Palestine Polytechnic University

College of Engineering & Technology

Electrical & Computer Engineering Department

Graduation Project

Transmission of Data Using LASER

Project Team

Ibtihal W. AL-Fatafta

Reem Y. Sayyed Ahmad

Project Supervisor

Dr. Ghandi Manasra

Hebron- Palestine

2010/2009

جامعة بوليتكنك فلسطين

الخليل- فلسطين

كلية الهندسة و التكنولوجيا

اسم المشروع

نقل معلومات (اشارة صوتية)باستخدام اشعة الليزر

اسماء الطلبة

ابتهال فطافطة　　　　　　　　　　ريم سيد احمد

بناء على نظام كلية الهندسة والتكنولوجيا واشراف و متابعة المشرف المباشر على المشروع و موافقة أعضاء اللجنة الممتحنة تم تقديم هذا المشروع الى دائرة الهندسة الكهربائية و الحاسوب و ذلك للوفاء بمتطلبات درجة البكالوريوس في الهندسة تخصص هندسة كهربائية فرع هندسة اتصالات و الكترونيات.

توقيع المشرف

....

توقيع اللجنة الممتحنة

....　　............................　　...................................

توقيع رئيس الدائرة

....

PALESTINE POLYTECHNIC UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Graduation Project

Transmission of Data Using LASER

Project Team

Ibtihal Fatafta **Reem Sayyed Ahmad**

According to the system of the College of Engineering and Technology, and to the recommendation of the Project Supervisor, this project is presented to Electrical and Computer Engineering Department as a part of requirements of B.Sc. degree in Electrical Engineering – Communication and Electronic Engineering.

Project Supervisor signature

…………………………...

Testing Group signature

………………...   ……………………….   ……………...…

Department Headmaster signature

………………………………….

Hebron-Palestine

DEDICATION

To our fathers

To our mothers

To our brothers and sisters

To our teachers

To our friends

To everyone who helped us

To whom we love

We dedicate our humble effort

Acknowledgment

We want to thank all the people who have direct or indirect contributions in our project.

Also we want to thank

Dr-Ghandi Manasra the supervisor for his efforts …

Also we want to express our deepest gratitude to Eng- Walid Keishi For guidance and valuable information.

And Special thanks for Eng- Mohammad Qabaja for his great effort to success our project.

Ibtihal Fatafta

Reem Sayyed Ahmad

Abstract

In this project, a system for modulating a voice signal using the laser beam as a carrier signal has been constructed.

This system in general consists of two parts, the transmitter where the amplitude modulation process happens to modulate the voice signal using laser beam as carrier.

The laser diode used in this project provides laser beam of 650nm wave length and 5mW of light power. Therefore, the modulated signal can be received by photosensitive resistor LDR in the receiver side which apart from the transmitter by several meters, and then the signal will be processed by a power audio amplifier to extract the voice signal from the modulated signal.

A concave mirror behind the sensitive resistor was used to improve the system by collecting all the laser beam in the focus point of the mirror and make use of all laser power.

الملخص

يهدف هذا المشروع الى بناء نظام قادر على نقل الصوت من مكان الى أخر وذلك باستخدام أشعة الليزر كحامل لإشارة الصوت.

يتكون هذا النظام بشكل أساسي من جزأين، الجزء الأول هو عبارة عن المرسل حيث استخدم فيه ليزر ديود ليكون مصدرا لأشعة الليزر التي سيتم تحميل إشارة الصوت عليها ليتم بعد ذلك إرسالها ومن ثم استقبالها في الجزء الثاني من النظام والذي يمثل المستقبل الذي يبعد مسافة لا تقل عن مئة متر عن المرسل حيث يتم فيه استرجاع إشارة الصوت مرة ثانية.

لزيادة فعالية النظام تم إضافة مرآة مقعرة في جهة المستقبل لتتجمع في بؤرتها جميع أشعة الليزر للتخلص من تشتت الأشعة.

List of contents

List of tables

List of figures

List of appendices

1

Chapter One

Introduction

1.1 Introduction

1.2 Project Objective

1.3 The Importance of the Project

1.4 Lecturer Review

1.5 Time Plan

1.6 Estimated Cost

1.7 Risk Management

1.8 Project contents

Chapter One

Introduction

1.1 Introduction:

As the need for a higher bandwidth to transmit the data with a high speed is increasing, optical communication became a very important technology in communication field. Optical communication is the transmission of data by means of the visible and infrared portion of the electromagnetic spectrum.

