GAS LEAKAGE DETECTION SYSTEM USING INFRARED RADIATION

By

FITRIAH BINTI SHAFE'I

FINAL PROJECT REPORT

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

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

GAS LEAKAGE DETECTION SYSTEM USING INFRARED RADIATION

by

Fitriah Binti Shafe'i

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Approved:

Dr Mumtaj Begam
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2007

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.

Fitriah Binti Shafe'i

ABSTRACT

The main objective of this project is to build a model for detecting gas using Infrared radiation (IR), applicable for detecting gas leakage for home and industry usage. It is always essential to have a reliable and practical gas leakage detection system for safety purpose especially at home and industry. This project will focus on Liquefied Petroleum Gas (LPG) detection. The method used to detect gas is by measuring IR intensity at the source as well as the detector. The IR intensity at detector is less than at the source since the gas absorbs IR radiation. Student tries to use two IR radiation sources for this project, which are the transmitter circuit and incandescent lamp. However, transmitter circuit is not functioned as expected and incandescent lamp is used to transmit IR radiation. Researches done for this project are understand about IR and LPG characteristics, search, construct and test the circuits used and understand how it works, construct a chamber for project model as well as doing experiment for proving the theory. As a conclusion, this project has exposed to new knowledge of LPG and IR applications besides introducing a cheap and simple concept of gas leakage detection, making it a reliable and practical system to be implemented.

ACKNOWLEDGEMENTS

All praise be to Allah, Lord of the worlds, who, through His mercy and grace, has revealed some of His knowledge to me in finishing this project. Verily all good are from Allah and all shortcomings are due to my own weaknesses.

The successful completion of this project has been made possible through the help and support of many individuals. First and foremost I would like to extend deepest appreciation to my project supervisor, Dr. Mumtaj Begam, who has graciously accepted me as her Final Year Project student, without which this project would not be possible in the first place. Her attention and assistance have encouraged me to put extra effort in finishing this project. Special thanks and mention is due to my co-supervisor, Dr.John Ojur Dennis whose endlessly support and guidance had helped me a great deal. His comments and advices have enabled me to realize the objectives of this project.

My thanks and appreciation also goes to all the technicians, especially Puan Hawa who always be there to help me during project execution. A big thanks for your advice and guidance too. Finally, I would like to show my gratitude to all my friends who always help and support me throughout this project. The associations I've made during this project will truly be memorable for years to come.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Due to the fact that most gases such as CO_2, CO, NO and all carbon hydrogen (HC) are able to absorb infrared (IR) light at certain wavelength, this gas leakage detection system uses IR radiation to detect presence of certain gaseous [1]. This theory can be manipulated to solve gas leakage problem at home. This project, however, is an initial state in introducing gas leakage detection using IR radiation. The main objective of this project is to build a model for detecting gas using Infrared radiation (IR), applicable for detecting gas leakage for home and industry usage. The method used is by measuring and comparing IR intensity at both source and detector. This project will focus on Liquefied Petroleum Gas (LPG) leakage at home as well as in industry. LPG is an energy source primarily composed of propane and butane [2]. For future improvement, a circuit consist of an alarm is recommended to be attached to the model which is activated in the presence of LPG. It is use to warn the user about gas leakage either in home or in industry.

1.2 Problem Statement

1.2.1 Problem Identification

Nowadays, gas leakage incidents happen almost every day and there is a need to have practical and reliable gas leakage detection system especially at home. As LPG is hardly detectable due to its properties which are colourless and odourless, this project will implement a gas detector which shall detect LPG [2].

1.2.2 Significance of Project

Since LPG is odourless and colourless, it cannot be seen by our naked eye and detected by smell. LPG leakage can be very dangerous because it increases the risk of fire and explosion. There will be difference in IR intensity at the source and detector in the presence of LPG in which IR intensity at detector is less than at the source. Expose to low levels of LPG is not harmful to our health. If the gas leakage is severe, the amount of oxygen available for breathing could be drastically reduced, which will lead to asphyxia. Symptoms of asphyxia are;

- Dizziness
- Fatigue
- Nausea
- Headache
- Irregular breathing

1.3 Objectives and Scope of Study

1.3.1 Objectives

Following are the objectives of this project;

1. To come out with a low-cost and practical gas leakage detection system
2. To construct prototype/ model for gas leakage detection
3. To construct a gas chamber
4. To test the designed system in the presence of gas in order to evaluate its practicability.

1.3.2 Scope of Study

This project requires studying LPG and infrared (IR) characteristics, such as wavelength/frequency at which LPG absorbs IR, IR sources, which are transmitter circuit and incandescent lamp, the detector circuits besides deep understanding on how these circuits work to transmit and detect gas. It also requires knowledge and concepts such as LPG and IR technology and its applications to solve gas leakage detection problem. In constructing and testing the circuits, some errors might happen and troubleshooting process is required to overcome the problem.

CHAPTER 2
LITERATURE REVIEW AND/OR THEORY

2.1 Gas detection Principle by Infrared (IR) Absorption

A large number of materials absorb infrared radiation due to intermolecular vibrations. The IR light is capable to excite higher energy levels (excited states) of the molecule (rotational or vibrational excitation) by coupling to the dipole moment of the heteroatomic assembly. Heat energy from IR radiation transferred into gas and heats up. As a result, intensity of the beam of the light passes though a gas volume diminishes [1]. For any specific material, the strength of absorption varies with the wavelength of the impinging radiation (the absorption spectrum). The absorption spectrum is different for different materials [8]. Figure 1 shows the absorption spectra for a number of typical materials. LPG (Propane) absorbs IR at wavelength of **3.3μm** to **3.5μm.**

Respective equipments capable of this task consist of IR source, a measurement volume in which gas to be detected is confined, an element which allows picking out the desired wavelength region as well as a detector that measures the radiation intensity [1]. In this project, incandescent lamp is used to transmit desired IR frequency for detecting LPG. The thermopile detector circuit works as detector for both IR sources. A chamber, equipped with either circuit or incandescent lamp and gas source, allows the desired IR radiation to be absorbed by LPG, thus enables measuring IR radiation intensity.

Dealing with IR frequency is much easier compared to IR wavelength, especially when calculation is involved. Using Equation 1, frequency of desired IR wavelength can be obtained;

$c = \lambda f$ .... (Equation 1)

where c = speed of light (3.0 x10^8)m/s ; λ = IR wavelength (m) ; f = IR frequency (Hz)

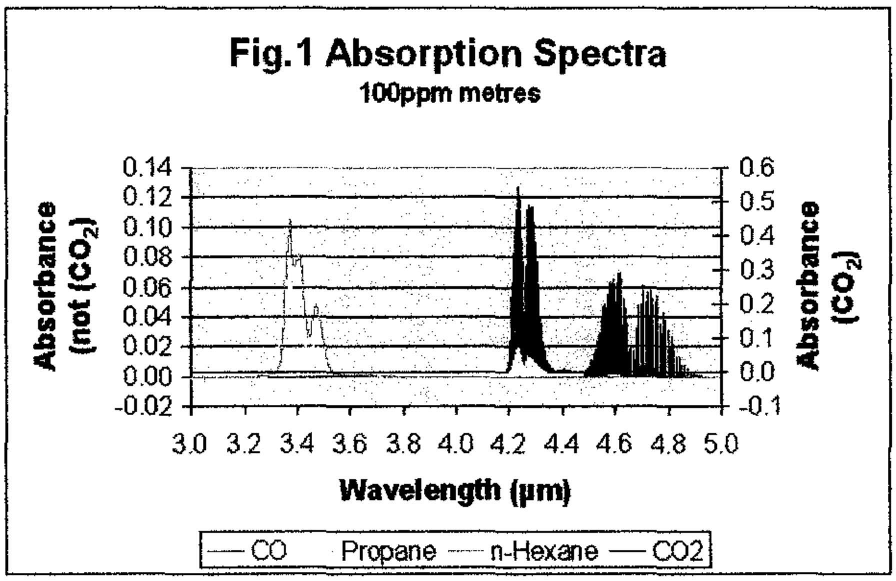


Figure 1: Absorbance of infrared radiation (absorption spectra) [8].

It is known that from Figure 1, CO_2 is the reference gas. It is well understood that the intensity of IR will be reduced in the presence of certain gases that can absorbed IR of certain wavelength.

The reduction of intensity of the radiation is equal to the amount of radiation absorbed by the gas. However, since the output in the present case is in the form of voltage, the relation of the input and output voltage corresponding to the intensity of the IR wavelength, given by Equation 2 below. The IR intensity at the detector, $\mathbf{I}_{Rx}$ is corresponding to output voltage after gas been released into the chamber and $\mathbf{I}_{Tx}$ is corresponding to Vi value, which is the output voltage before the gas been released into the chamber.

$\mathbf{V_O/V_i = I_{Rx} / I_{Tx}}$ .... (Equation 2) [1].

where $\mathbf{I}_{Rx}$ is the IR intensity in the detector and $\mathbf{I}_{Tx}$, is the transmitted IR intensity.

2.2 Infrared (IR) Radiation

Infrared (IR) radiation is electromagnetic radiation of wavelength longer than that of visible light, but shorter than that of radio waves. The name means "below red" (from the Latin *infra*, "below"), red being the color of visible light of longest wavelength. Infrared radiation spans three orders of magnitude and has wavelengths between approximately 750 nm and 1 mm [5]. Infrared light lies between the visible and microwave portions of the electromagnetic spectrum. Infrared light has range of wavelengths, just like visible light, which has wavelengths ranging from red to violet. "Near infrared" light is closest in wavelength to visible light and "far infrared" is closer to the microwave region of the electromagnetic spectrum. The longer, far infrared wavelengths are about the size of a pin head and the shorter, near infrared ones have the size of cells, or are microscopic [6].

Figure 2 shows IR electromagnetic spectrum in which, IR wavelength falls in a range between 10^{-5} to 10^{-2} cm. There are three IR regions of electromagnetic spectrum, which are far, mid and near, as shown in Figure 3.

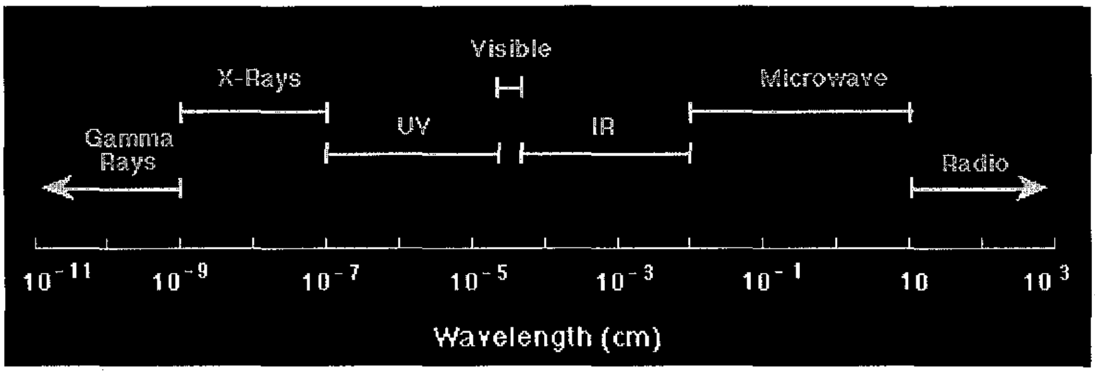


Figure 2: IR Electromagnetic spectrum [7].

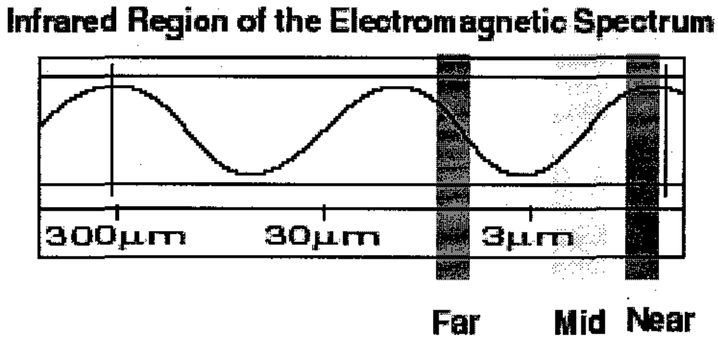


Figure 3: IR Region of electromagnetic spectrum [7].

2.3 Liquefied Petroleum Gas (LPG)

Liquefied Petroleum Gas (LPG) is a mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles, and increasingly replacing chlorofluorocarbons as an aerosol propellant and a refrigerant to reduce damage to the ozone layer.

LPG is the generic name for a number of low-pressure, liquefied hydrocarbon gases. LPG are hydrocarbon products in the C3-C4 range, propane (C_3H_8) and butane (C_4H_{10}) constituting the components. These products, gaseous at normal temperature and pressure conditions, can be very easily liquefied under low pressure and therefore can be handled very easily. It is not toxic, nevertheless, precautions should be taken in order to avoid long term exposure [3].It is the gas that is commonly used for cooking and heating at home and also in plant/ industry. They are readily liquefied by pressurizing at atmospheric temperatures and are used in the vapor phase as a fuel with air or oxygen [4]. The characteristics of LPG are:

- Colourless.
- Odourless. (It's normal to odorise LPG by adding an odorant prior to supply to the user, to aid the detection of any leaks).
- Flammable.
- Heavier than air.
- Approximately half the weight of water.
- Non toxic but can cause asphyxiation.

- LPG expands upon release and 1 litre of liquid will form approximately 250 litres of vapour.

(See Appendix A for properties of LPG-Propane and Butane)

2.4 Thermopile Detector

Thermopile is an electronic device that converts thermal energy into electrical energy. It is composed of thermocouples either connected in series or in parallel. Thermopiles are used in situations where a single thermocouple generates insufficient output. Based on various features suitable top realize the objectives of this project, TPS 534-Thermopile Detector from PerkinElmer Optoelectronic is selected, as shown I Figure 4. The features include;

- Large absorber size, suitable for high signal output
- Low temperature coefficient of sensitivity
- Include Thermistor temperature reference
- Appropriate for Pyrometers application, equipped with Bandpass filter, in gas detector.

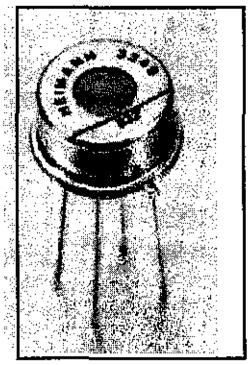


Figure 4: TPS 534- Thermopile detector.

2.5 Incandescent Lamp

The incandescent light bulb or incandescent lamp is a source of artificial light that works by incandescence. An electrical current passes through a thin filament, heating it and causing it to become excited, releasing thermally equilibrated photons in the process. The enclosing glass bulb prevents the oxygen in air from reaching the hot filament, which otherwise would be destroyed rapidly by oxidation. Heat emitted by this lamp is also the IR radiation. For this project, incandescent lamp is used as IR radiation source as shown in Figure 5.

Figure 5: An incandescent light bulb

2.6 Operational Amplifier (OpAmp)

Basically, the Op-Amp is nothing more than a differential amplifier which amplifies the difference between two inputs. One input has a positive effect on the output signal, whereas the other input has a negative effect on the output [9]. In its ordinary usage, the output of the Op-Amp is controlled by negative feedback which, because of the amplifier's high gain, almost completely determines the output voltage for any given input [10]. Figure 6 and 7 below shows schematic symbol for an op amp as well as circuit model of an operational amplifier (Op Amp) with gain A and input and output resistances R in and R out. In this project, two types of Op-Amps are used for the detector circuits, which are the standard LM714 Op-Amp and low noise Op-Amp.

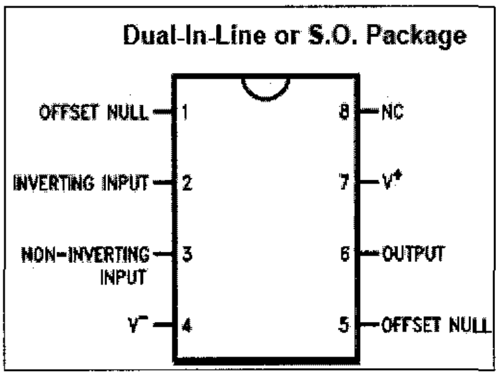


Figure 6: Connection diagram of LM741 OpAmp

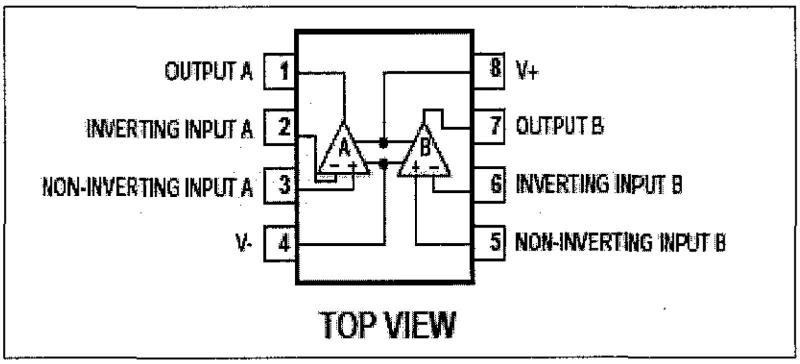


Figure 7: Pin configuration of NE5532A low noise OpAmp

2.7 555 Timer

555 Timer is used to generate frequency value of infrared (IR) transmission, which enables IR been absorbed by LPG. The connection and circuit diagram of 555 Timer is shown in Figure 8 below. Using Timer equation below, the desired frequency for IR transmission is obtained.

f = 1.44/ (R1 + 2R2) C ....Equation 4. [11]

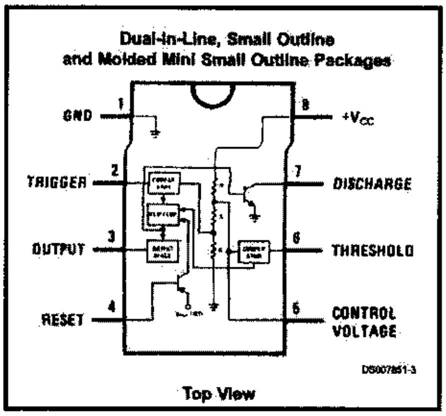


Figure 8: Connection and circuit diagram of 555 Timer [2].

2.8 Explosive Range

This includes all concentrations (measured as a percent of volume in air) of a flammable gas or vapor that will propagate flame when exposed to a source of ignition. Many common flammable liquids have very wide explosive ranges. The explosive range of all flammable gases and vapors will vary with temperature and pressure.

2.8.1 Lower Explosive Limit (LEL)

LEL is the lowest amount of gas that can explode. This is the minimum concentration of a flammable gas or vapor that will propagate flame when exposed to a source of ignition. Commonly abbreviated LEL or LFL, a mixture below this concentration level is considered too "lean" to burn. Above LEL, explosion can occur.

CHAPTER 3
METHODOLOGY/ PROJECT WORK

3.1 Procedure Identification

The step by step sequential procedure to be followed throughout this project is given below;

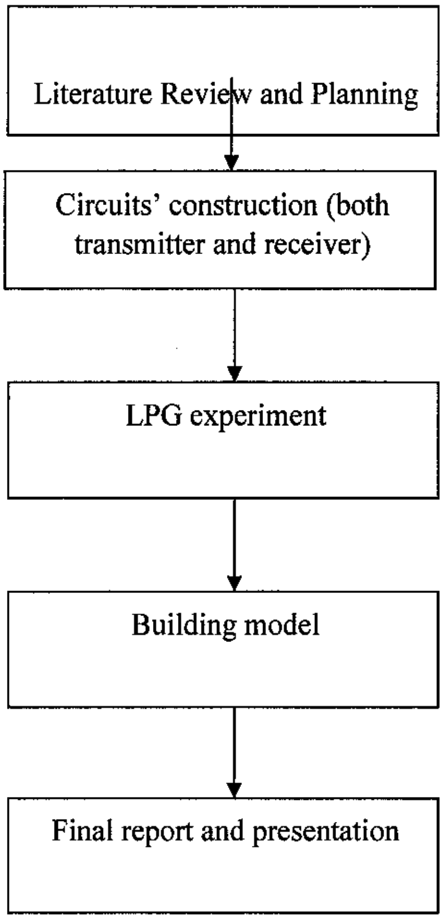


Figure 9: Project procedure

3.1.1 Literature Review and Planning

To start with, detailed research to be done first to gain sufficient information in order to understand the topic. After getting the idea, planning is needed to schedule the tasks and works to be completed throughout this project. Planning is necessary for tracking progress of the project. Research has been done on LPG and IR properties, found the most suitable IR transmitter and detector circuits to be used, to check for the availability of components, to set up equipments for testing IR absorption by LPG and to construct the final prototype for this project.

