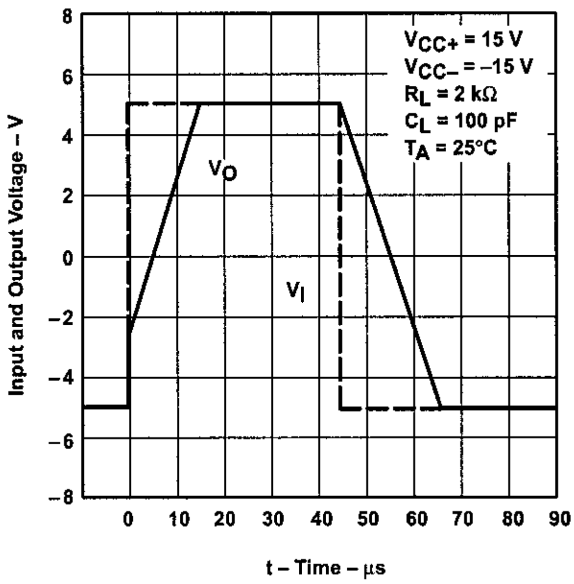


Figure 10

APPENDIX III

FAIRCHILD
SEMICONDUCTOR ™

March 1998

DM7408
Quad 2-Input AND Gates

General Description

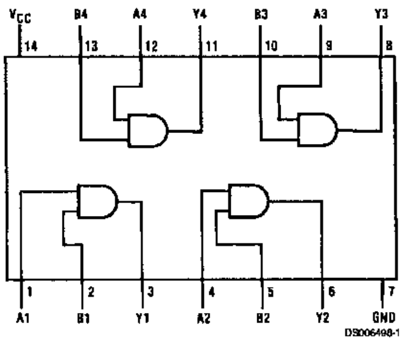
This device contains four independent gates each of which performs the logic AND function.

Features

- Alternate Military/Aerospace device (5408) is available. Contact a Fairchild Semiconductor Sales Office/Distributor for specifications.

Connection Diagram

Dual-In-Line Package



Order Number 5408DMQB, 5408FMQB, DM5408J, DM5408W or DM7408N
See Package Number J14A, N14A or W14B

Function Table

Y = AB

Inputs		Output
A	B	Y
L	L	L
L	H	L
H	L	L
H	H	H

H = High Logic Level
L = Low Logic Level

Absolute Maximum Ratings (Note 1)

Supply Voltage	7V
Input Voltage	5.5V
Operating Free Air Temperature Range	
DM54 and 54	−55°C to +125°C
DM74	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Recommended Operating Conditions

Symbol	Parameter	DM5408			DM7408			Units
		Min	Nom	Max	Min	Nom	Max	
V_{CC}	Supply Voltage	4.5	5	5.5	4.75	5	5.25	V
V_{IH}	High Level Input Voltage	2			2			V
V_{IL}	Low Level Input Voltage			0.8			0.8	V
I_{OH}	High Level Output Current			−0.8			−0.8	mA
I_{OL}	Low Level Output Current			16			16	mA
T_A	Free Air Operating Temperature	−55		125	0		70	°C

Note 1: *The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the "Electrical Characteristics" table are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.*

Electrical Characteristics

over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions		Min	Typ (Note 2)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −12 mA				−1.5	V
V_{OH}	High Level Output Voltage	V_{CC} = Min, I_{OH} = Max, V_{IL} = Max		2.4	3.4		V
V_{OL}	Low Level Output Voltage	V_{CC} = Min, I_{OL} = Max, V_{IH} = Min			0.2	0.4	V
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 5.5V				1	mA
I_{IH}	High Level Input Current	V_{CC} = Max, V_I = 2.4V				40	μA
I_{IL}	Low Level Input Current	V_{CC} = Max, V_I = 0.4V				−1.6	mA
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 3)	DM54	−20		−55	mA
			DM74	−18		−55	
I_{CCH}	Supply Current with Outputs High	V_{CC} = Max			11	21	mA
I_{CCL}	Supply Current with Outputs Low	V_{CC} = Max			20	33	mA