Optical communication is one of the newest and most advanced forms of communication by electromagnetic waves. In one sense, it differs from radio and microwave communication only in that the wavelengths employed are shorter or equivalently, the frequencies employed are higher. However, in another very real sense it differs markedly from these older technologies because, for the first time, the wavelengths involved are much shorter than the dimensions of the devices which are used to transmit, receive and otherwise handle the signals [1].

The advantages of optical communication are threefold. Firstly: the high frequency of the optical carrier (typically of the order of 300,000 GHz) permits much more information to be transmitted over a single channel than that possible with a conventional radio or microwave system. Another advantage is that the very short wavelength of the optical carrier typically of the order of 1 micrometer permits the realization of very small, compact components. Lastly: the highest transparency for electromagnetic radiation yet achieved in any solid material is that of silica glass in the wavelength region 1–1.5 μm. This transparency is orders of magnitude higher than that of any other solid material in any other part of the spectrum [4].

Because of the advantages of the optical signals as a carrier over the other types of signals we decided to transmit a voice signal with a high speed for a distance more than 100m using a laser beam. And because the speech signal is a continuous signal, the amplitude modulation had been used to modulate this signal on the optical carrier, while all other communication techniques are possible.

In the following sections a brief discussion about the importance of the project, the literature review, the time line of the project, economical study and the risk management are presented forward.

1.2 Project objectives:

The project aims at designing a system that consists of a transmitter which transmits a voice signal on the laser beam using AM modulation, then receive the signal after a certain distance and demodulate it to get the voice signal a gain at the receiver side.

1.3 The importance of the project:

By improving this system to a longer distance; one can have several advantages as transmitting many kinds of data using the laser, because the laser has a wide band width depending on the color of the beam. The beam of the laser is coherent and directed, so interference with other types of signals would be lower. Also the security in this system is higher because it is not easy to detect the beam of the laser or knowing the transmitter position.

This project opens a wide range of using laser systems in transmitting different kinds of data, this is done by changing the kind of the laser or by changing the kind of the modulation.

1.4 Literature review:

The principle of the laser was first presented in 1917, when physicist Albert Einstein described the theory of stimulated emission. However, it was not until the late 1940s that engineers began to utilize this principle for practical purposes [13]. Nowadays, several experiments and research using laser to transmit the data had been done, here is some of what the group used.

First of all, in reference [1], a designed system that transmits an audio signal based on amplitude modulation using laser beam as a carrier for a distance of (40 - 50m) was implemented.

In reference [2], Georgia State University (GSU) published an article about the laser beam and its characteristics, applications and structure.

In reference [3], Tuominen gave a design of a system that consists of a transmitter with a first light source for transmitting high intensity power using laser, and a second light source arranged around the first one to transmit lower intensity power to prevent the effect of the first light source on eyes, and two photo detectors to receive the transmitted power.

In reference [4], a designed system that transmits the audio signal using FM by the laser beam as a carrier for a short distance was designed.

1.5 Time plan

The following table defines the main tasks in the project:

Table (1.1): Time line for finishing the project

T1	Project Definition	1 Week
T2	Collecting data	14 Weeks
T3	Analysis	8 Weeks
T4	Design	8 Weeks
T5	Theoretical calculation	2 Weeks
T6	Building and testing the system	4 Weeks
T7	Documentation	8 Weeks

The time of the project is scheduled over 16 weeks, table 1.2 shows how the work was scheduled over this time:

Table (1.2): Time plan table

Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T1																
T2																
T3																
T4																
T5																
T6																
T7																

1.6 Estimated cost

The following is a list of different costs needed to implement the system:

Table (1.3): Estimated costs

Number	Object	Cost(NIS)
1	Laser	45
2	Resistors	6
3	Capacitors	26
4	Transistors	32
5	Microphone	8
6	Potentiometer	10
7	Bred board	18
8	Printing board	70
9	LDR	5
10	ICs	24
11	Speaker	12
12	Batteries	10
13	Mirror	95
14	Diodes	12
15	حامض نحاس	60
16	كاوي لحام	130
17	Shield	10
18	Solder 0.8	45
19	Aluminum	100
Total cost (NIS)		**718**

1.7 Risk management

As mentioned in section one in this chapter the first problem that the group has been met is that the whole system including the theoretical analysis and system design must be finished in one semester because we were forced to change our old project. When we started designing the new system, multiple difficulties have arisen including: the problem in finding different hardware components, deciding on the way to do the line of sight between the transmitter and the receiver and the problem of meeting there time with the time table that is suggested to work according to at the beginning of the semester

1.8 Project contents

This chapter mainly discussed the definition of the project from multiple sides, its objectives and importance. Then it discussed some studies in using laser beam in communication applications and talking about the time plan and the estimated costs of the system components that were needed to implement the designed system. Finally the difficulties that the group faced throughout the project were presented.