3.1.2 Circuits' Construction

Study of circuit examples from previous projects as well as solutions available in the market needs to be done before choosing the most appropriate IR circuit to be used for this project. After deciding the suitable IR circuits to be used, it is then constructed and tested before being used to conduct gas detection experiment.

3.1.2.1 Transmitter Circuit

Transmitter circuit is one of the IR radiation source for this project. A circuit has been designed to transmit desired IR frequency for gas absorption. This circuit is designed from 555 timer circuit, as shown in Figure 10 below.

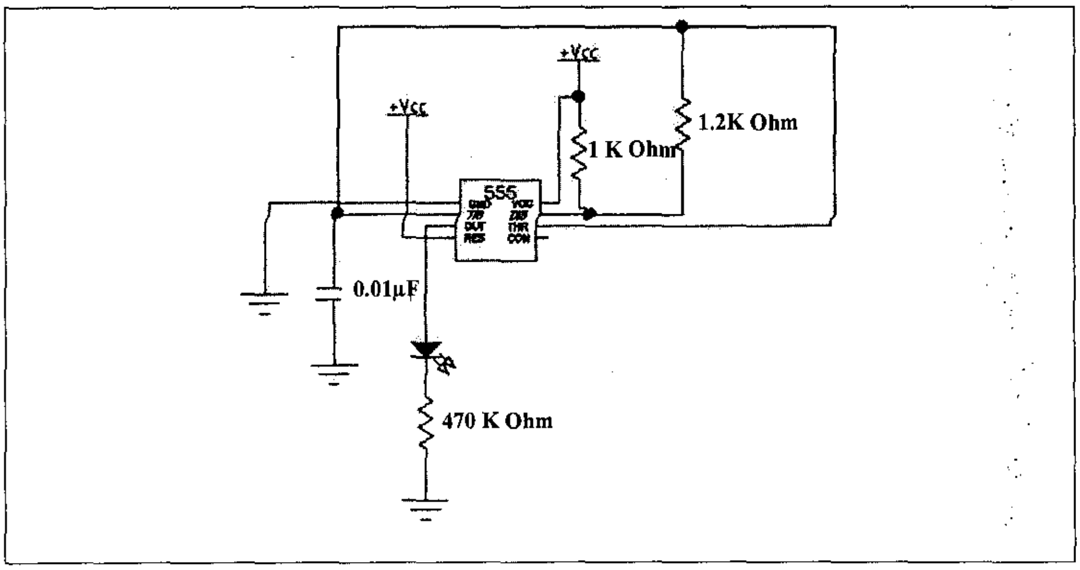


Figure 10: 555 timer circuit

This circuit will produce 38 kHz frequency using 555 timer. The frequency value generated is determined using the Equation 4.

f (calculated) = 1.44/ (1k + (2)1.2k)

= **42.35 kHz**

f (measured) = **41.67 kHz**

From theory, we know that for IR to be absorbed by LPG, the IR wavelength must be between 3.3 μm to 3.5 μm. Using Equation 1, it is corresponding to 85.7 THz to 90.9 THz frequency.

f (min) = 3.0×10^8 / 3.3 μm = **90.9 THz**

f (max)= 3.0×10^8 / 3.5 μm = **85.7 THz**.

For that reason, a circuit been designed by modifying 555 timer circuit to transmit IR of frequency between 85.7THz to 90.9 THz. Using Timer equation, **(Equation 4)**, the frequency value is increased by reducing the resistor and the capacitor value.

Using resistor and capacitor values of 0.22Ω and 1pF respectively, few calculations have been done to increase the frequency value of IR transmission. Three alternatives have been figured out to modify the existing circuit in order to get the required frequency value.

<u>Alternative 1:</u>

f = 1.44/ (R1 + 2R2) C;

R_1 = 3 resistors of 0.22 ohm connected in parallel

R_2 = 8 resistors of 0.22 ohm connected in parallel

C = 8 capacitors of 1 pF connected is series

} 19 resistors and 8 capacitors are used

f (calculated) = **89.79 THz**

Alternative 2:

f = 1.44/ (R1 + 2R2) C;

R_1 = 4 resistors of 0.22 ohm connected in parallel

R_2 = 6 resistors of 0.22 ohm connected in parallel

C = 8 capacitors of 1 pF connected is series

f (calculated) = **89.76 THz**

} 16 resistors and 8 capacitors are used

Alternative 3:

f = 1.44/ (R1 + 2R2) C;

R_1 = 5 resistors of 0.22 ohm connected in parallel

R_2 = 5 resistors of 0.22 ohm connected in parallel

C = 8 capacitors of 1 pF connected is series

f (calculated) = **87.27 THz**

} 15 resistors and 8 capacitors are used

From the 3 solutions, **Alternative 3** is chosen since it uses minimum number of components. Besides, less number of resistors used will reduce losses in the circuit. Simulation is done to test the designed circuit, as shown in Figure 11 below. The constructed circuit of this transmitter circuit is shown in Appendix B.

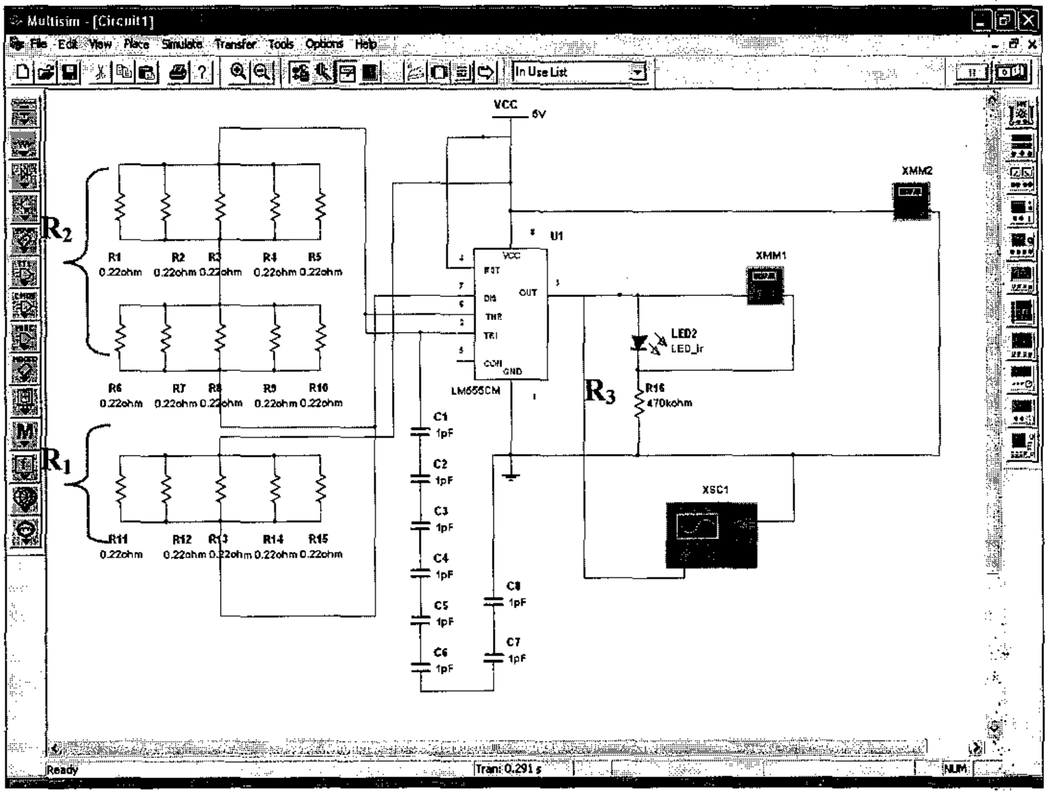


Figure 11: Designed IR transmitter circuit (Alternative 3), simulation based

To check the functionality of this circuit, simulation for the 555 timer circuit has been done to see the minimum voltage required for IR LED to transmit desire frequency value. From the simulation, the minimum required voltage across IR LED is **635.360mV**, as shown in Figure 12 below.

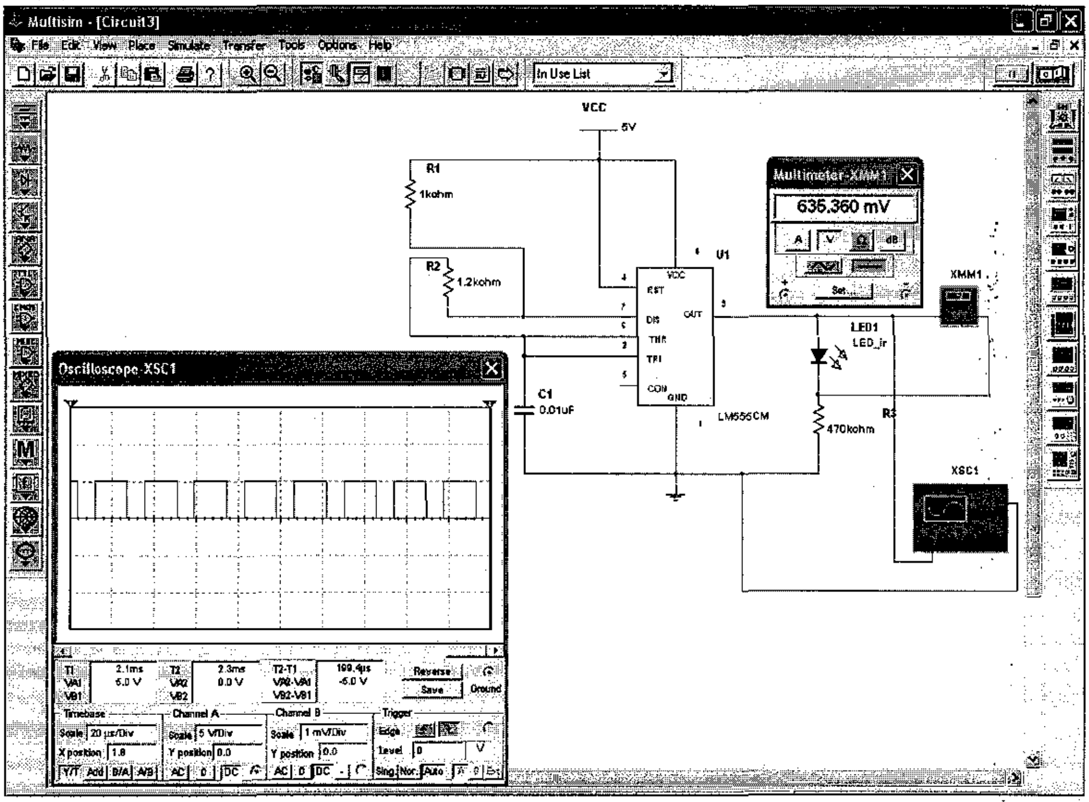


Figure 12: Simulation on transmitter circuit to show required voltage

However, simulation of designed circuit in Figure 13 showed very small voltage, **47.304μV,** which is insufficient for the LED to transmit IR.

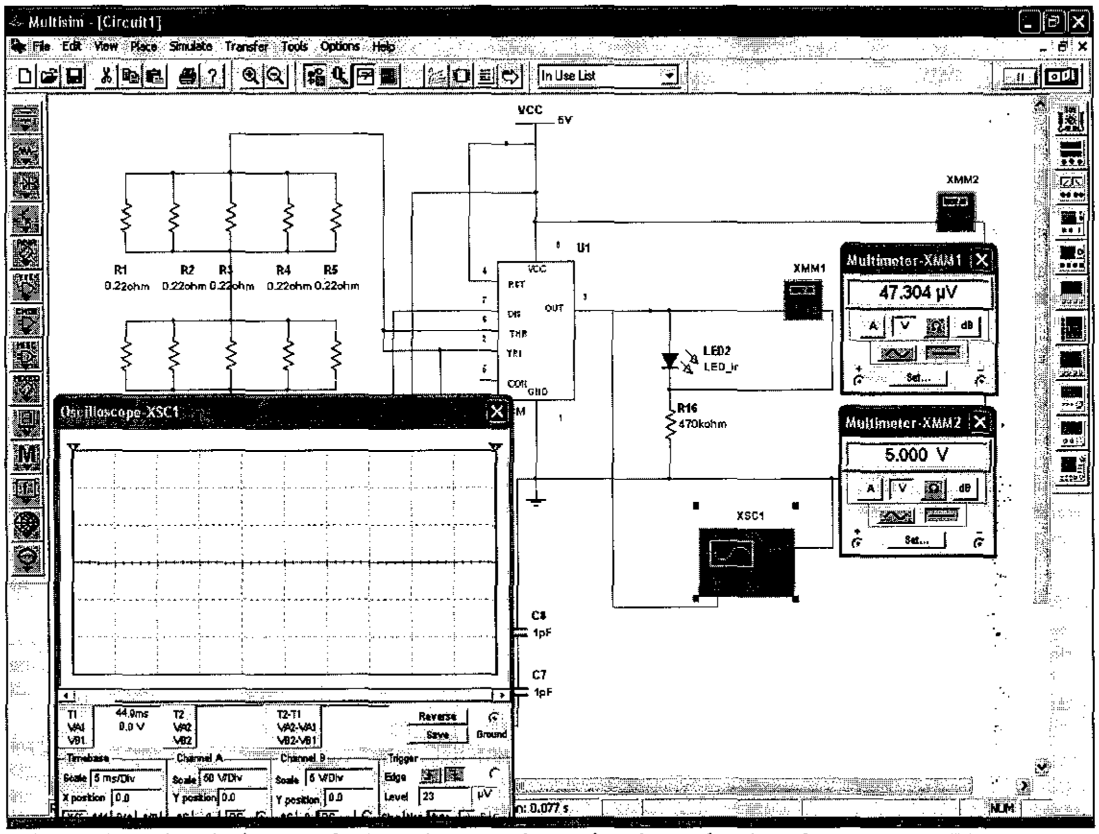


Figure 13: Simulation on designed transmitter circuit to check voltage across IR LED

From equation 4, R_1, R2 and capacitor are the manipulated parameters. One way of increasing the voltage across IR LED value is by changing R_1 and R_2 values, as shown in Table 1 below.

Table 1: Voltage across IR LED value when R_1 and R_2 values are changed

Parameter	Voltage across IR LED	Frequency Transmitted
R_1 increase, R_2remain	increase	decrease
R_1 decrease, R_2 remain	decrease	increase
R_2 increase, R_1 remain	decrease	decrease
R_2 decrease, R_1 remain	increase	increase
R_1 increase, R_2 decrease	increase	decrease
R_2 increase, R_1 decrease	decrease	decrease
Both R_1 and R_2 increase	increase	decrease
Both R_1 and R_2 decrease	decrease	increase

This result shows that the voltage across the IR LED can be increased by reducing the value of R_2. From Equation 4, reducing R_2 value will increase output frequency to be out of the desired range for LPG absorption. Thus, this approach cannot be used.

The other alternative that could possibly be used is by increasing the R_3 value. However, to maintain the voltage threshold across IR LED, R_3 should be very large value. The circuit is not function as expected to transmit IR. However, using incandescent lamp can be an alternative to transmit IR radiation, student continues this project by using incandescent lamp as IR radiation source.

The operation of incandescent lamp is based on the theory that if an electric current is passed through any conductor other than a perfect one, a certain amount of energy is expended that appears as heat in the conductor. In as much as any heated body will give off a certain amount of light at temperatures over 525° C (977° F), a conductor heated above that temperature by an electric current will act as a light source. The incandescent lamp consists of a filament of a material with a high melting point sealed inside a glass bulb from which the air has been evacuated, or which is filled with an inert gas. Filaments with high melting points must be used, because the proportion of light energy to heat energy radiated by the filament rises as the temperature increases, and the most efficient light source is obtained at the highest filament temperature [13].

3.1.2.2 Detector Circuit

For the detector circuit, thermopile is used for detecting the desired frequency value. The schematic of IR detector circuit is shown in Figure 14 below and the constructed circuit is shown in Appendix C .The output signals are very small and need amplification. The circuit is standard for the first signal conditioning stage in a thermopile-based IR absorption gas detector. To amplify the thermopile signal, a low noise Op-Amp is used. The Rv serial resistor value has to be determined to ensure that the maximum current through thermistor will not exceed 5μm. If higher values used, signal fluctuations may occur due to heating effect [12]. For this circuit, the Rv value is set to be 2.5 μm. Based on Ohm's Law, V=IR, as Vdd value is set to 5V, which is constant, I and R values are inversely proportional.

$R = V / I;$

$= 5V / 2.5A$

$= 2M\Omega$

So, 2MΩ resistor value is used for Rv.

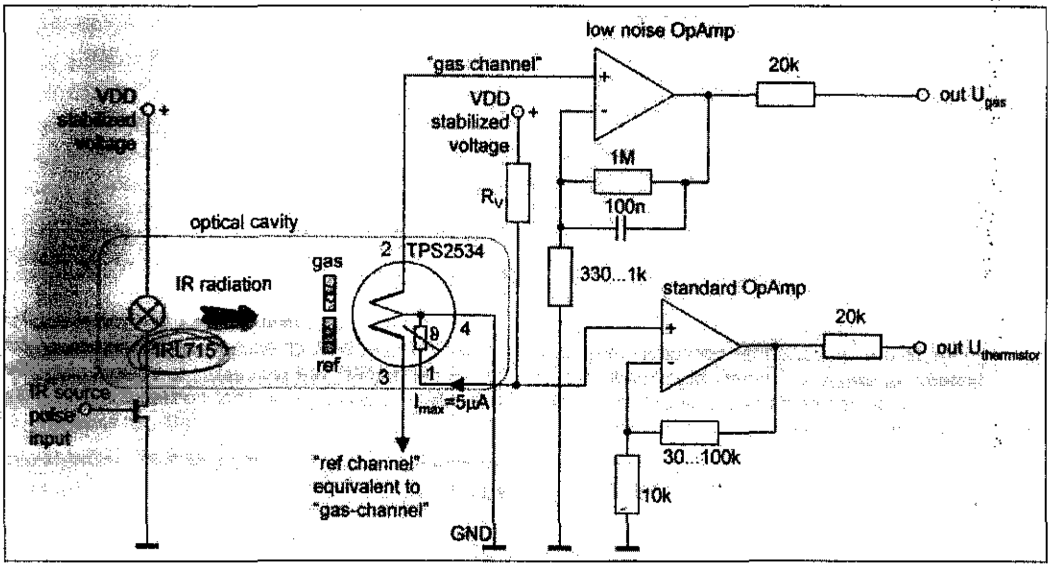


Figure 14: Circuit diagram for detector circuit[12].

3.1.3 LPG Experiment

Basically, there are 2 IR sources that student wants to introduce for this project, but the transmitter circuit does not transmit the desired IR frequency. Thus, this project is done using the other IR source, which is the incandescent lamp. Heat emitted by this lamp is also the IR radiation, but in a wide frequency range. The experiment has been done to get the Vi and Vo values from the detector circuit after the LPG is absorbed IR. When the lamp is ON, the IR radiation is pointing straight to the thermopile on the detector circuit.

Experiment is done to allow reaction between LPG and infrared (IR) radiation, where reduction in IR radiation intensity is expected to result. The experiment is done using a temporary chamber, where the LPG is released inside the chamber after the incandescent lamp is ON. The output voltage value, Vo is observed and measured from the detector circuit, which indicate the reductions in IR intensity.

The voltage reading is observed from the graph and table by using PASCO (Data Studio) software, where there is an increase in voltage reading from its baseline value. This indicates that the detector circuit is working properly. After reaching constant value, the LPG is then released into the chamber. Voltage value changes where it is rapidly decreased for a while, before it starts to increase back to its baseline value. This happen because the when the gas is released, the IR radiation has been absorbed by LPG. The value gets back to its baseline value after the gas vent out from the chamber. The flowchart of sequential procedure of the LPG detection experiment is shown in Figure 15.