Switching Characteristics

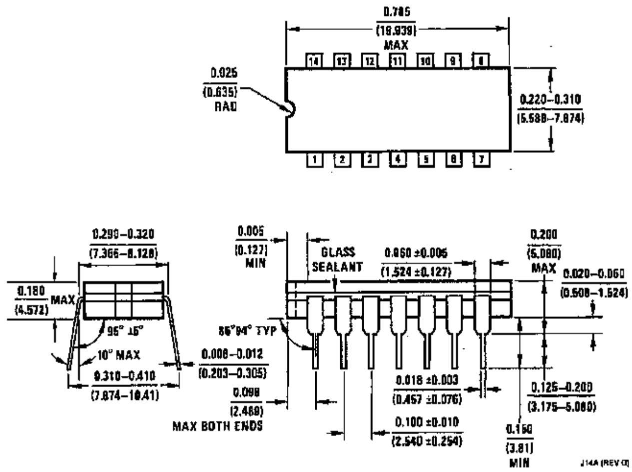
at V_{CC} = 5V and T_A = 25°C (See Section 1 for Test Waveforms and Output Load)

Symbol	Parameter	Conditions	Min	Max	Units
t_{PLH}	Propagation Delay Time Low to High Level Output	C_L = 15 pF, R_L = 400Ω		27	ns
t_{PHL}	Propagation Delay Time High to Low Level Output			19	ns

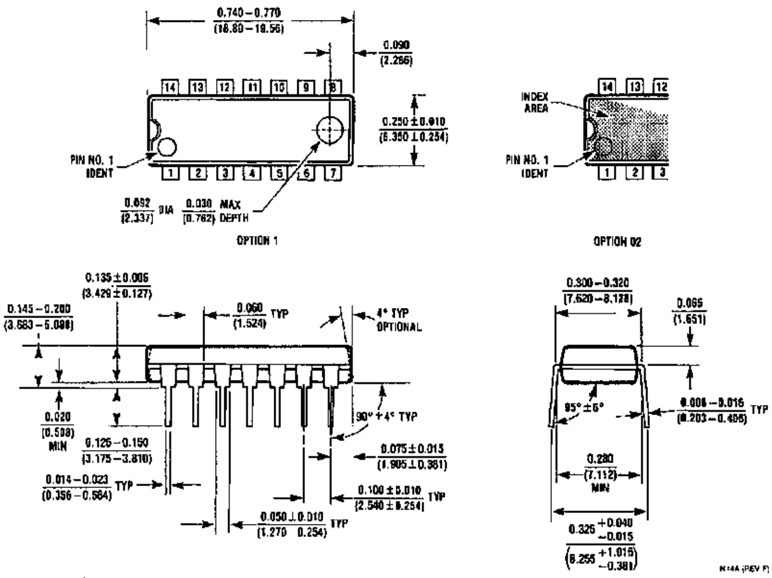
Note 2: All typicals are at V_{CC} = 5V, T_A = 25°C.

Note 3: Not more than one output should be shorted at a time.

Physical Dimensions inches (millimeters) unless otherwise noted

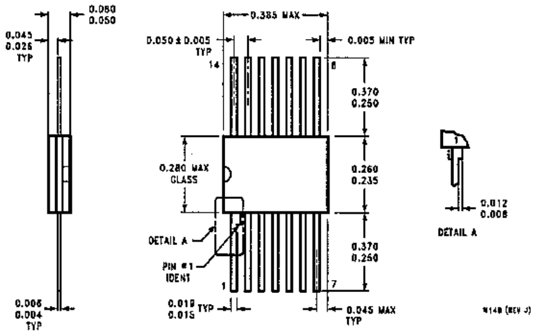


14-Lead Ceramic Dual-In-Line Package (J)
Order Number 5408DMQB or DM5408J
Package Number J14A



14-Lead Molded Dual-In-Line Package (N)
Order Number DM7408N
Package Number N14A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



14-Lead Ceramic Flat Package (W)
Order Number 5408FMQB or DM5408W
Package Number W14B

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