In the following chapter the principle of the laser beam which is used as carrier in the system is explained. this includes its definition, characteristic and types.

The amplitude modulation process which is the main process in the system has been explained in chapter three, which also includes the demodulation process.

In chapter four, the general block diagram of the system is designed and discussed; also this chapter includes the explanation of the circuits that were implemented in this project.

The results of the tested system were explained in chapter five. This was followed by providing some conclusions and future recommendations to improve the system.

2

Chapter Two

Theoretical Background

Chapter Two

Laser Concept

This chapter discusses the definition of the laser, characteristics and types as well as presenting justifications for why it was used as a carrier in our system.

2.1 The Definition of Laser

Stimulated emission is a process similar to absorption, but operates in the opposite direction. In absorption, an incoming photon is absorbed by an atom, leaving the atom in an excited state and annihilating the photon in the process. In stimulated emission, an incoming photon stimulates an excited atom to give up its stored energy in the form of a photon that is identical in wavelength, direction, polarization, and phase to the stimulus photon. If the excited atom is unable to produce a photon that matches the incoming photon, then stimulated emission cannot take place.

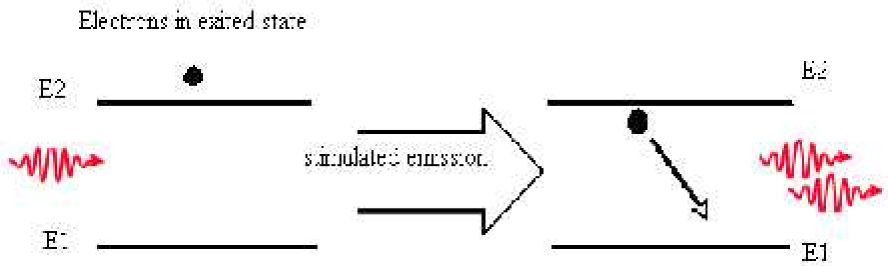


Figure 2.1: The Stimulated Emission

The above figure (2.1) shows the stimulated emission technique. The stimulated emission can be modeled mathematically by considering an atom which may be in one of two electronic energy states, the *ground state* (1) and the *excited state* (2), with energies E_1 and E_2 respectively.

If the atom is in the excited state, it may decay into the ground state by the process of spontaneous emission, releasing the difference in energies between the two states as a photon. The photon will have frequency ν and energy *h*ν, given by:

$$E_2 - E_1 = h\nu \qquad (1)$$

Where *h* is Planck's constant.

Alternatively, if the excited-state atom is perturbed by the electric field of a photon with frequency ν, it may release a *second* photon of the same frequency, in phase with the first photon. The atom will again decay into the ground state. This process is known as stimulated emission [2].

For laser action to occur, a majority of the atoms in the active medium must be excited into an energetic state, creating a population inversion of energized atoms ready to emit light. This is generally accomplished by pumping the atoms optically or electrically. As a photon passes through the collection of excited atoms, it can stimulate the generation of many trillions of photons, or more, creating an avalanche of light. The active medium can thus be regarded as an amplifier that takes in a small signal (one photon, say) and delivers a large signal (many photons, all identical to the first) at the output. This amplification, or gain, is provided by stimulated emission; hence the term laser, which is actually an acronym for light amplification by stimulated emission of radiation [8].

2.1.1 Laser characteristics

Lasers have many characteristics that can be utilized for different applications in engineering industries, like pollution monitoring, non-destructive testing, holography, laser material processing, etc. These find applications in the nuclear industry due to easy transportability of laser beams over long distances without many distortions.

Given below are the main characteristics of lasers:

1- **Directional:** all the atoms in the laser beam travels in the same direction and have the same plane of polarization.

2- **Monochromatic:** the light waves have the same wavelength (or the same colors).
3- **High intensity:** the light waves in a laser beam have very high frequency. Thus, the energy of the laser beam is also very high.
4- **Coherence:** all the light waves in a laser beam are in phase with each other. The word coherence means that the radiations emitted by atoms, molecules, or photons in the source have same phase, same direction, same plane of polarization, and same wavelength or color (monochromatic).

The other characteristics responsible for the high-quality performance by lasers are high power densities and focus ability. The power density and interaction time can be varied to achieve the desirable conditions for different processes [8].