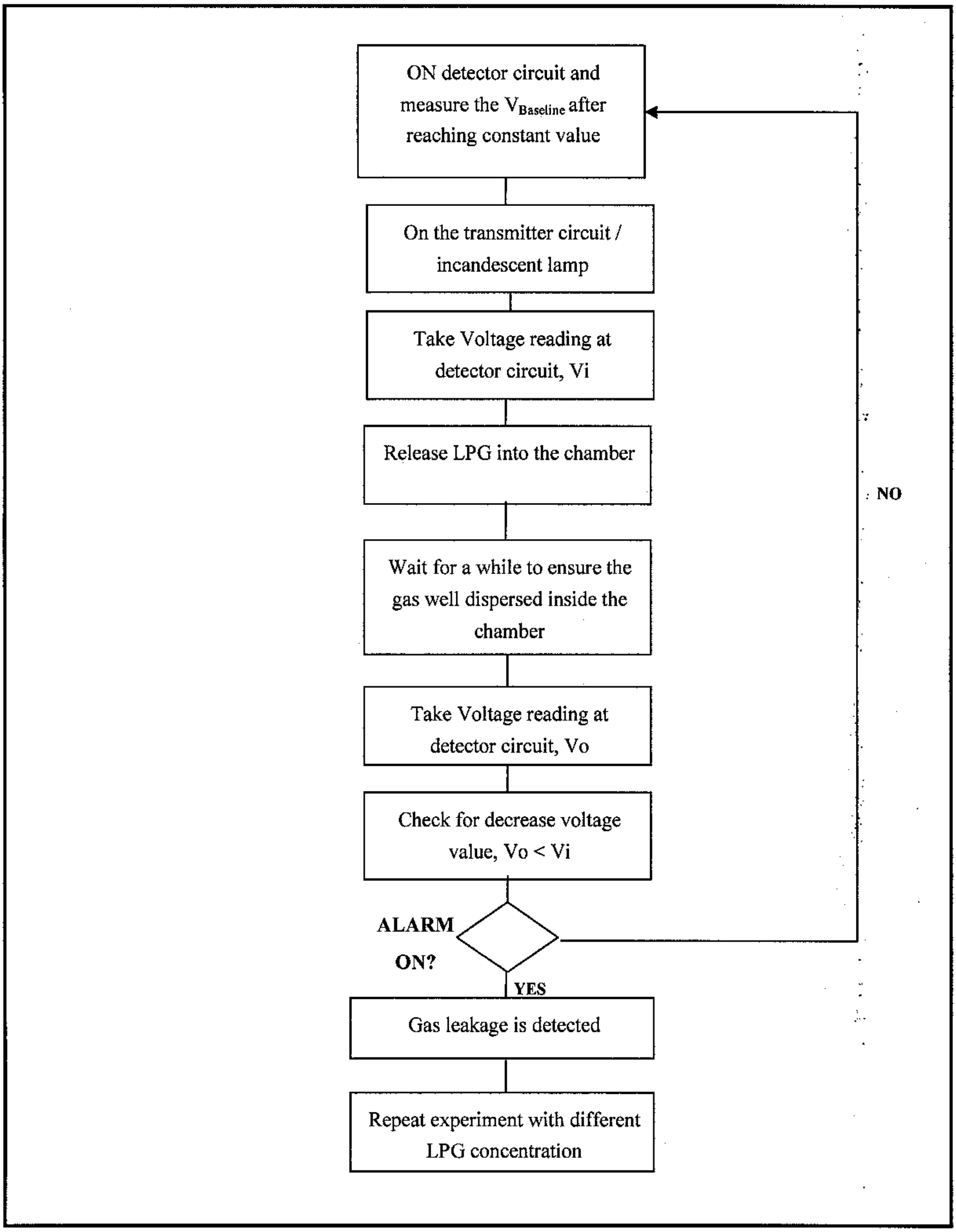


Figure 15: Flowchart showing procedure of LPG detection experiment

Concentration of LPG is varied to validate the result obtained. Since there is no specific LPG concentration device available, the LPG concentration is varied by varying the time taken to observe the reaction between LPG and IR radiation from incandescent lamp. As LPG concentration increases, voltage drop value is increasing as well. However, since LPG is an explosive gas, the limit is set to ensure the concentration of gas released into the chamber not exceed its Lower Explosive Limit (LEL). The experimental results are shown in Chapter 4: Result & Discussion.

3.1.4 Building Model

This project will be fully fledged once after final prototype is built. In order to come out with the prototype, few things must be considered such as the size and appearance of the prototype. The design of the prototype will be based totally on the requirements for the project. LPG is not dangerous if been used in low concentration. One of the main concerns in constructing the chamber is to know the distance between the Transmitter (Tx) and Receiver (Rx) circuits. This is needed to determine the size of the chamber to be constructed. Based on the research done, the distance between the two circuits is basically determined by Beer's Law, shown in Equation 3.

$\mathbf{I = I_0 \exp(-kcl)}$.................. (Equation 3) [1].

I = Detected intensity

$\mathbf{I_0}$ = Initial intensity

k = absorption or extinction coefficient

c = concentration of the absorbing gas

l = measurement length (distance between transmitter and detector circuit in chamber)

There is a fixed path length between the IR source and the IR detector. Typically the length is a few inches and the gas is assumed to be uniform across this length. **I** is inversely proportional to the distance, **l**. Larger is the distance l, smaller is the value of I obtained. The model built for this project is shown in the Figure 16 below;

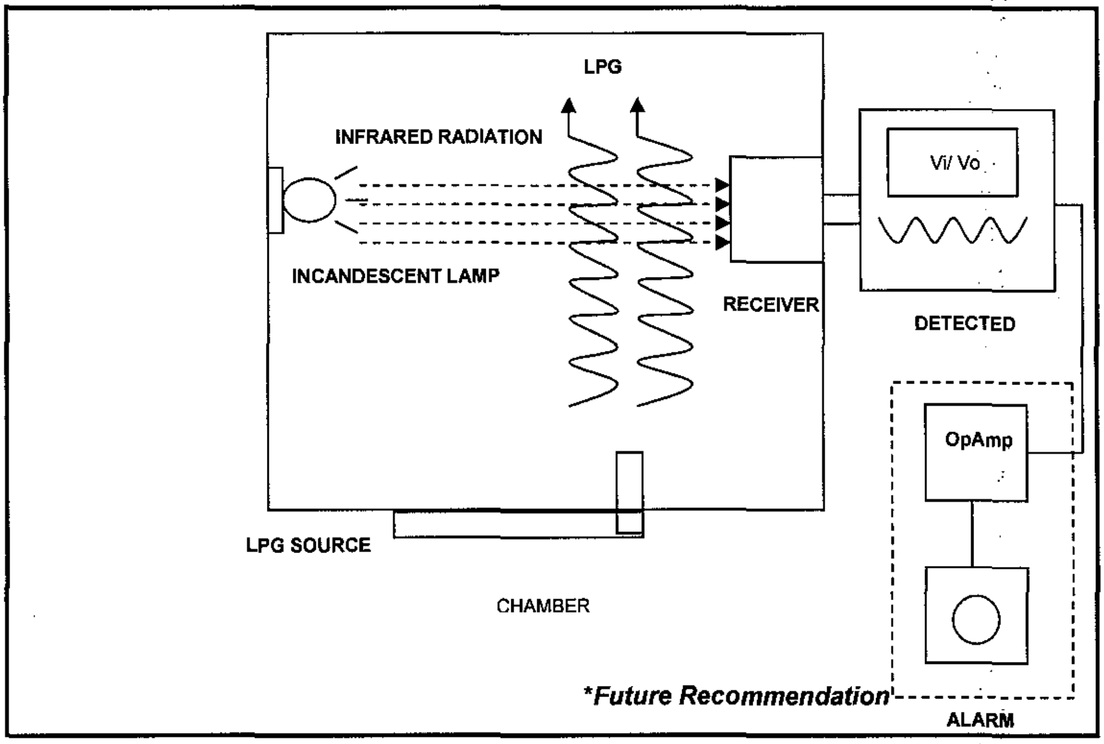


Figure 16: Illustration of project model (using incandescent lamp)

3.1.5 Final Report and Presentation

The final report as well as final presentation will be carried out as scheduled. For FYI II, student is expected to present a working prototype besides showing deep understanding of the theories, researches, findings and results of the experiments.

3.1.6 Tools Required

This project requires both hardware and software. Table 2 below lists all the hardware as well as the software needed for this project;

Table 2: Tools Required for LPG Detection

HARDWARE	SOFTWARE
• IR circuit (transmitter, detector) • LPG source (butane) • A chamber • Multimeter/ Oscilloscope • Incandescent lamp (IR light source-optional)	• PASCO (Data Studio) • Multisim

CHAPTER 4
RESULT AND DISCUSSION

4.1 Result of LPG Experiment

Experiment Result:

Baseline Voltage, V_{base}: **4.3086V**

Output voltage when incandescent lamp is ON, Vi: **4.3104V**

Output voltage when incandescent lamp is ON and LPG been released into the chamber, Vo: **4.2977V**

From the result, voltage value after Vo < Vi, which corresponds to the transmitted IR intensity, I_{TX} and detected IR intensity, I_{RX} where $I_{RX} < I_{TX}$. This shows that the IR intensity has been reduced in presence of the LPG inside the chamber, and thus validates the theory of IR absorption by LPG at certain frequency.

To see the response of the experiment result better, student used PASCO interface and Data Studio software to get graph and table for showing the experimental. The graph and table obtained are as in Figure 17 and Table 3 below. From the graph and table obtained, the 10 seconds show the baseline voltage for the detector circuit. From 10 to 35 seconds, the incandescent lamp is ON and the there are increase in voltage. From 35 to 39 seconds, LPG has been released into the chamber. The result is there is fast voltage drop, indicate the absorption of the IR by LPG. From 39 until 100 seconds, the reaction has end and the voltage increases back to its baseline value. This experimental result however can be further improved by varying the LPG concentrations released into the chamber.

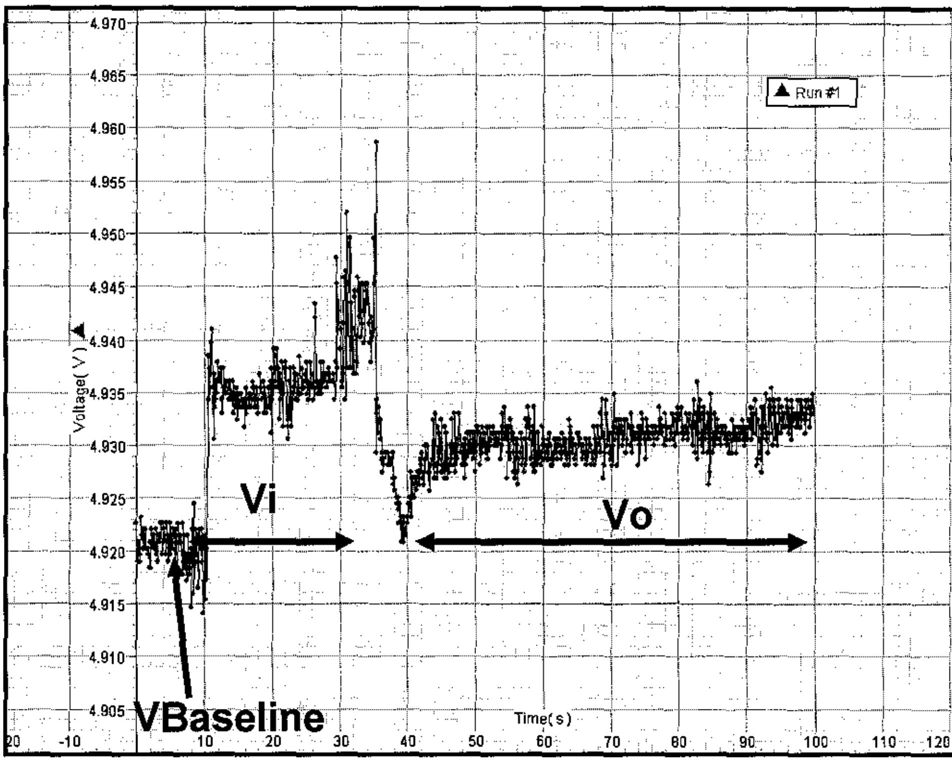


Figure 17: Experimental result for IR absorption by LPG, Voltage (V) Vs Time(s)

Table 3: Voltage and time result from LPG experiment.

▲Voltage, ChA Run #1	
Time (s)	Voltage (V)
7.1000	4.921
7.2000	4.918
7.3000	4.917
7.4000	4.920
7.5000	4.919
7.6000	4.921
7.7000	4.918
7.8000	4.916
7.9000	4.920
8.0000	4.920
8.1000	4.915
8.2000	4.922
8.3000	4.922
8.4000	4.924
8.5000	4.916
8.6000	4.921
8.7000	4.922
8.8000	4.921
8.9000	4.919
9.0000	4.920
9.1000	4.917
9.2000	4.921
9.3000	4.922
9.4000	4.921
9.5000	4.920
9.6000	4.919
9.7000	4.922

(a) Baseline Voltage

▲Voltage, ChA Run #1	
Time (s)	Voltage (V)
35.6000	4.931
35.7000	4.934
35.8000	4.934
35.9000	4.931
36.0000	4.932
36.1000	4.929
36.2000	4.929
36.3000	4.928
36.4000	4.929
36.5000	4.928
36.6000	4.929
36.7000	4.929
36.8000	4.929
36.9000	4.929
37.0000	4.929
37.1000	4.928
37.2000	4.928
37.3000	4.928
37.4000	4.929
37.5000	4.928
37.6000	4.929
37.7000	4.929
37.8000	4.927
37.9000	4.926
38.0000	4.927
38.1000	4.926
38.2000	4.926

(b)Incandescent lamp is ON

▲Voltage, ChA Run #1	
Time (s)	Voltage (V)
97.2000	4.932
97.3000	4.933
97.4000	4.932
97.5000	4.934
97.6000	4.932
97.7000	4.933
97.8000	4.934
97.9000	4.932
98.0000	4.934
98.1000	4.932
98.2000	4.933
98.3000	4.934
98.4000	4.933
98.5000	4.933
98.6000	4.931
98.7000	4.934
98.8000	4.933
98.9000	4.932
99.0000	4.934
99.1000	4.934
99.2000	4.934
99.3000	4.934
99.4000	4.932
99.5000	4.934
99.6000	4.934
99.7000	4.935
99.8000	4.933

(c) After reaction ends

To monitor the experiment performance, the experiment is repeated by varying LPG concentration been released gas into the chamber. Since there is no specific LPG concentration device available, the LPG concentration is varied by varying the time taken to observe the reaction between LPG and IR radiation from incandescent lamp. The expected result is that the voltage drop value will increase in increasing of time of injecting gas into the chamber. This procedure is done by considering that the longer time taken to release the gas, the more LPG concentration will be. However, since the circuit used is still not yet stable, result obtained also not consistent, but still given the desired pattern, where Vo<Vi. The circuit performance will be improved to obtain better result. The experimental result is shown in the Table 4 below.

Table 4: Experimental result for different LPG concentration

Time (s)	V_{base} (V)	Vi(V)	Vo(V)
5	4.217	4.220	4.156
7	4.218	4.220	4.211
10	4.216	4.220	4.211
12	4.214	4.220	4.157

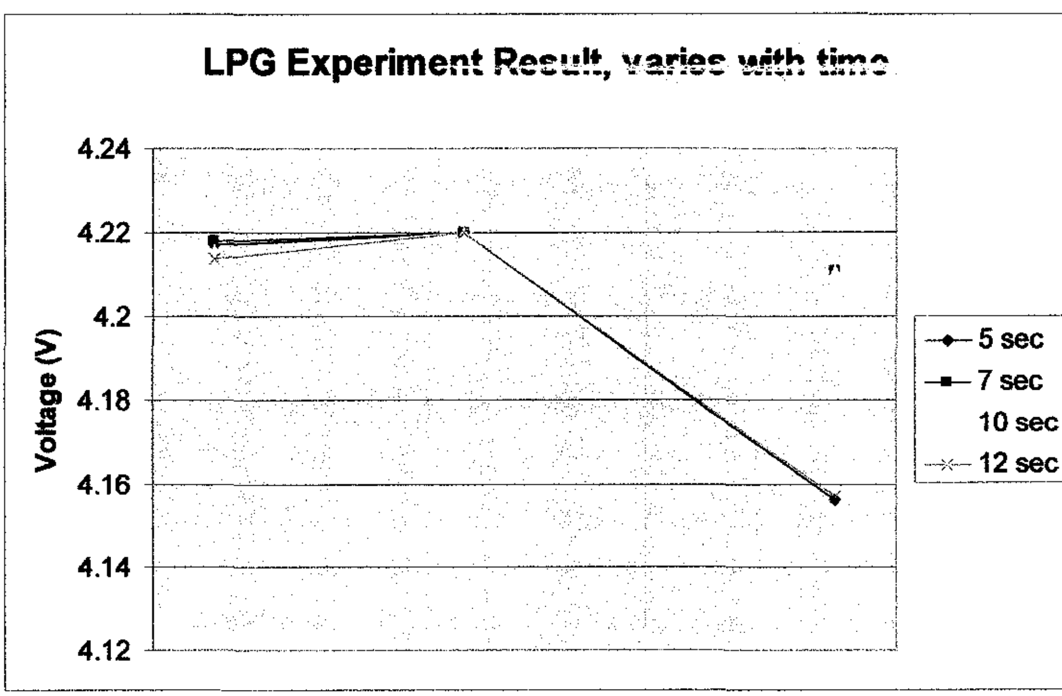


Figure 18: Graph of Experimental result for different LPG concentration

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project is a good approach for detecting gas leakage at home as well as industry. The method used is simple and less expensive, but at the same time reliable and practical. Compare to other methods currently used, this system is more reliable since it immunes to all chemical poisons, does not need oxygen or air to detect gas and can work in continuous exposure gas environments. This approach has contributed to another method of detecting gas leakage in addition to the current method exist in the market nowadays.

5.2 Recommendations

For improvement, some additional features could be added in order to make the system more efficient and user-friendly. Some recommendations suggested for 'Gas Leakage Detection System Using Infrared' are briefly explained below;

5.2.1 Automatic Room Ventilation

Whenever gas leakage occurs at home, there is a need to vent out the gas from the room (kitchen) so that outside air will mix with the gases inside the room and thus, reduce the gas volume. Automatic room ventilation is necessary to ensure that the leakage gases are no more combustible and the room is safe to be used for cooking and heating purpose. It will be such a good idea to have automatic room ventilation feature for the gas detection system, so that the user will not need to manually open the window, especially in the time where the user is not at home.

5.2.2 Automatic Valve Closed Feature

One of the ways to stop gas leakage at home is by closing the valve from where gas comes out. To make this system more practical, an automatic valve closed feature can be added for user's safety and convenience. A special circuit will be designed to automatically close the valve whenever gas leakage is detected.

5.2.3 Alarm System

Since current model can only detect gas, it is recommended that this model can be equipped with alarm system to warn user about gas leakage. The current model is built only to detect gas using Infrared radiation (IR), applicable for detecting gas leakage for home and industry usage. With an alarm system features, this project will be more realistic to be implemented.

5.2.4 Various Gas Detection System

This project is focus on LPG. Using the theory that most gases such as CO_2, CO, NO and all carbon hydrogen (HC) are able to absorb infrared (IR) radiation at certain wavelength, this project can be extended to detect other gaseous also. This will improve its functionality thus make it more practical and has high market value.

5.2.5 Improve Circuit Performance

The detector circuit currently used is still not yet stable. For better model performance, the circuit needs to be further tested and improved in order to come out with reliable gas leakage detection system.

REFERENCES

Websites and books:

[1] http://optoelectronics.perkinelmevr.com/content/whitepapers/Gas_detection.pdf

[2] Final Year Report December 2004: Microcontroller-Based Electronic LPG

[3] http://www.e-lpg.com/lp_gas_faqgen.asp#f

[4] http://www.generalmonitors.com/downloads/white_papers/COMBUSTIBLE_HANDBOOK.PDF

[5] http://en.wikipedia.org/wiki/Infrared_spectroscopy

[6] http://imagers.gsfc.nasa.gov/ems/waves3.html

[7] http://imagers.gsfc.nasa.gov/ems/infrared.html

[8] http://www.habmigern2003.info/future_trends/infrared_analyser/ndir/IR-Absorption-GB.html

[9] http://web.telia.com/~u85920178/begin/opamp00.htm

[10] http://en.wikipedia.org/wiki/Operational_amplifier

[11] Final Year Report December 2004: Electronic Object Motion Detection

[12] TPS 2534 Product Note

[13] http://users.mis.net/~pthrush/lighting/bulb.html

APPENDICES

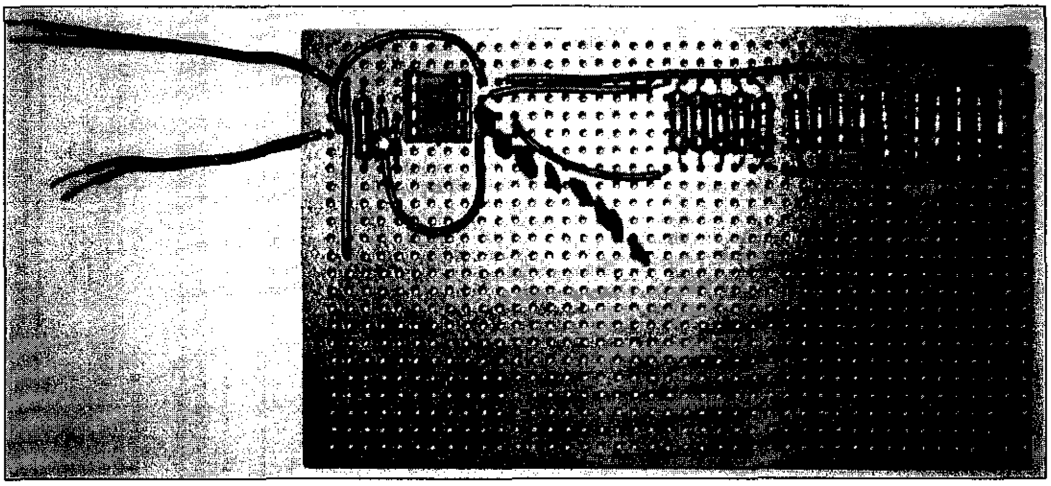
APPENDIX A

PROPERTIES OF LPG

Gas name	Explosion limit(%)		Gas proportion (air=1)	Sparking point	toxicity	Permission concentration
	Low er limit	Upper lim				
Methane	5	15	0.55	537.8	asphyxiation	
Ethane	3	12.5	1.406	515	asphyxiation	
Propane	**2.3**	**9.15**	**1.56**	**467.8**	**asphyxiation**	**1000ppm**
Butane	**1.8**	**8.44**	**2**		**asphyxiation**	
Ethene	2.7	28.5			narcosis	
Propylene	2.4	11			narcosis	
Acetylene	1.5	82	0.906	305		
Hydrogen	4.1	74.2	0.069	585	asphyxiation	
CO	12.5	75.6	0.967	608	toxicosis	50ppm
Natural gases	5	15	<1		asphyxiation	
LPG	**3**		**>1**		**asphyxiation**	
City gas	4	30	0.4		toxicosis	100ppm
Gasoline	1.2	7.5	3.3	280	Asphyxiation& asphyxiation	
Coal oil	0.7	5	4~5			
Alcohol	3.3	19	1.58	392		1000ppm
Ethanol	3.5	6.7	0.78	422		1mg/m
Methyl Alcohol	6.7	36	0.79	385		0.05mg/m
Acetone	8.1	13	0.79			1000ppm

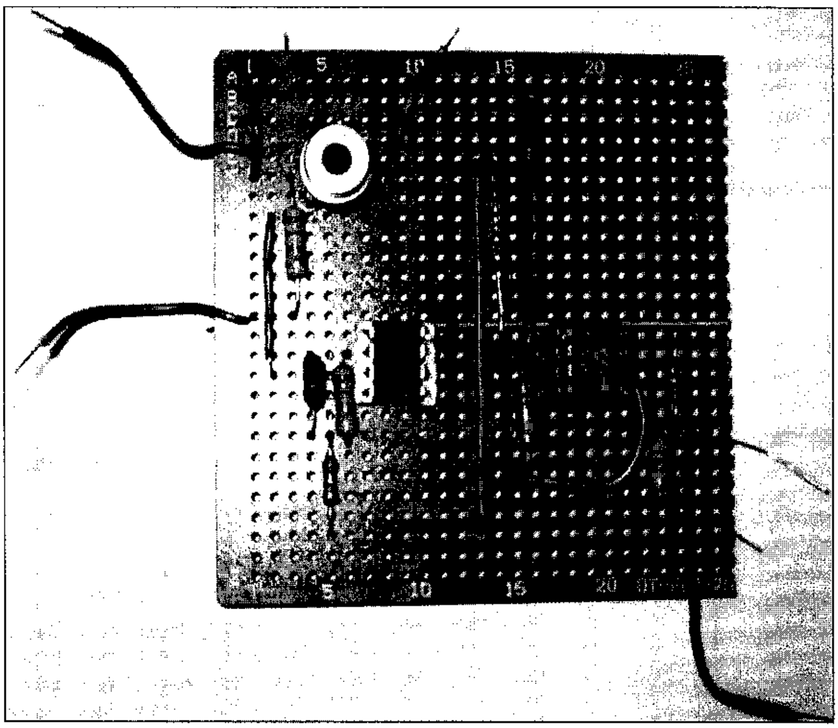
APPENDIX B

CONSTRUCTED TRANSMITTER CIRCUIT (ALTERNATIVE 3)



APPENDIX C

CONSTRUCTED DETECTOR CIRCUIT USING THERMOPILE



APPENDIX D

555 TIMER DATASHEET

National Semiconductor

July 2006

LM555
Timer

General Description

The LM555 is a highly stable device for generating accurate time delays or oscillation. Additional terminals are provided for triggering or resetting if desired. In the time delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For astable operation as an oscillator, the free running frequency and duty cycle are accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200mA or drive TTL circuits.

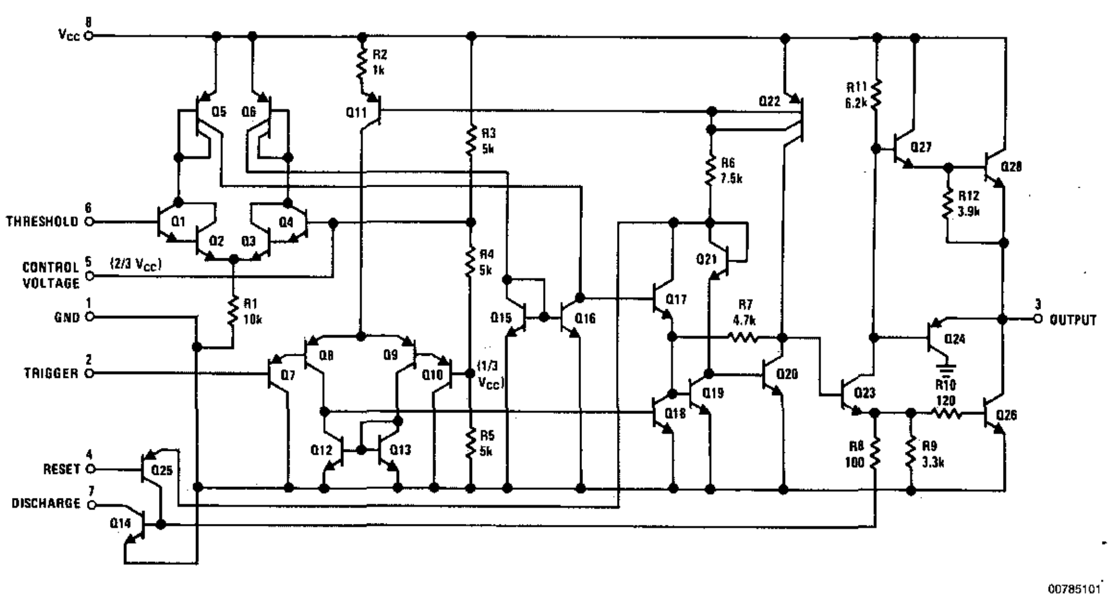
Features

- Direct replacement for SE555/NE555
- Timing from microseconds through hours
- Operates in both astable and monostable modes
- Adjustable duty cycle
- Output can source or sink 200 mA
- Output and supply TTL compatible
- Temperature stability better than 0.005% per °C
- Normally on and normally off output
- Available in 8-pin MSOP package

Applications

- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Linear ramp generator

Schematic Diagram

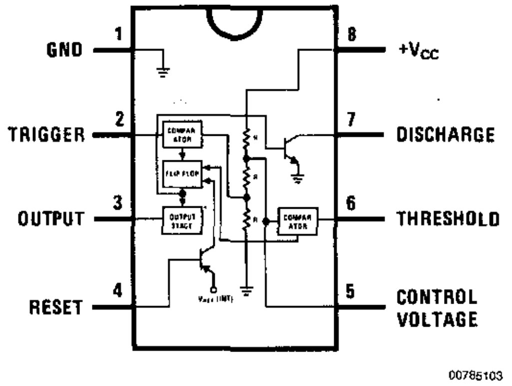


00785101

 DS007851

Connection Diagram

Dual-In-Line, Small Outline and Molded Mini Small Outline Packages



Top View

Ordering Information

Package	Part Number	Package Marking	Media Transport	NSC Drawing
8-Pin SOIC	LM555CM	LM555CM	Rails	M08A
	LM555CMX	LM555CM	2.5k Units Tape and Reel	
8-Pin MSOP	LM555CMM	Z55	1k Units Tape and Reel	MUA08A
	LM555CMMX	Z55	3.5k Units Tape and Reel	
8-Pin MDIP	LM555CN	LM555CN	Rails	N08E

Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	+18V
Power Dissipation (Note 3)	
LM555CM, LM555CN	1180 mW
LM555CMM	613 mW
Operating Temperature Ranges	
LM555C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Soldering Information	
Dual-In-Line Package	
Soldering (10 Seconds)	260°C
Small Outline Packages (SOIC and MSOP)	
Vapor Phase (60 Seconds)	215°C
Infrared (15 Seconds)	220°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

Electrical Characteristics (Notes 1, 2)

(T_A = 25°C, V_{CC} = +5V to +15V, unless othewise specified)

Parameter	Conditions	Limits LM555C Min	Typ	Max	Units
Supply Voltage		4.5		16	V
Supply Current	V_{CC} = 5V, R_L = ∞ V_{CC} = 15V, R_L = ∞ (Low State) (Note 4)		3 10	6 15	mA
Timing Error, Monostable					
Initial Accuracy			1		%
Drift with Temperature	R_A = 1k to 100kΩ, C = 0.1µF, (Note 5)		50		ppm/°C
Accuracy over Temperature			1.5		%
Drift with Supply			0.1		%/V
Timing Error, Astable					
Initial Accuracy			2.25		%
Drift with Temperature	R_A, R_B = 1k to 100kΩ, C = 0.1µF, (Note 5)		150		ppm/°C
Accuracy over Temperature			3.0		%
Drift with Supply			0.30		%/V
Threshold Voltage			0.667		x V_{CC}
Trigger Voltage	V_{CC} = 15V V_{CC} = 5V		5 1.67		V V
Trigger Current			0.5	0.9	µA
Reset Voltage		0.4	0.5	1	V
Reset Current			0.1	0.4	mA
Threshold Current	(Note 6)		0.1	0.25	µA
Control Voltage Level	V_{CC} = 15V V_{CC} = 5V	9 2.6	10 3.33	11 4	V
Pin 7 Leakage Output High			1	100	nA
Pin 7 Sat (Note 7)					
Output Low	V_{CC} = 15V, I_7 = 15mA		180		mV
Output Low	V_{CC} = 4.5V, I_7 = 4.5mA		80	200	mV

Electrical Characteristics (Notes 1, 2) (Continued)

(T_A = 25°C, V_{CC} = +5V to +15V, unless othewise specified)

Parameter	Conditions	Limits			Units
		LM555C			
		Min	Typ	Max	
Output Voltage Drop (Low)	V_{CC} = 15V				
	I_{SINK} = 10mA		0.1	0.25	V
	I_{SINK} = 50mA		0.4	0.75	V
	I_{SINK} = 100mA		2	2.5	V
	I_{SINK} = 200mA		2.5		V
	V_{CC} = 5V				
	I_{SINK} = 8mA				V
	I_{SINK} = 5mA		0.25	0.35	V
Output Voltage Drop (High)	I_{SOURCE} = 200mA, V_{CC} = 15V		12.5		V
	I_{SOURCE} = 100mA, V_{CC} = 15V	12.75	13.3		V
	V_{CC} = 5V	2.75	3.3		V
Rise Time of Output			100		ns
Fall Time of Output			100		ns

Note 1: All voltages are measured with respect to the ground pin, unless otherwise specified.

Note 2: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

Note 3: For operating at elevated temperatures the device must be derated above 25°C based on a +150°C maximum junction temperature and a thermal resistance of 106°C/W (DIP), 170°C/W (S0-8), and 204°C/W (MSOP) junction to ambient.

Note 4: Supply current when output high typically 1 mA less at V_{CC} = 5V.

Note 5: Tested at V_{CC} = 5V and V_{CC} = 15V.

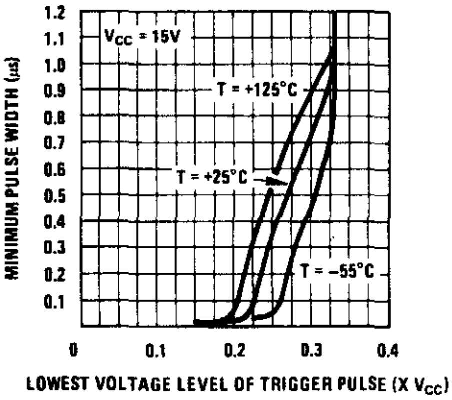
Note 6: This will determine the maximum value of $R_A + R_B$ for 15V operation. The maximum total ($R_A + R_B$) is 20MΩ.

Note 7: No protection against excessive pin 7 current is necessary providing the package dissipation rating will not be exceeded.

Note 8: Refer to RETS555X drawing of military LM555H and LM555J versions for specifications.

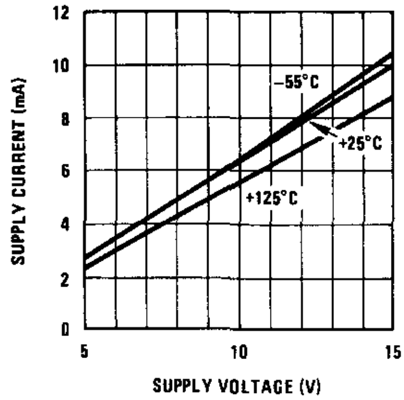
Typical Performance Characteristics

Minimuim Pulse Width Required for Triggering



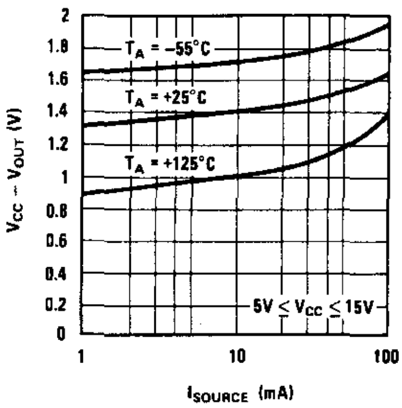
00785104

Supply Current vs. Supply Voltage



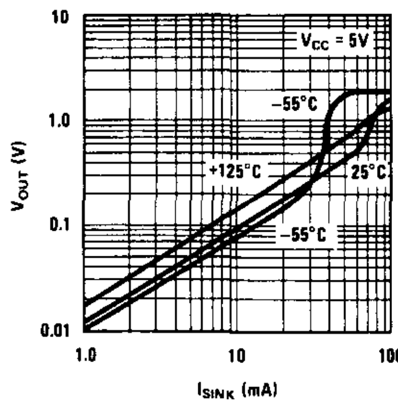
00785119

High Output Voltage vs. Output Source Current



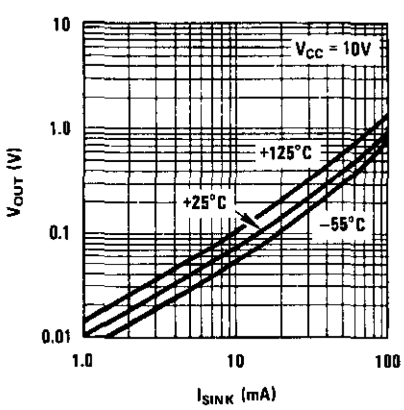
00785120

Low Output Voltage vs. Output Sink Current



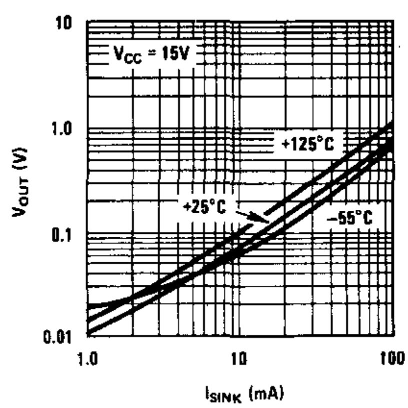
00785121

Low Output Voltage vs. Output Sink Current



00785122

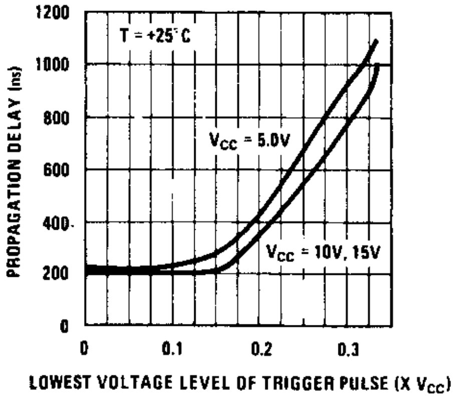
Low Output Voltage vs. Output Sink Current



00785123

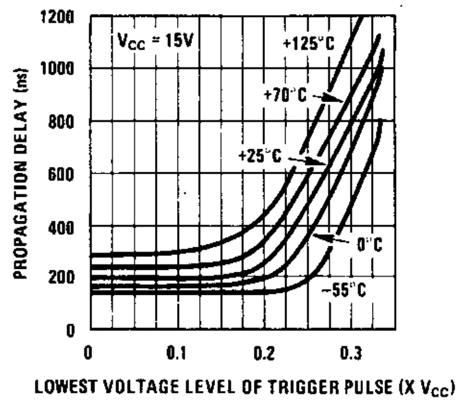
Typical Performance Characteristics (Continued)

Output Propagation Delay vs. Voltage Level of Trigger Pulse



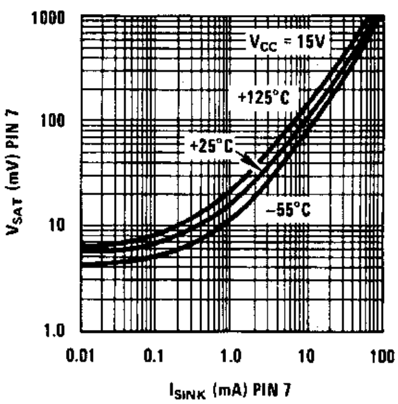
00785124

Output Propagation Delay vs. Voltage Level of Trigger Pulse



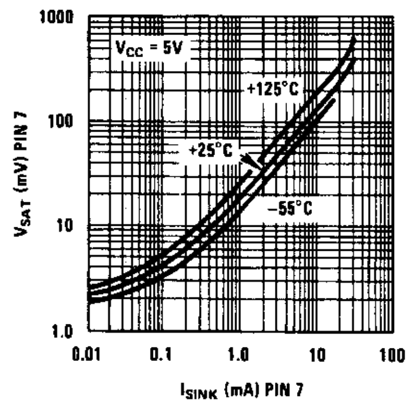
00785125

Discharge Transistor (Pin 7) Voltage vs. Sink Current



00785126

Discharge Transistor (Pin 7) Voltage vs. Sink Current



00785127

\pplications Information

IONOSTABLE OPERATION

ı this mode of operation, the timer functions as a one-shot *Figure 1*). The external capacitor is initially held discharged ·y a transistor inside the timer. Upon application of a nega- ve trigger pulse of less than 1/3 V_{CC} to pin 2, the flip-flop is et which both releases the short circuit across the capacitor .nd drives the output high.

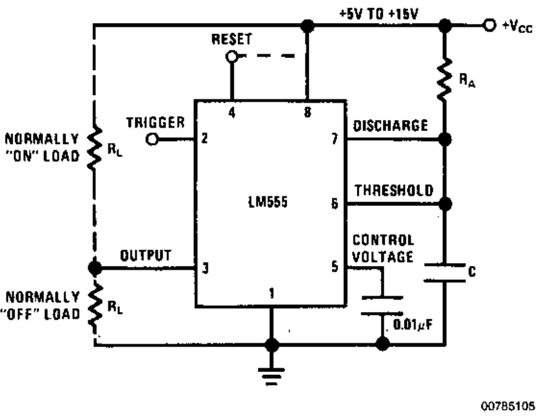
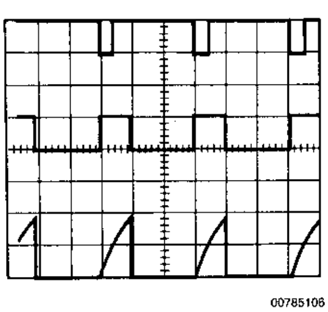


FIGURE 1. Monostable

'he voltage across the capacitor then increases exponen- :ally for a period of t = 1.1 R_A C, at the end of which time the 'oltage equals 2/3 V_{CC}. The comparator then resets the lip-flop which in turn discharges the capacitor and drives the ıutput to its low state. *Figure 2* shows the waveforms gen- ːrated in this mode of operation. Since the charge and the hreshold level of the comparator are both directly propor- ional to supply voltage, the timing interval is independent of ;upply.



'$_{CC}$ = 5V Top Trace: Input 5V/Div.
'IME = 0.1 ms/DIV. Middle Trace: Output 5V/Div.
$\text{}_A$ = 9.1kΩ Bottom Trace: Capacitor Voltage 2V/Div.
; = 0.01µF

FIGURE 2. Monostable Waveforms

)uring the timing cycle when the output is high, the further ıpplication of a trigger pulse will not effect the circuit so long ıs the trigger input is returned high at least 10µs before the ənd of the timing interval. However the circuit can be reset during this time by the application of a negative pulse to the reset terminal (pin 4). The output will then remain in the low state until a trigger pulse is again applied.

When the reset function is not in use, it is recommended that it be connected to V_{CC} to avoid any possibility of false triggering.

Figure 3 is a nomograph for easy determination of R, C values for various time delays.

NOTE: In monostable operation, the trigger should be driven high before the end of timing cycle.

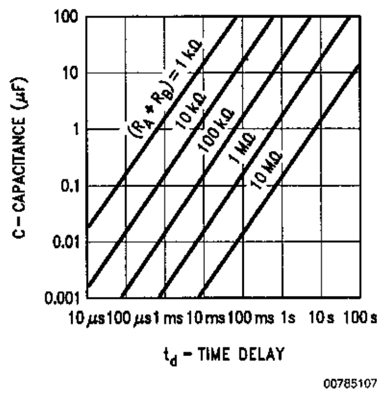


FIGURE 3. Time Delay

ASTABLE OPERATION

If the circuit is connected as shown in *Figure 4* (pins 2 and 6 connected) it will trigger itself and free run as a multivibrator. The external capacitor charges through R_A + R_B and discharges through R_B. Thus the duty cycle may be precisely set by the ratio of these two resistors.

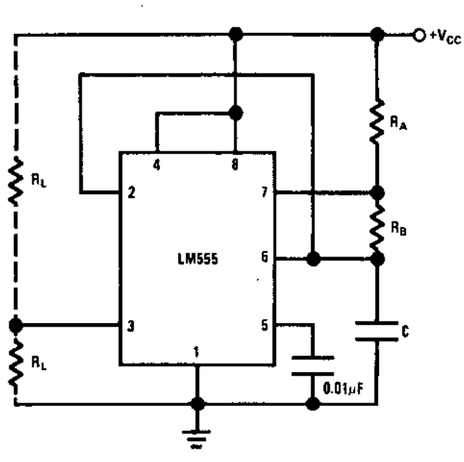
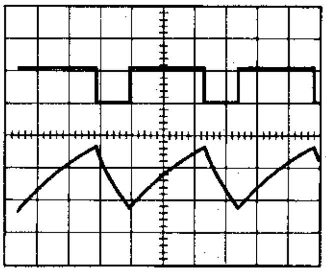


FIGURE 4. Astable

In this mode of operation, the capacitor charges and discharges between 1/3 V_{CC} and 2/3 V_{CC}. As in the triggered mode, the charge and discharge times, and therefore the frequency are independent of the supply voltage.

Applications Information (Continued)

Figure 5 shows the waveforms generated in this mode of operation.



00785109

V_{CC} = 5V Top Trace: Output 5V/Div.
TIME = 20µs/DIV. Bottom Trace: Capacitor Voltage 1V/Div.
R_A = 3.9kΩ
R_B = 3kΩ
C = 0.01µF

FIGURE 5. Astable Waveforms

The charge time (output high) is given by:

$$t_1 = 0.693\ (R_A + R_B)\ C$$

And the discharge time (output low) by:

$$t_2 = 0.693\ (R_B)\ C$$

Thus the total period is:

$$T = t_1 + t_2 = 0.693\ (R_A + 2R_B)\ C$$

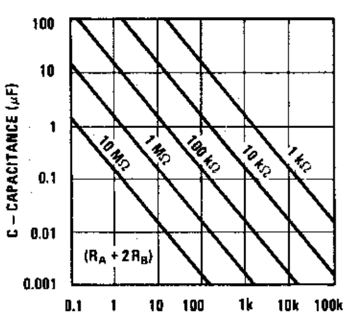
The frequency of oscillation is:

$$f = \frac{1}{T} = \frac{1.44}{(R_A + 2\,R_B)\,C}$$

Figure 6 may be used for quick determination of these RC values.

The duty cycle is:

$$D = \frac{R_B}{R_A + 2R_B}$$

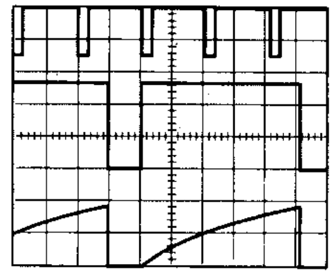


00785110

FIGURE 6. Free Running Frequency

FREQUENCY DIVIDER

The monostable circuit of *Figure 1* can be used as a frequency divider by adjusting the length of the timing cycle. *Figure 7* shows the waveforms generated in a divide by three circuit.



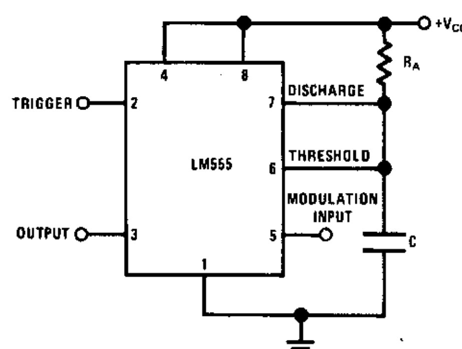
00785111

V_{CC} = 5V Top Trace: Input 4V/Div.
TIME = 20µs/DIV. Middle Trace: Output 2V/Div.
R_A = 9.1kΩ Bottom Trace: Capacitor 2V/Div.
C = 0.01µF

FIGURE 7. Frequency Divider

PULSE WIDTH MODULATOR

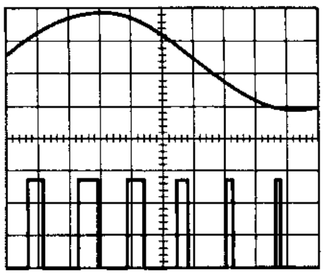
When the timer is connected in the monostable mode and triggered with a continuous pulse train, the output pulse width can be modulated by a signal applied to pin 5. *Figure 8* shows the circuit, and in *Figure 9* are some waveform examples.



00785112

FIGURE 8. Pulse Width Modulator

›pplications Information (Continued)



'$_{CC}$ = 5V Top Trace: Modulation 1V/Div.
IME = 0.2 ms/DIV. Bottom Trace: Output Voltage 2V/Div.
ı$_A$ = 9.1kΩ
; = 0.01µF

FIGURE 9. Pulse Width Modulator

›ULSE POSITION MODULATOR

'his application uses the timer connected for astable opera- ion, as in *Figure 10,* with a modulating signal again applied ɔ the control voltage terminal. The pulse position varies with he modulating signal, since the threshold voltage and hence he time delay is varied. *Figure 11* shows the waveforms ɟenerated for a triangle wave modulation signal.

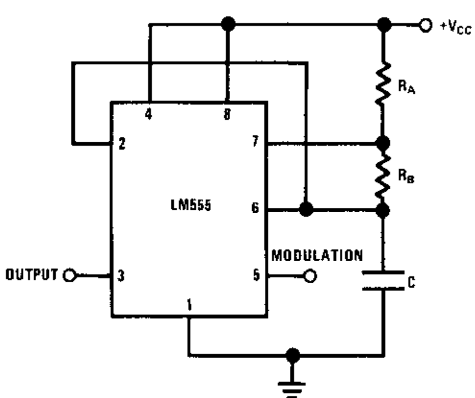
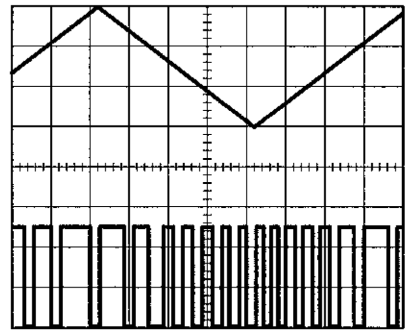


FIGURE 10. Pulse Position Modulator



V_{CC} = 5V Top Trace: Modulation Input 1V/Div.
TIME = 0.1 ms/DIV. Bottom Trace: Output 2V/Div.
R_A = 3.9kΩ
R_B = 3kΩ
C = 0.01µF

FIGURE 11. Pulse Position Modulator

LINEAR RAMP

When the pullup resistor, R_A, in the monostable circuit is replaced by a constant current source, a linear ramp is generated. *Figure 12* shows a circuit configuration that will perform this function.

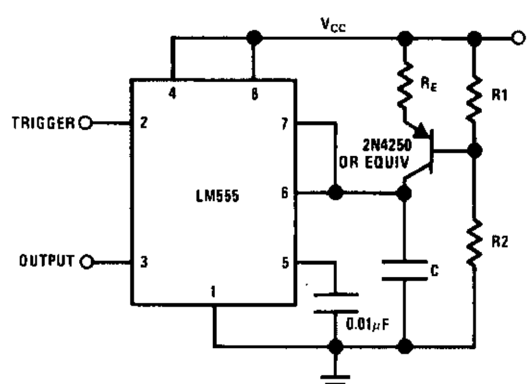


FIGURE 12.

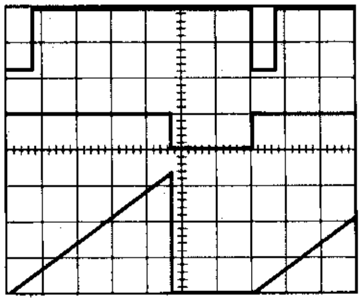
Figure 13 shows waveforms generated by the linear ramp. The time interval is given by:

$$T = \frac{2/3\,V_{CC}\,R_E\,(R_1 + R_2)\,C}{R_1\,V_{CC} - V_{BE}\,(R_1 + R_2)}$$

$$V_{BE} \cong 0.6V$$

$$V_{BE} \cong 0.6V$$

Applications Information (Continued)



00785117

V_{CC} = 5V   Top Trace: Input 3V/Div.
TIME = 20µs/DIV.   Middle Trace: Output 5V/Div.
R_1 = 47kΩ   Bottom Trace: Capacitor Voltage 1V/Div.
R_2 = 100kΩ
R_E = 2.7 kΩ
C = 0.01 µF

FIGURE 13. Linear Ramp

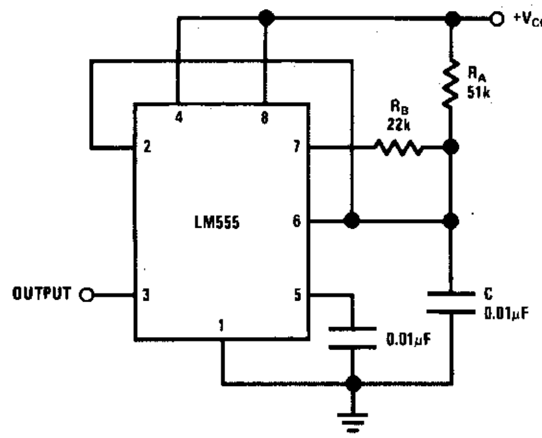
50% DUTY CYCLE OSCILLATOR

For a 50% duty cycle, the resistors R_A and R_B may be connected as in *Figure 14.* The time period for the output high is the same as previous, $t_1 = 0.693\ R_A\ C$. For the output low it is t_2 =

$$\left[(R_A R_B)/(R_A + R_B)\right] C\ \ell n \left[\frac{R_B - 2R_A}{2R_B - R_A}\right]$$

Thus the frequency of oscillation is

$$f = \frac{1}{t_1 + t_2}$$



00785118

FIGURE 14. 50% Duty Cycle Oscillator

Note that this circuit will not oscillate if R_B is greater than 1/2 R_A because the junction of R_A and R_B cannot bring pin 2 down to 1/3 V_{CC} and trigger the lower comparator.

ADDITIONAL INFORMATION

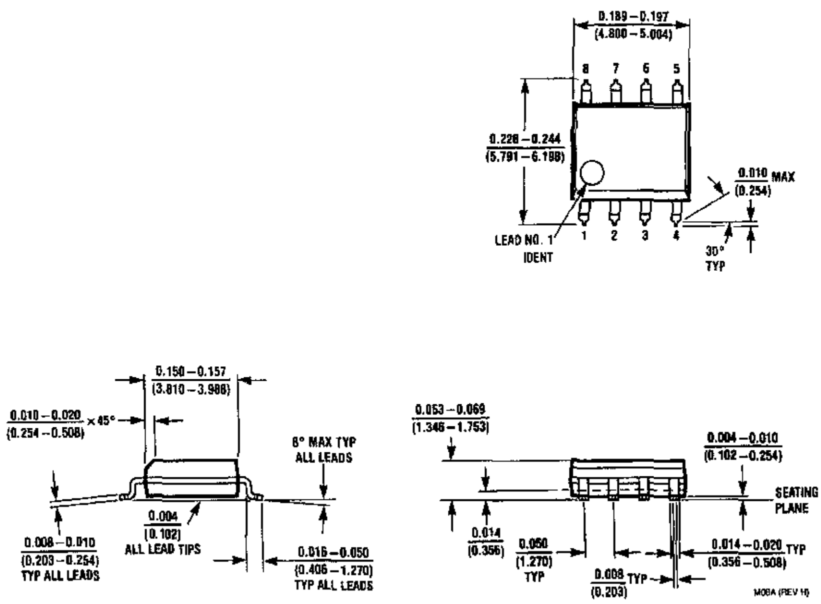
Adequate power supply bypassing is necessary to protect associated circuitry. Minimum recommended is 0.1µF in parallel with 1µF electrolytic.

Lower comparator storage time can be as long as 10µs when pin 2 is driven fully to ground for triggering. This limits the monostable pulse width to 10µs minimum.

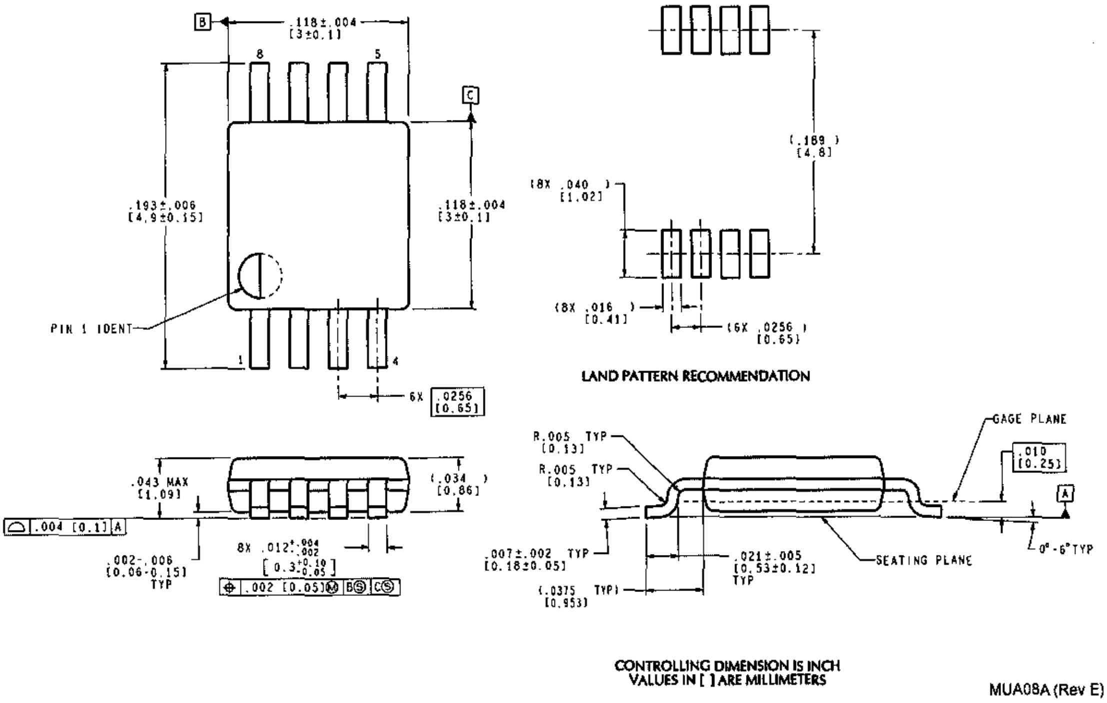
Delay time reset to output is 0.47µs typical. Minimum reset pulse width must be 0.3µs, typical.

Pin 7 current switches within 30ns of the output (pin 3) voltage.

ʼhysical Dimensions inches (millimeters) unless otherwise noted

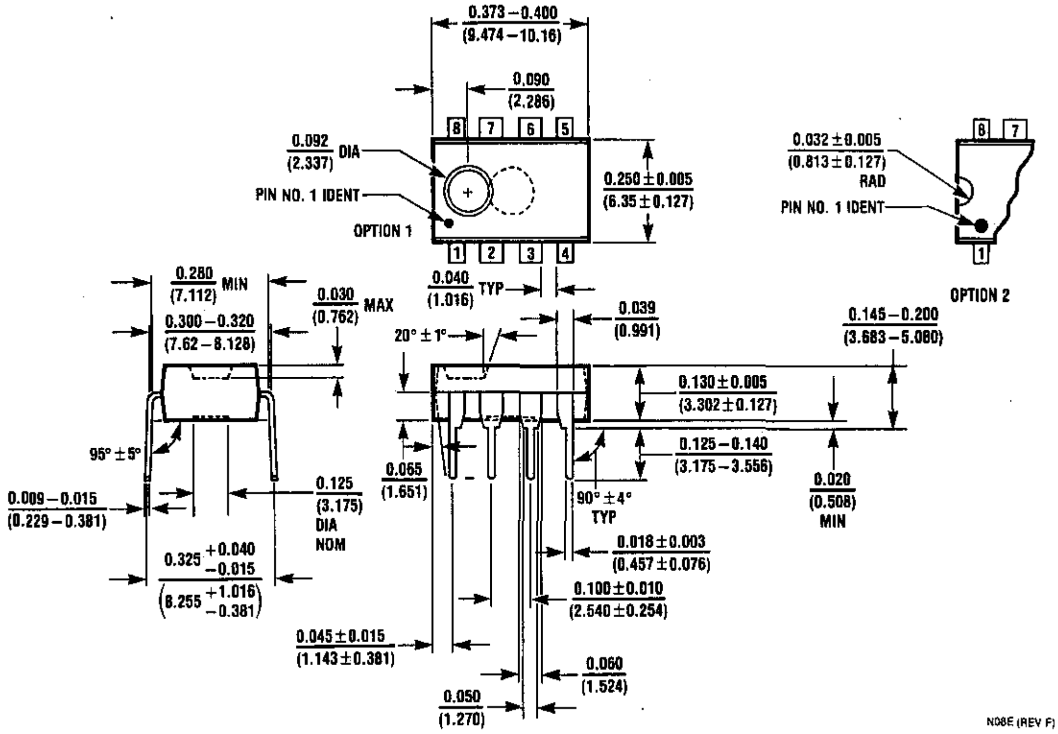


Small Outline Package (M)
NS Package Number M08A



8-Lead (0.118" Wide) Molded Mini Small Outline Package
NS Package Number MUA08A

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



Molded Dual-In-Line Package (N)
NS Package Number N08E

National Semiconductor Americas Customer Support Center
Email: new.feedback@nsc.com
Tel: 1-800-272-9959

National Semiconductor Europe Customer Support Center
Fax: +49 (0) 180-530 85 86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 69 9508 6208
English Tel: +44 (0) 870 24 0 2171
Français Tel: +33 (0) 1 41 91 8790

National Semiconductor Asia Pacific Customer Support Center
Email: ap.support@nsc.com

National Semiconductor Japan Customer Support Center
Fax: 81-3-5639-7507
Email: jpn.feedback@nsc.com
Tel: 81-3-5639-7560

www.national.com

APPENDIX E

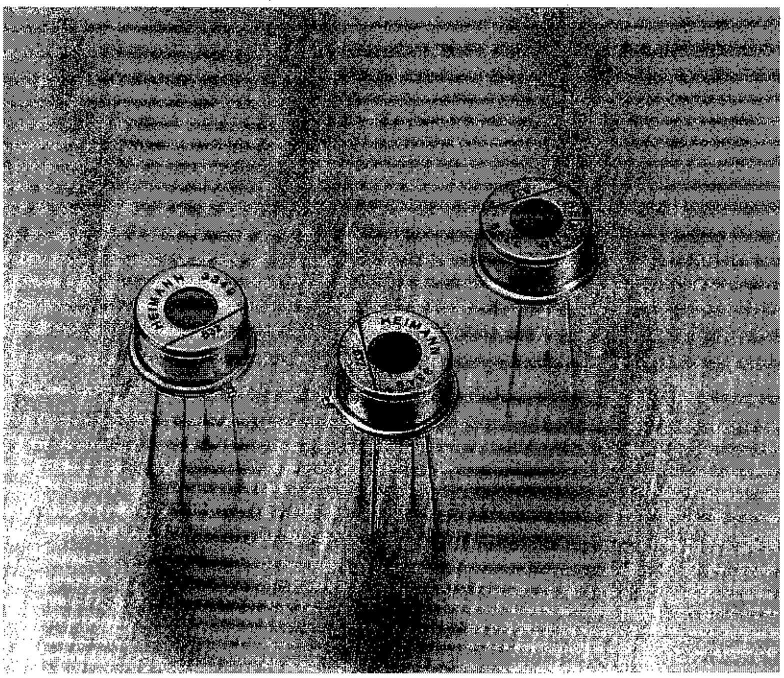
THERMOPILE DATASHEET

Optoelectronics

DATASHEET

TPS 534 - Thermopile Detector

Large Absorber Size



)escription

'he **TPS 534** thermopile sensor in a 'O 5 type housing employs a chip of .2 x 1.2 mm^2 absorber size and a ·0 kΩ thermistor as temperature eference. The round window opening ; equipped with a 5.5 µm longpass standard) infrared filter. The sensor hows a flat sensitivity characteristic ver the wavelength.

Remark: The TPS 534 can also be quipped with infrared bandpass filters or NDIR gas detection.

Features

- Large Absorber Size - High Signal Output
- Low Temperature Coefficient of Sensitivity
- Thermistor Temperature Reference included
- Applications in Pyrometers, and with Additional Bandpass Filters, in Gas Detectors

PerkinElmer®
precisely.

'PS 534 - Thermopile Detector Large Absorber Size

Figure 1. Package Drawing

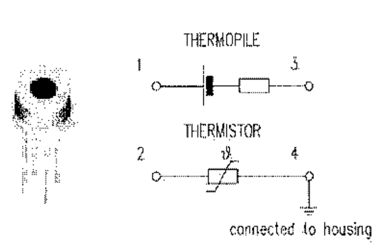


Figure 2.

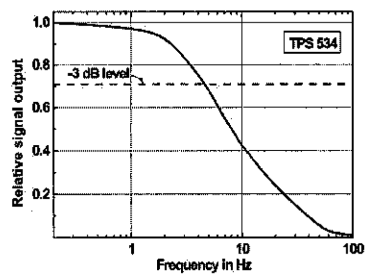
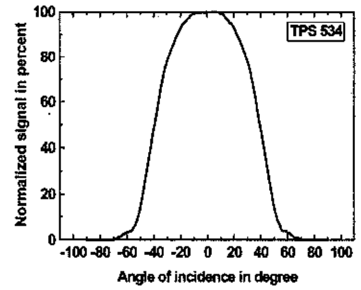


Figure 3.



'igure 4 'op View Package Dimension

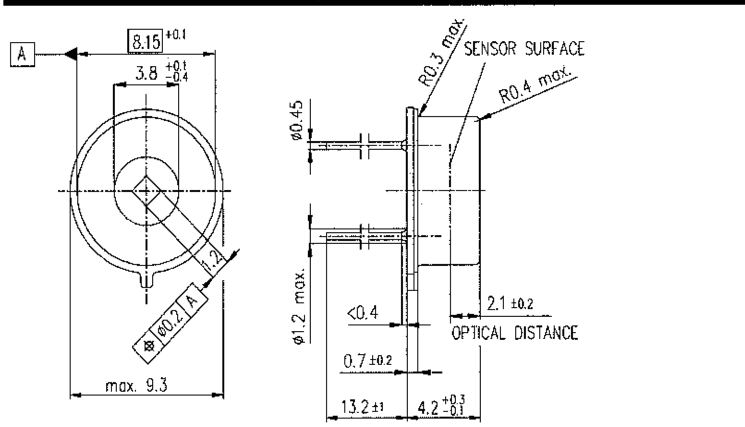
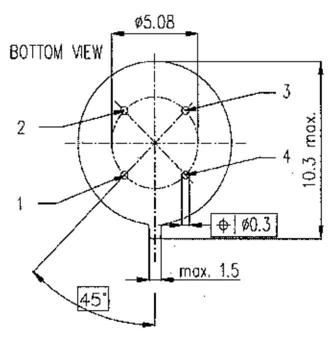


Figure 5. Bottom View



'able 1 'PS 534

Parameter	Typical	Units	Condition
Sensitive area	1.2 x 1.2	mm^2	absorbing area
Window size	3.8	mm	diameter
DC sensitivity	20	V/W	500K BB 5 ... 14µm
Resistance	40	kΩ	25°C
Noise	25	nV/√Hz	r.m.s. 300K, 1 Hz
NEP	1.26	nW/√Hz	500K BB 5 ... 14µm
D*	0.96×10^8	cm√Hz/W	500K BB 5 ... 14µm
TC of responsivity	-0.01	%/K	
TC of resistance	0.02	%/K	
Time constant	35	ms	
Operating temperature	-40 to 100	°C	non permanent
Storage temperature	-40 to 100	°C	non permanent
Thermistor resistance	30	kΩ	25°C
beta	3964	K	25°C/100°C
Field of view	80	°	at 50% points

For more information e-mail us at opto@perkinelmer.com or visit our website at **www.perkinelmer.com/optoelectronics**

All values are nominal; specifications subject to change without notice.

lorth America:
'erkinElmer Optoelectronics
6800 Trans-Canada Highway
:irkland, Quebec J7V 8P7 Canada
'oll Free: (877) 734-OPTO (6786)
'hone: +1-450-424-3300
'ax: +1-450-424-3411

Europe:
PerkinElmer Optoelectronics
Wenzel-Jaksch-Str. 31
D-65199 Wiesbaden, Germany
Phone: +49-611-492-430
Fax: +49-611-492-165

Asia:
PerkinElmer Optoelectronics
47 Ayer Rajah Crescent #06-12
Singapore 139947
Phone: +65-6770-4366
Fax: +65-6775-1008

PerkinElmer® precisely.

APPENDIX F

LOW NOISE APERATIONAL AMPLIFIER DATASHEET

DATA SHEET

NE/SA/SE5532/5532A
Internally-compensated dual low noise operational amplifier

Product specification

1997 Sept 29

IC11 Data Handbook

Philips Semiconductors

PHILIPS

DESCRIPTION

The 5532 is a dual high-performance low noise operational amplifier. Compared to most of the standard operational amplifiers, such as the 1458, it shows better noise performance, improved output drive capability and considerably higher small-signal and power bandwidths.

This makes the device especially suitable for application in high-quality and professional audio equipment, instrumentation and control circuits, and telephone channel amplifiers. The op amp is internally compensated for gains equal to one. If very low noise is of prime importance, it is recommended that the 5532A version be used because it has guaranteed noise voltage specifications.

FEATURES

- Small-signal bandwidth: 10MHz
- Output drive capability: 600Ω, $10V_{RMS}$
- Input noise voltage: $5nV/\sqrt{Hz}$ (typical)
- DC voltage gain: 50000
- AC voltage gain: 2200 at 10kHz
- Power bandwidth: 140kHz
- Slew rate: 9V/μs
- Large supply voltage range: ±3 to ±20V
- Compensated for unity gain

PIN CONFIGURATIONS

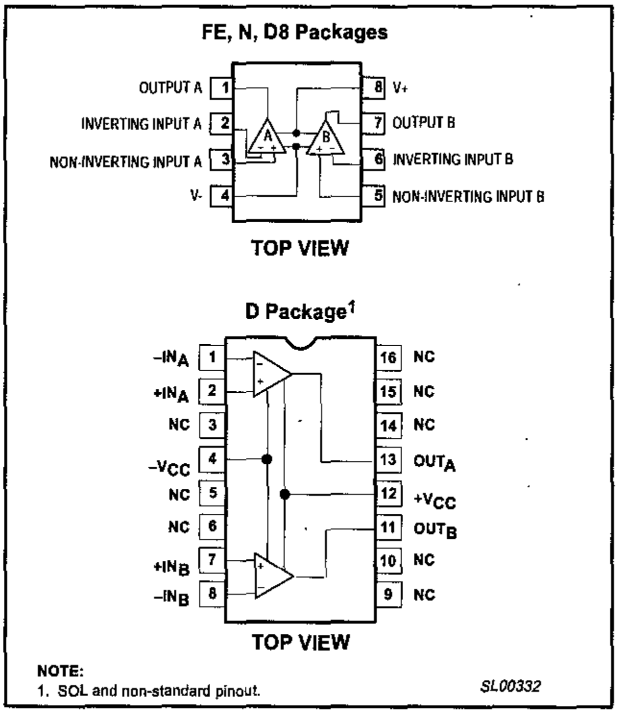


Figure 1. Pin Configurations

ORDERING INFORMATION

DESCRIPTION	TEMPERATURE RANGE	ORDER CODE	DWG #
8-Pin Plastic Dual In-Line Package (DIP)	0 to 70°C	NE5532N	SOT97-1
8-Pin Plastic Dual In-Line Package (DIP)	–40°C to +85°C	SA5532N	SOT97-1
8-Pin Plastic Dual In-Line Package (DIP)	–40°C to +85°C	SA5532AN	SOT97-1
8-Pin Ceramic Dual In-Line Package (CERDIP)	0 to 70°C	NE5532FE	0580A
8-Pin Plastic Dual In-Line Package (DIP)	0 to 70°C	NE5532AN	SOT97-1
8-Pin Ceramic Dual In-Line Package (CERDIP)	0 to 70°C	NE5532AF	0580A
8-Pin Ceramic Dual In-Line Package (CERDIP)	-55°C to +125°C	SE5532FE	0580A
8-Pin Ceramic Dual In-Line Package (CERDIP)	-55°C to +125°C	SE5532AF	0580A
8-Pin Small Outline Package (SO)	0 to 70°C	NE5532AD8	SOT96-1
8-Pin Small Outline Package (SO)	–40°C to 85°C	SA5532D8	SOT96-1
8-Pin Small Outline Package (SO)	–40°C to 85°C	SA5532AD8	SOT96-1
8-Pin Small Outline Package (SO)	-55°C to +125°C	SE5532AD8	SOT96-1
8-Pin Small Outline Package (SO)	0 to 70°C	NE5532D8	SOT96-1
8-Pin Small Outline Package (SO)	–40°C to 85°C	SA5532D8	SOT96-1
8-Pin Small Outline Package (SO)	–40°C to 85°C	SA5532AD8	SOT96-1
8-Pin Small Outline Package (SO)	-55°C to +125°C	SE5532D8	SOT96-1
16-Pin Plastic Small Outline Large (SOL) Package	0 to 70°C	NE5532D	SOT162-1
16-Pin Plastic Dual In-Line Package (DIP)	-55°C to +125°C	SE5532N	SOT38-4

EQUIVALENT SCHEMATIC (EACH AMPLIFIER)

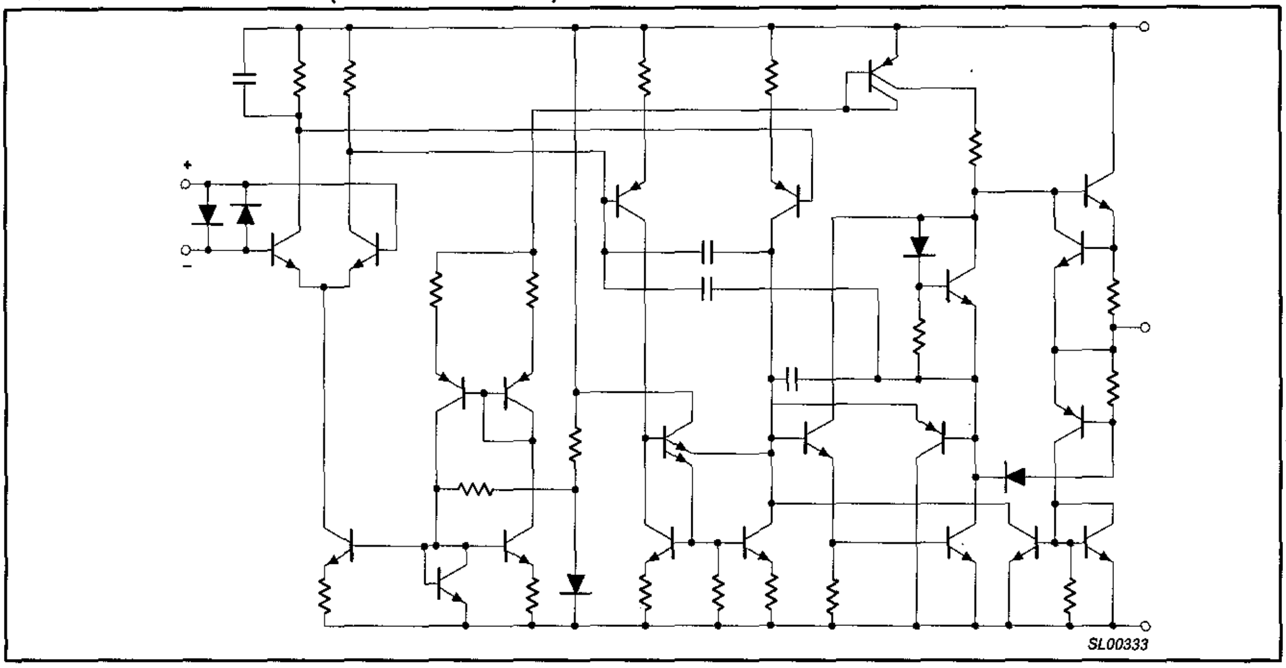


Figure 2. Equivalent Schematic (Each Amplifier)

ABSOLUTE MAXIMUM RATINGS

SYMBOL	PARAMETER	RATING	UNIT
V_S	Supply voltage	±22	V
V_{IN}	Input voltage	$\pm V_{SUPPLY}$	V
V_{DIFF}	Differential input voltage[1]	±0.5	V
T_A	Operating temperature range SA5532/A NE5532/A SE5532/A	 –40 to +85 0 to 70 -55 to +125	 °C °C °C
T_{STG}	Storage temperature	-65 to +150	°C
T_J	Junction temperature	150	°C
P_D	Maximum power dissipation, T_A=25°C (still-air)[2] 8 D8 package 8 N package 8 FE package 16 D package	 780 1200 1000 1200	 mW mW mW mW
T_{SOLD}	Lead soldering temperature (10sec max)	300	°C

NOTES:

1. Diodes protect the inputs against over-voltage. Therefore, unless current-limiting resistors are used, large currents will flow if the differential input voltage exceeds 0.6V. Maximum current should be limited to ±10mA.
2. Thermal resistances of the above packages are as follows:
   N package at 100°C/W
   F package at 135°C/W
   D package at 105°C/W
   D8 package at 160°C/W

DC ELECTRICAL CHARACTERISTICS

T_A=25°C V_S=±15V, unless otherwise specified. [1, 2, 3]

SYMBOL	PARAMETER	TEST CONDITIONS	SE/5532/5532A			NE/SA/5532/5532A			UNIT
			Min	Typ	Max	Min	Typ	Max	
V_{OS}	Offset voltage			0.5	2		0.5	4	mV
		Over temperature			3			5	mV
$\Delta V_{OS}/\Delta T$				5			5		µV/°C
I_{OS}	Offset current				100		10	150	nA
		Over temperature			200			200	nA
$\Delta I_{OS}/\Delta T$				200			200		pA/°C
I_B	Input current			200	400		200	800	nA
		Over temperature			700			1000	nA
$\Delta I_B/\Delta T$				5			5		nA/°C
I_{CC}	Supply current			8	10.5		8	16	mA
		Over temperature			13				mA
V_{CM}	Common-mode input range		±12	±13		±12	±13		V
CMRR	Common-mode rejection ratio		80	100		70	100		dB
PSRR	Power supply rejection ratio			10	50		10	100	µV/V
A_{VOL}	Large-signal voltage gain	R_L≥2kΩ, V_O=±10V	50	100		25	100		V/mV
		Over temperature	25			15			V/mV
		R_L≥600Ω, V_O=±10V	40	50		15	50		V/mV
		Over temperature	20			10			V/mV
V_{OUT}	Output swing	R_L≥600Ω	±12	±13		±12	±13		V
		Over temperature	±10	±12		±10	±12		
		R_L≥600Ω, V_S=±18V	±15	±16		±15	±16		
		Over temperature	±12	±14		±12	±14		
		R_L≥2kΩ	±13	±13.5		±13	±13.5		
		Over temperature	±12	±12.5		±10	±12.5		
R_{IN}	Input resistance		30	300		30	300		kΩ
I_{SC}	Output short circuit current		10	38	60	10	38	60	mA

NOTES:

1. Diodes protect the inputs against overvoltage. Therefore, unless current-limiting resistors are used, large currents will flow if the differential input voltage exceeds 0.6V. Maximum current should be limited to ±10mA.
2. For operation at elevated temperature, derate packages based on the package thermal resistance.
3. Output may be shorted to ground at V_S=±15V, T_A=25°C Temperature and/or supply voltages must be limited to ensure dissipation rating is not exceeded.

AC ELECTRICAL CHARACTERISTICS

T_A=25°C V_S=±15V, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	NE/SA/SE5532/5532A			UNIT
			Min	Typ	Max	
R_{OUT}	Output resistance	A_V=30dB Closed-loop f=10kHz, R_L=600Ω		0.3		Ω
	Overshoot	Voltage-follower V_{IN}=100mV_{P-P} C_L=100pF, R_L=600Ω		10		%
A_V	Gain	f=10kHz		2.2		V/mV
GBW	Gain bandwidth product	C_L=100pF, R_L=600Ω		10		MHz
SR	Slew rate			9		V/µs
	Power bandwidth	V_{OUT}=±10V		140		kHz
		V_{OUT}=±14V, R_L=600Ω, V_{CC}=±18V		100		kHz

ELECTRICAL CHARACTERISTICS

T_A=25°C V_S=±15V, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	NE/SE5532			NE/SA/SE5532A			UNIT
			Min	Typ	Max	Min	Typ	Max	
V_{NOISE}	Input noise voltage	f_O=30Hz		8			8	12	nV/√Hz
		f_O=1kHz		5			5	6	nV/√Hz
I_{NOISE}	Input noise current	f_O=30Hz		2.7			2.7		pA/√Hz
		f_O=1kHz		0.7			0.7		pA/√Hz
	Channel separation	f=1kHz, R_S=5kΩ		110			110		dB

TYPICAL PERFORMANCE CHARACTERISTICS

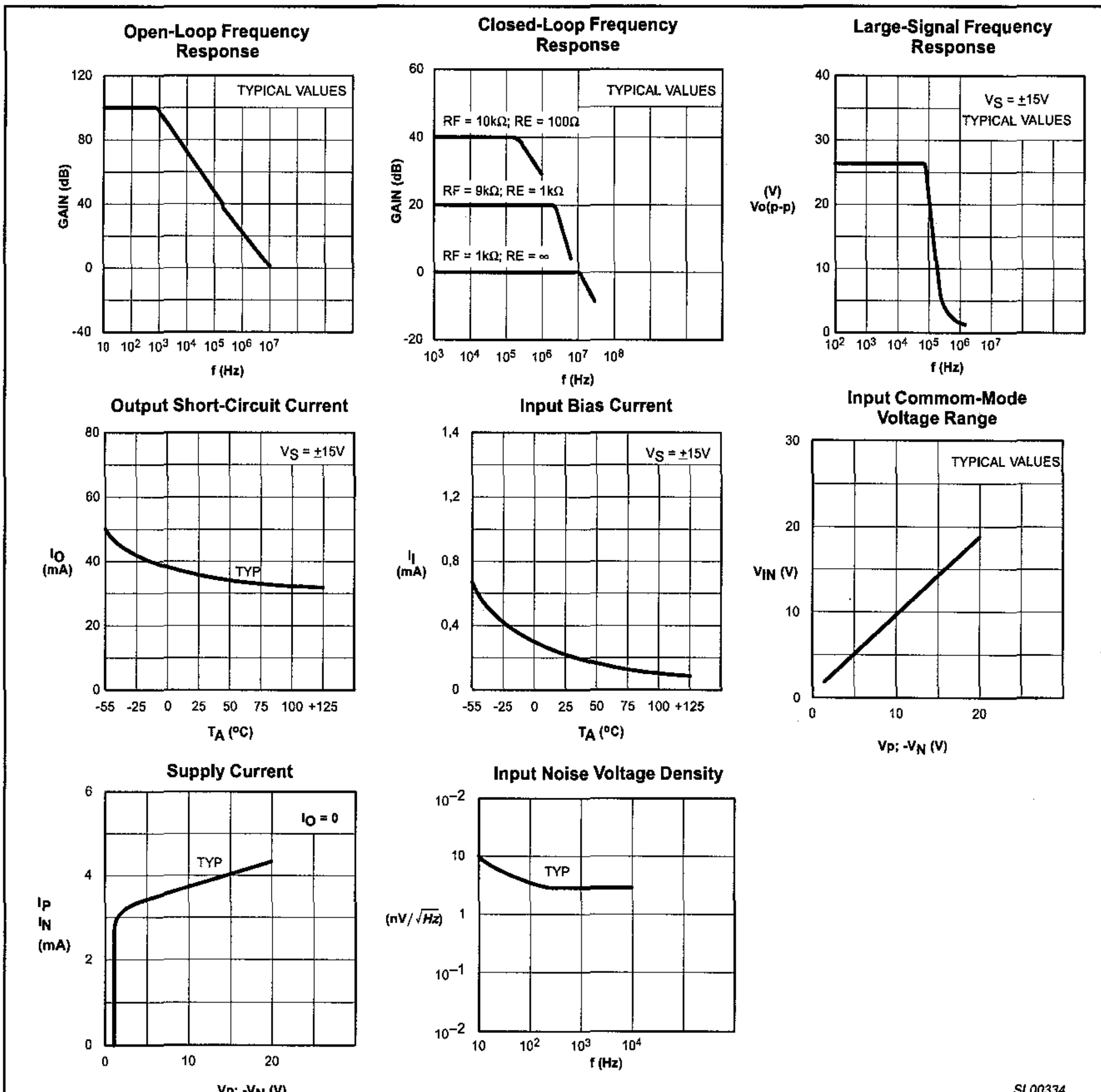


Figure 3. Typical Performance Characteristics

TEST CIRCUITS

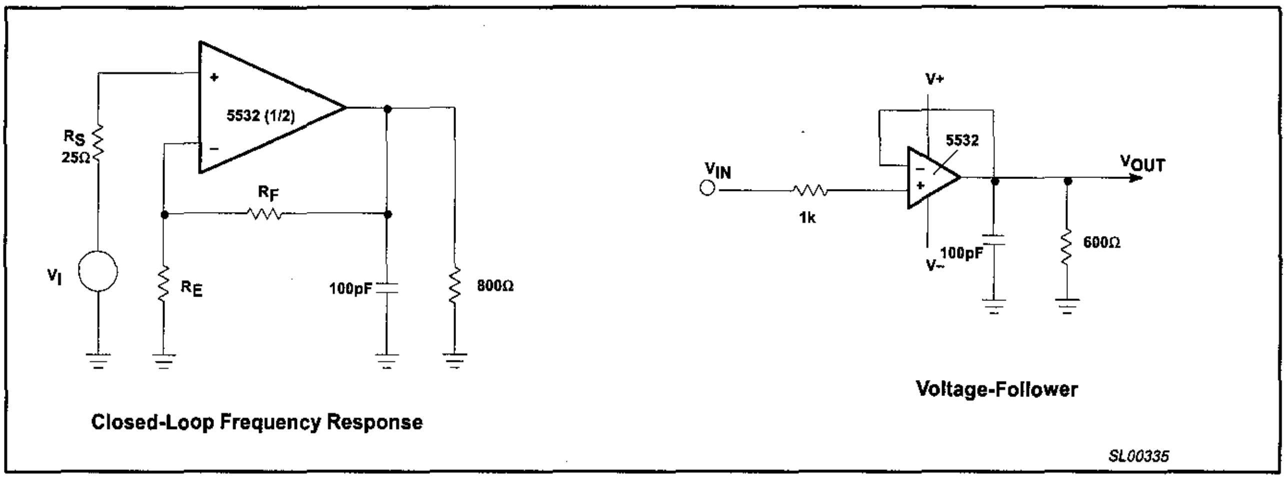
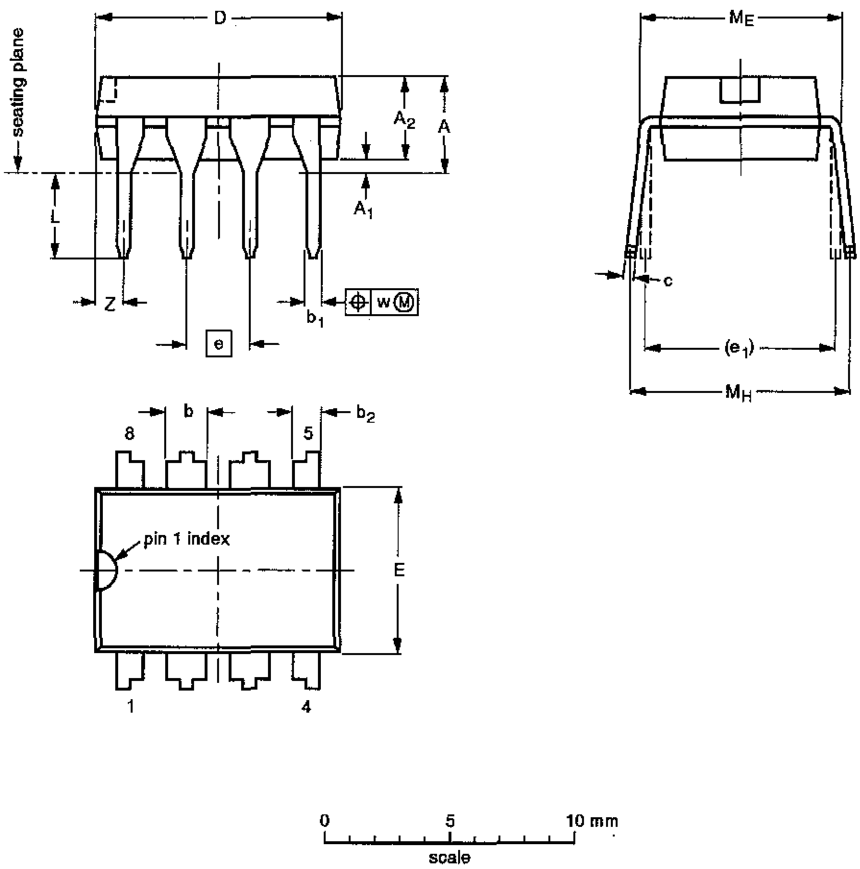


Figure 4. Test Circuits

DIP8: plastic dual in-line package; 8 leads (300 mil) SOT97-1



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

UNIT	A max.	A_1 min.	A_2 max.	b	b_1	b_2	c	D(1)	E(1)	e	e_1	L	M_E	M_H	w	Z(1) max.
mm	4.2	0.51	3.2	1.73 1.14	0.53 0.38	1.07 0.89	0.36 0.23	9.8 9.2	6.48 6.20	2.54	7.62	3.60 3.05	8.25 7.80	10.0 8.3	0.254	1.15
inches	0.17	0.020	0.13	0.068 0.045	0.021 0.015	0.042 0.035	0.014 0.009	0.39 0.36	0.26 0.24	0.10	0.30	0.14 0.12	0.32 0.31	0.39 0.33	0.01	0.045

Note

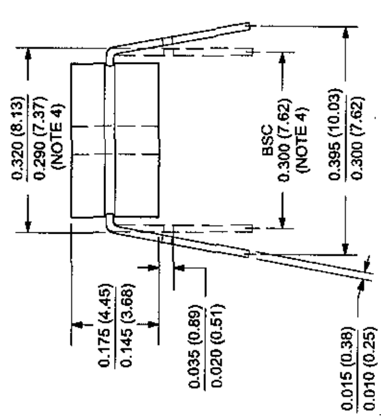
1. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

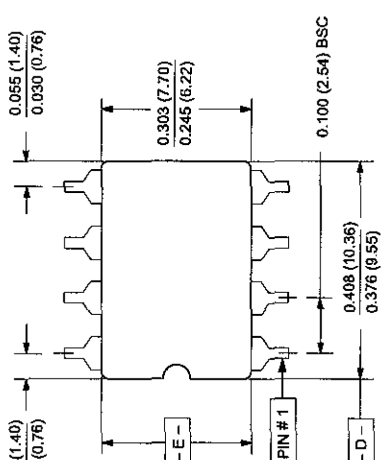
OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT97-1	050G01	MO-001AN				~~92-11-17~~ 95-02-04

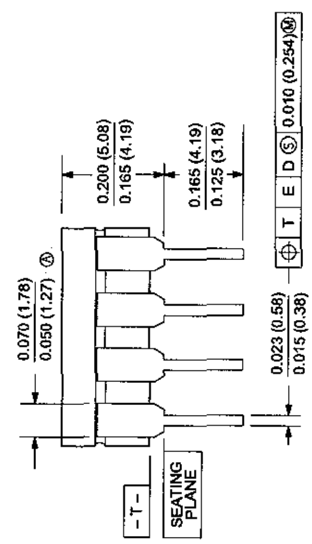
0580A 8-PIN (300 mils wide) CERAMIC DUAL IN-LINE (F) PACKAGE

NOTES:

1. Controlling dimension: Inches. Millimeters are shown in parentheses.
2. Dimension and tolerancing per ANSI Y14. 5M-1982.
3. "T", "D", and "E" are reference datums on the body and include allowance for glass overrun and meniscus on the seal line, and lid to base mismatch.
4. These dimensions measured with the leads constrained to be perpendicular to plane T.
5. Pin numbers start with Pin #1 and continue counterclockwise to Pin #8 when viewed from the top.

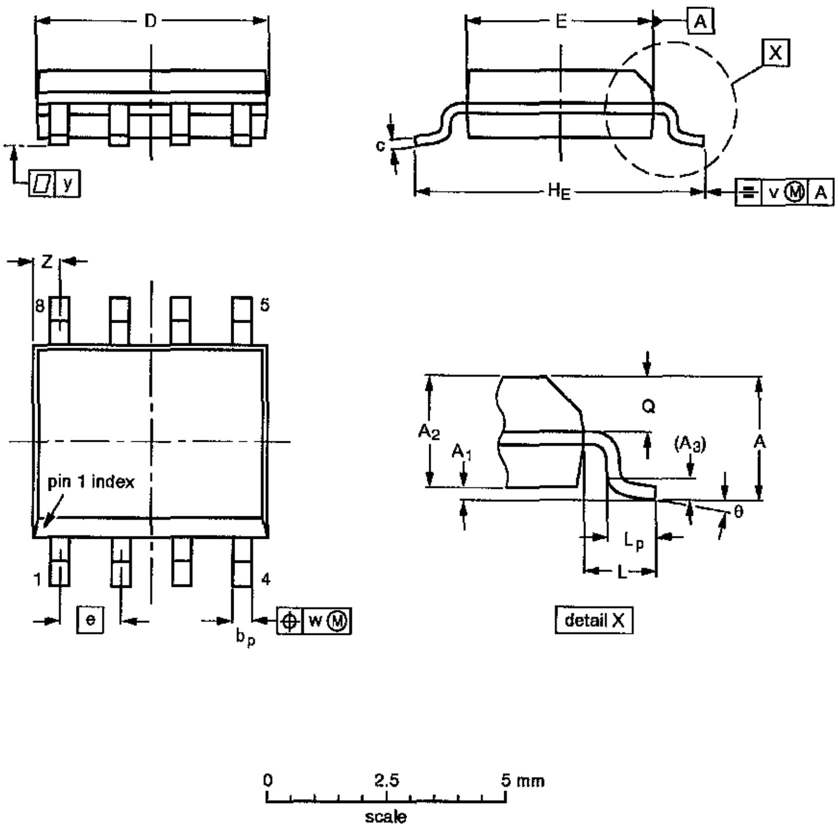






853–0580A 006688

SO8: plastic small outline package; 8 leads; body width 3.9mm — SOT96-1



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

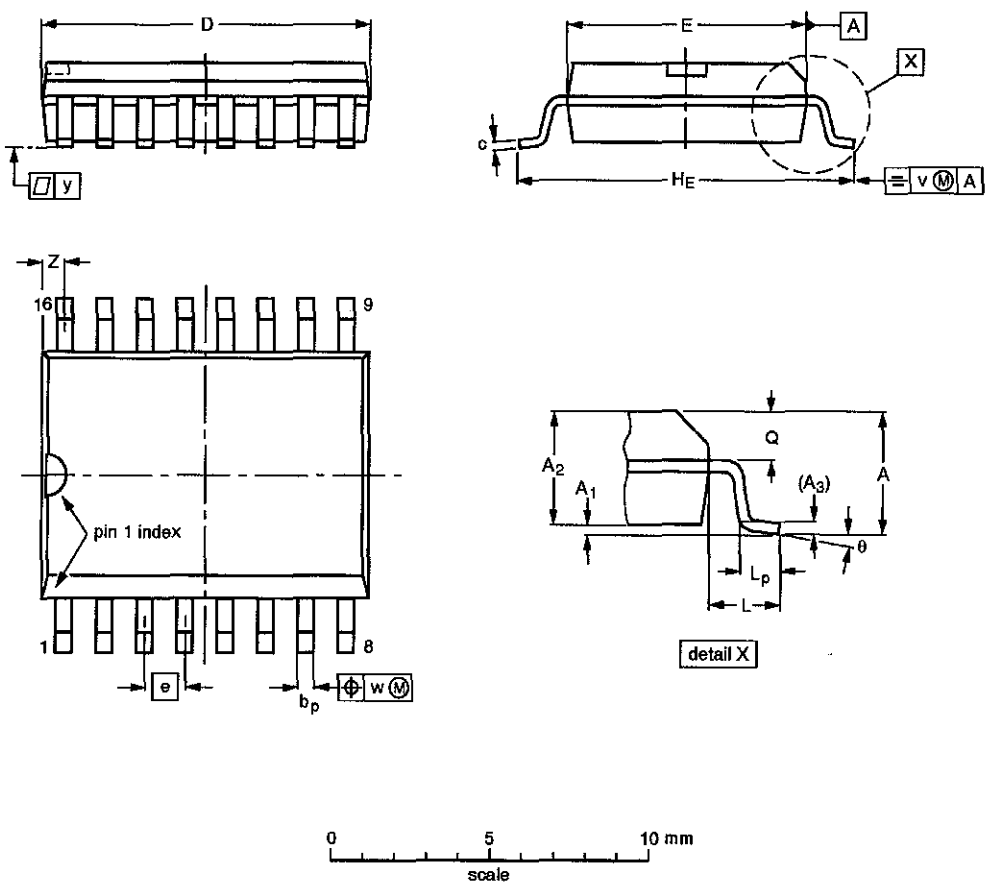
UNIT	A max.	A_1	A_2	A_3	b_p	c	D(1)	E(2)	e	H_E	L	L_p	Q	v	w	y	Z(1)	θ
mm	1.75	0.25 0.10	1.45 1.25	0.25	0.49 0.36	0.25 0.19	5.0 4.8	4.0 3.8	1.27	6.2 5.8	1.05	1.0 0.4	0.7 0.6	0.25	0.25	0.1	0.7 0.3	8° 0°
inches	0.069	0.0098 0.0039	0.057 0.049	0.01	0.019 0.014	0.0098 0.0075	0.20 0.19	0.16 0.15	0.050	0.24 0.23	0.041	0.039 0.016	0.028 0.024	0.01	0.01	0.004	0.028 0.012	

Notes

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT96-1	076E03S	MS-012AA				~~92-11-17~~ 95-02-04

SO16: plastic small outline package; 16 leads; body width 7.5 mm SOT162-1



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

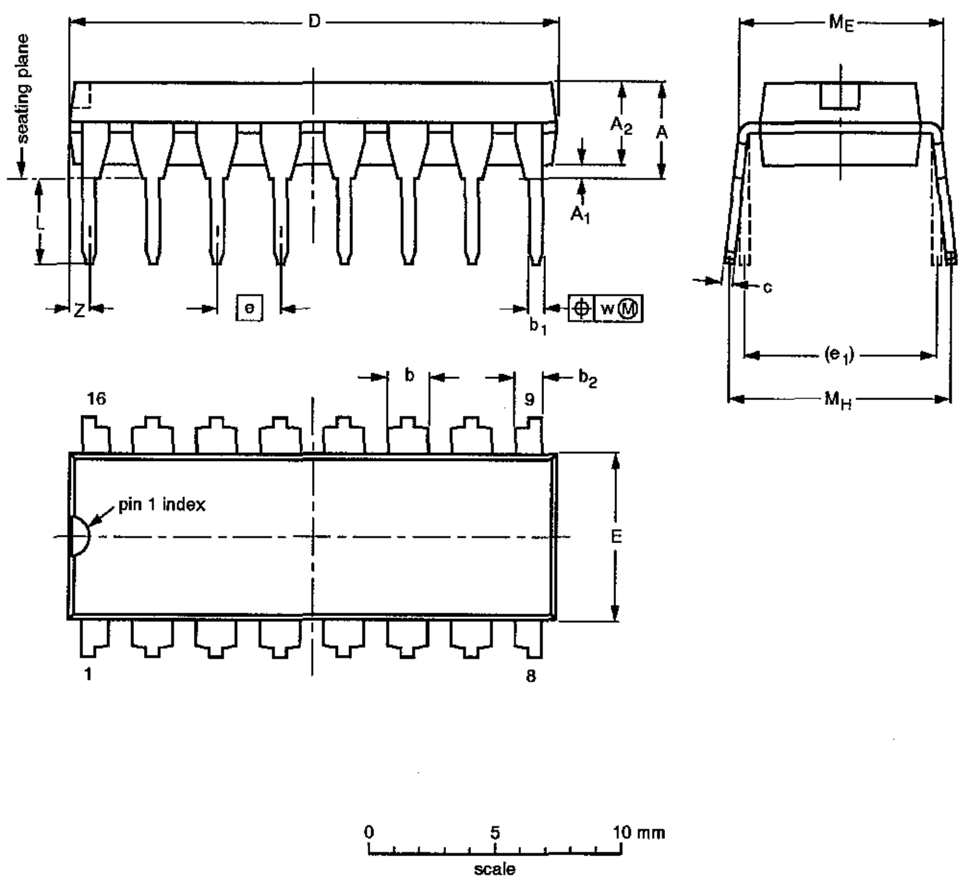
UNIT	A max.	A_1	A_2	A_3	b_p	c	D (1)	E (1)	e	H_E	L	L_p	Q	v	w	y	Z (1)	θ
mm	2.65	0.30 0.10	2.45 2.25	0.25	0.49 0.36	0.32 0.23	10.5 10.1	7.6 7.4	1.27	10.65 10.00	1.4	1.1 0.4	1.1 1.0	0.25	0.25	0.1	0.9 0.4	8° 0°
inches	0.10	0.012 0.004	0.096 0.089	0.01	0.019 0.014	0.013 0.009	0.41 0.40	0.30 0.29	0.050	0.42 0.39	0.055	0.043 0.016	0.043 0.039	0.01	0.01	0.004	0.035 0.016	

Note

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT162-1	075E03	MS-013AA				~~92-11-17~~ 95-01-24

DIP16: plastic dual in-line package; 16 leads (300 mil) SOT38-4



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

UNIT	A max.	A_1 min.	A_2 max.	b	b_1	b_2	c	D (1)	E (1)	e	e_1	L	M_E	M_H	w	Z (1) max.
mm	4.2	0.51	3.2	1.73 1.30	0.53 0.38	1.25 0.85	0.36 0.23	19.50 18.55	6.48 6.20	2.54	7.62	3.60 3.05	8.25 7.80	10.0 8.3	0.254	0.76
inches	0.17	0.020	0.13	0.068 0.051	0.021 0.015	0.049 0.033	0.014 0.009	0.77 0.73	0.26 0.24	0.10	0.30	0.14 0.12	0.32 0.31	0.39 0.33	0.01	0.030

Note

1. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT38-4						~~92-11-17~~ 95-01-14

DEFINITIONS

Data Sheet Identification	Product Status	Definition
Objective Specification	Formative or In Design	This data sheet contains the design target or goal specifications for product development. Specifications may change in any manner without notice.
Preliminary Specification	Preproduction Product	This data sheet contains preliminary data, and supplementary data will be published at a later date. Philips Semiconductors reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.
Product Specification	Full Production	This data sheet contains Final Specifications. Philips Semiconductors reserves the right to make changes at any time without notice, in order to improve design and supply the best possible product.

Philips Semiconductors
811 East Arques Avenue
P.O. Box 3409
Sunnyvale, California 94088–3409
Telephone 800-234-7381

print code Date of release: 04-96

Document order number: 9397 750 01699

Let's make things better.

Philips Semiconductors

PHILIPS

APPENDIX G

GENERAL OPERATIONAL AMPLIFIER DATASHEET

National Semiconductor

August 2000

LM741
Operational Amplifier

General Description

The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications.

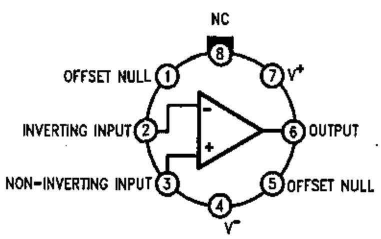
The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

The LM741C is identical to the LM741/LM741A except that the LM741C has their performance guaranteed over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

Features

Connection Diagrams

Metal Can Package

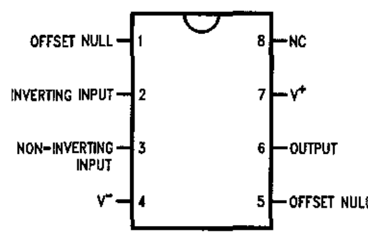


00934102

Note 1: LM741H is available per JM38510/10101

Order Number LM741H, LM741H/883 (Note 1), **LM741AH/883 or LM741CH**
See NS Package Number H08C

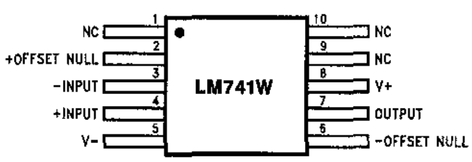
Dual-In-Line or S.O. Package



00934103

Order Number LM741J, LM741J/883, LM741CN
See NS Package Number J08A, M08A or N08E

Ceramic Flatpak

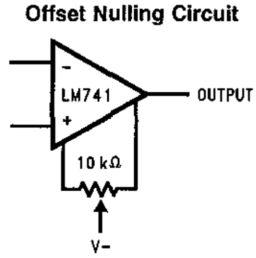


00934106

Order Number LM741W/883
See NS Package Number W10A

Typical Application

Offset Nulling Circuit



00934107

 DS009341

Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

(Note 7)

	LM741A	LM741	LM741C
Supply Voltage	±22V	±22V	±18V
Power Dissipation (Note 3)	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V
Input Voltage (Note 4)	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous
Operating Temperature Range	−55°C to +125°C	−55°C to +125°C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Junction Temperature	150°C	150°C	100°C
Soldering Information			
N-Package (10 seconds)	260°C	260°C	260°C
J- or H-Package (10 seconds)	300°C	300°C	300°C
M-Package			
Vapor Phase (60 seconds)	215°C	215°C	215°C
Infrared (15 seconds)	215°C	215°C	215°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering
surface mount devices.

	LM741A	LM741	LM741C
ESD Tolerance (Note 8)	400V	400V	400V

Electrical Characteristics (Note 5)

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	$T_A = 25°C$										
	$R_S \leq 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$R_S \leq 50\Omega$		0.8	3.0							mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 50\Omega$			4.0							mV
	$R_S \leq 10\ k\Omega$						6.0			7.5	mV
Average Input Offset Voltage Drift				15							μV/°C
Input Offset Voltage Adjustment Range	$T_A = 25°C$, $V_S = \pm 20V$	±10				±15			±15		mV
Input Offset Current	$T_A = 25°C$		3.0	30		20	200		20	200	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			70		85	500			300	nA
Average Input Offset Current Drift				0.5							nA/°C
Input Bias Current	$T_A = 25°C$		30	80		80	500		80	500	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			0.210			1.5			0.8	μA
Input Resistance	$T_A = 25°C$, $V_S = \pm 20V$	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $V_S = \pm 20V$	0.5									MΩ
Input Voltage Range	$T_A = 25°C$							±12	±13		V
	$T_{AMIN} \leq T_A \leq T_{AMAX}$				±12	±13					V

Electrical Characteristics (Note 5) (Continued)

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
arge Signal Voltage Gain	$T_A = 25°C$, $R_L \geq 2\ k\Omega$										
	$V_S = \pm 20V$, $V_O = \pm 15V$	50									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				50	200		20	200		V/mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$,										
	$R_L \geq 2\ k\Omega$,										
	$V_S = \pm 20V$, $V_O = \pm 15V$	32									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				25			15			V/mV
	$V_S = \pm 5V$, $V_O = \pm 2V$	10									V/mV
'utput Voltage Swing	$V_S = \pm 20V$										
	$R_L \geq 10\ k\Omega$	±16									V
	$R_L \geq 2\ k\Omega$	±15									V
	$V_S = \pm 15V$										
	$R_L \geq 10\ k\Omega$				±12	±14		±12	±14		V
	$R_L \geq 2\ k\Omega$				±10	±13		±10	±13		V
utput Short Circuit	$T_A = 25°C$	10	25	35		25			25		mA
urrent	$T_{AMIN} \leq T_A \leq T_{AMAX}$	10		40							mA
ommon-Mode	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
ejection Ratio	$R_S \leq 10\ k\Omega$, $V_{CM} = \pm 12V$				70	90		70	90		dB
	$R_S \leq 50\Omega$, $V_{CM} = \pm 12V$	80	95								dB
ıpply Voltage Rejection	$T_{AMIN} \leq T_A \leq T_{AMAX}$,										
ıtio	$V_S = \pm 20V$ to $V_S = \pm 5V$										
	$R_S \leq 50\Omega$	86	96								dB
	$R_S \leq 10\ k\Omega$				77	96		77	96		dB
ansient Response	$T_A = 25°C$, Unity Gain										
Rise Time			0.25	0.8		0.3			0.3		µs
Overshoot			6.0	20		5			5		%
ındwidth (Note 6)	$T_A = 25°C$	0.437	1.5								MHz
ew Rate	$T_A = 25°C$, Unity Gain	0.3	0.7			0.5			0.5		V/µs
ıpply Current	$T_A = 25°C$					1.7	2.8		1.7	2.8	mA
›wer Consumption	$T_A = 25°C$										
	$V_S = \pm 20V$		80	150							mW
	$V_S = \pm 15V$					50	85		50	85	mW
LM741A	$V_S = \pm 20V$										
	$T_A = T_{AMIN}$			165							mW
	$T_A = T_{AMAX}$			135							mW
LM741	$V_S = \pm 15V$										
	$T_A = T_{AMIN}$					60	100				mW
	$T_A = T_{AMAX}$					45	75				mW

ʼlote 2: "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is unctional, but do not guarantee specific performance limits.

Electrical Characteristics (Note 5) (Continued)

Note 3: For operation at elevated temperatures, these devices must be derated based on thermal resistance, and T_j max. (listed under "Absolute Maximum Ratings"). $T_j = T_A + (\theta_{jA} P_D)$.

Thermal Resistance	Cerdip (J)	DIP (N)	HO8 (H)	SO-8 (M)
θ_{jA} (Junction to Ambient)	100˚C/W	100˚C/W	170˚C/W	195˚C/W
θ_{jC} (Junction to Case)	N/A	N/A	25˚C/W	N/A

Note 4: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

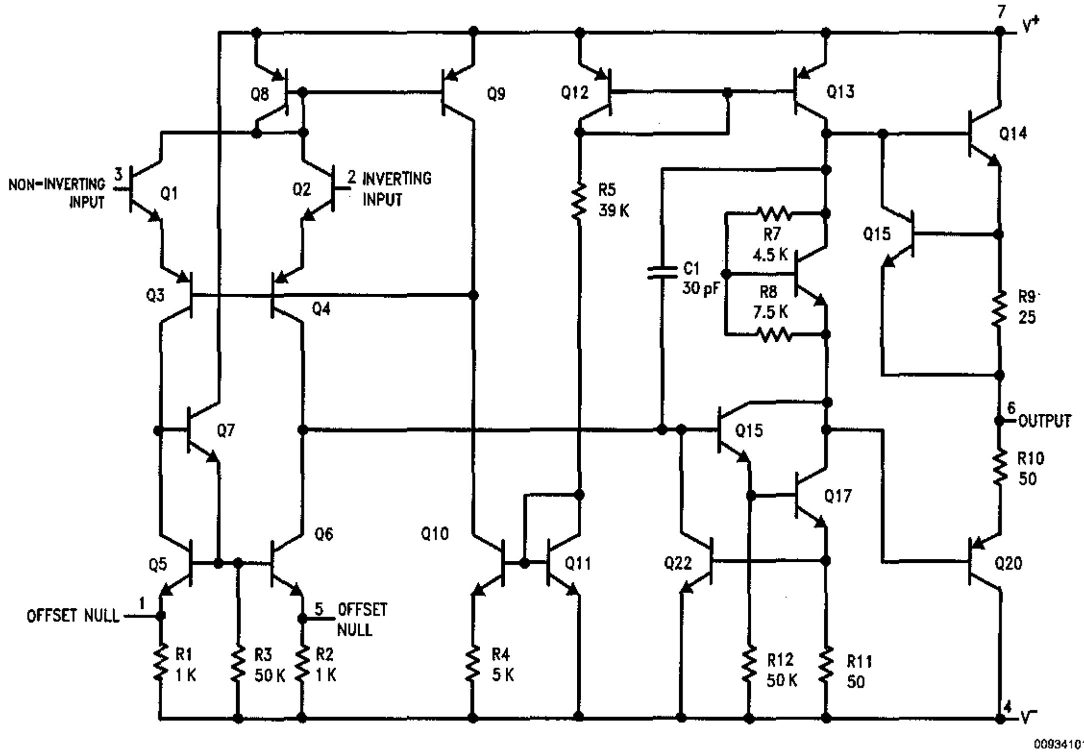
Note 5: Unless otherwise specified, these specifications apply for V_S = ±15V, −55˚C ≤ T_A ≤ +125˚C (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to 0˚C ≤ T_A ≤ +70˚C.

Note 6: Calculated value from: BW (MHz) = 0.35/Rise Time(µs).

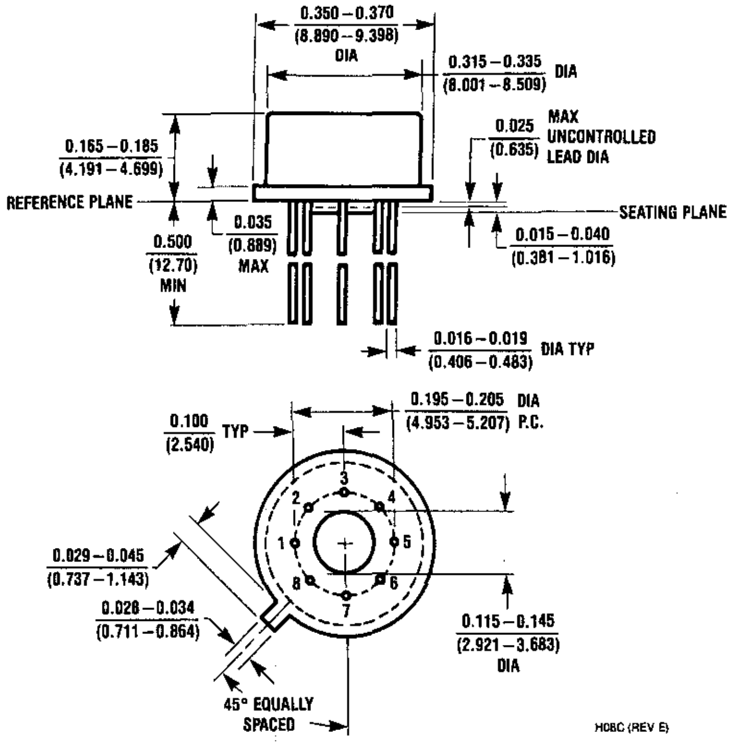
Note 7: For military specifications see RETS741X for LM741 and RETS741AX for LM741A.

Note 8: Human body model, 1.5 kΩ in series with 100 pF.

Schematic Diagram

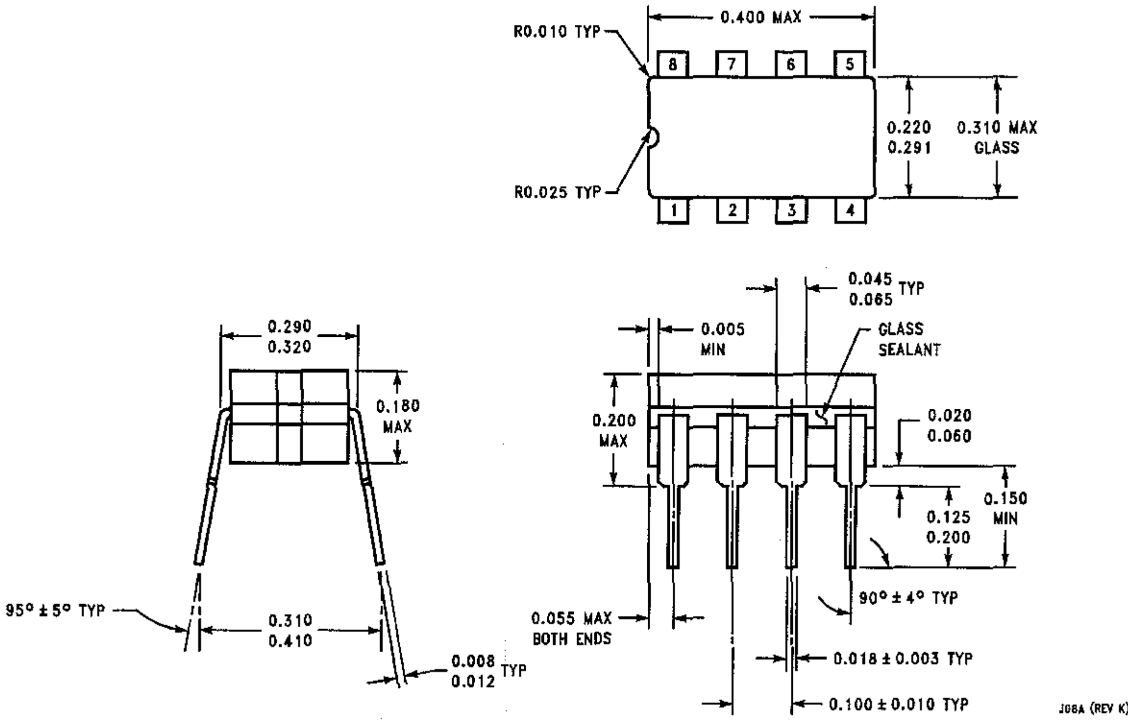


Physical Dimensions inches (millimeters) unless otherwise noted

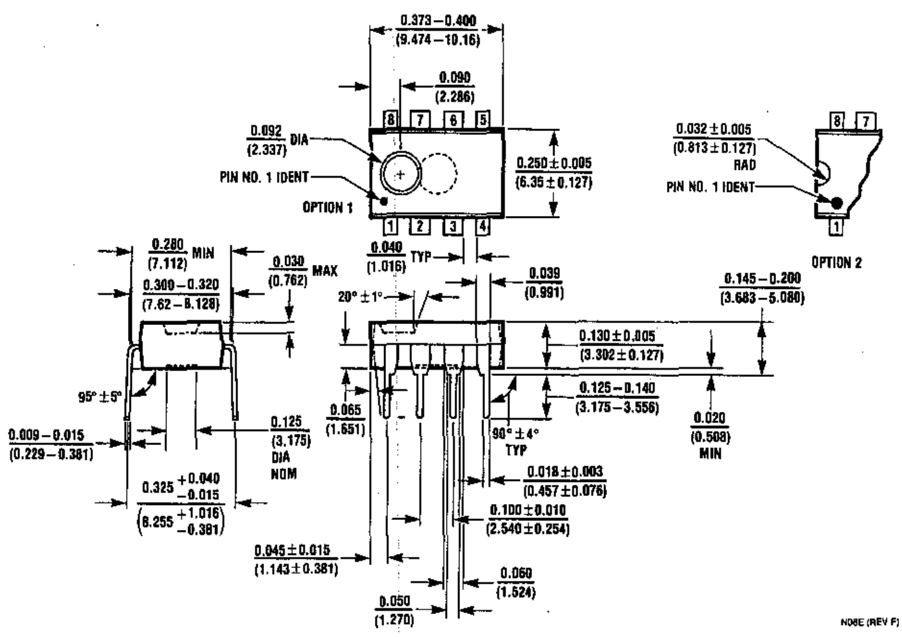


Metal Can Package (H)
Order Number LM741H, LM741H/883, LM741AH/883, LM741AH-MIL or LM741CH
NS Package Number H08C

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

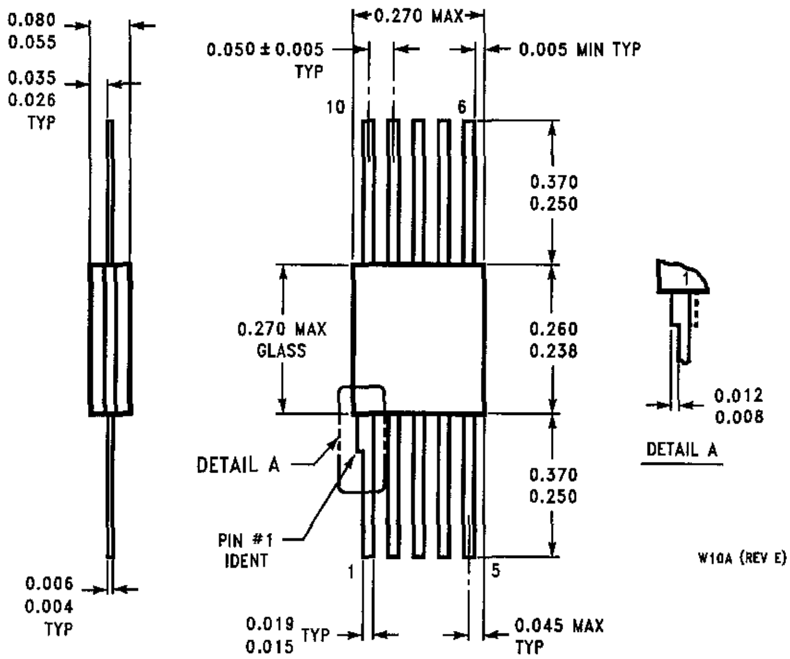


Ceramic Dual-In-Line Package (J)
Order Number LM741J/883
NS Package Number J08A



Dual-In-Line Package (N)
Order Number LM741CN
NS Package Number N08E

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



10-Lead Ceramic Flatpak (W)
Order Number LM741W/883, LM741WG-MPR or LM741WG/883
NS Package Number W10A

National Semiconductor
Americas Customer
Support Center
Email: new.feedback@nsc.com
Tel: 1-800-272-9959

National Semiconductor
Europe Customer Support Center
Fax: +49 (0) 180-530 85 86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 69 9508 6208
English Tel: +44 (0) 870 24 0 2171
Français Tel: +33 (0) 1 41 91 8790

National Semiconductor
Asia Pacific Customer
Support Center
Email: ap.support@nsc.com

National Semiconductor
Japan Customer Support Center
Fax: 81-3-5639-7507
Email: jpn.feedback@nsc.com
Tel: 81-3-5639-7560

ɹw.national.com