So, depending on these different characteristics, this project would use the laser to transmit the data, to have lower interference and higher speed of transportation.

Now, the system would use the laser as a carrier, but what type of laser would be used.

2.1.2 Types of lasers

Lasers can be broadly classified into three types according to the physical state. The gas lasers, the solid state lasers and the liquid lasers.

1) Gas lasers: The most important are CO_2 and excimer lasers. Helium neon laser gives bright red ray of 630 nm wave length, which suitable for lab optics experiments; laser can be generated by passing electric current through gas filled tube with high reflective ends and high voltage of 2-4 kv. Using CO_2 gas can generate high power laser, tens of watts.

2) Liquid lasers: The medium is a dye solution, as a result of which the color of the laser light can be varied over a wide range.

3) Solid-state type lasers: The most important one is the neodymium-YAG laser. The medium in this case is a synthetically produced monocrystal, yttrium-aluminumgarnet, in which some yttrium ions have been replaced by neodymium ions. Semi-conductor diode laser is a type of solid state lasers.

Semiconductor laser is a laser in which semiconductor serves as photon source. All diode lasers are built from semiconductor materials, and all electric properties which are characteristics of electrical diodes are the same [2].

A laser diode consists of a p-n diode with an active region where electrons and holes recombine resulting in the light emission. In addition, a laser diode contains an optical cavity where the stimulated emission takes its place. The laser cavity consists of a waveguide terminated on each end by a mirror. As an example, the structure of an edge-emitting laser diode is shown in figure 2.2. Photons, which are emitted into the waveguide, can travel back and forth in this waveguide provided they are reflected at the mirrors [8]. The distance between the two mirrors is the cavity length L.

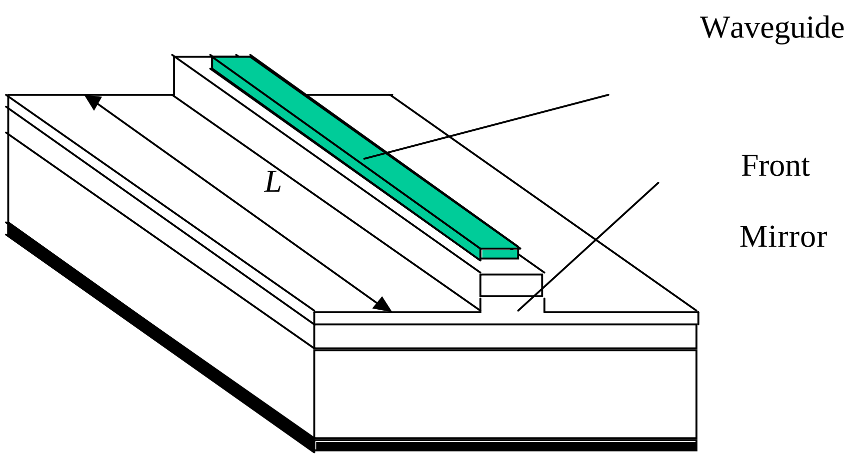


Figure 2.2: Structure of an Edge-emitting laser Diode.

In this project a laser diode type sld-650 which delivers 5 mW when it conducts 40 mA would be used. Sld-650 has threshold current 0f 10 mA and produce its full power at 40 mA.

2.2 Modulation process

The purpose of the communication system is to deliver a message signal from an information source in recognizable form to a user destination, with the source and the user being physically separated each other. To do this, the transmitter modifies the message signal into a form suitable for transmission over the channel. This modification is achieved by means of a process known as modulation, which involves varying some parameter of a carrier wave in according with the message signal. The receiver re-created the original message signal from a degraded version of the transmitted signal after propagation through the channel. This re-created is accomplished by using a process known as demodulation, which is the reverse of the modulation process used in the transmitter. It found that the receiver cannot re-create the original message signal exactly. The resulting degradation in overall system performance is influenced by the type of modulation scheme used. Specifically, some modulation schemes are less sensitive to the effects of noise and distortion than others.

The modulation process may classify into continuous-wave modulation and pulse modulation. In continuous –wave (CW) modulation, a sinusoidal wave is used as the carrier. When the amplitude of the carrier is varied in accordance with the message signal, the amplitude modulation (AM) present, and when the angle of the carrier is varied the angle modulation present. The latter form of CW modulation may be further subdivided into frequency modulation (FM) and phase modulation (PM), in accordance with the message signal.

In pulse modulation, on the other hand, the carrier consists of a periodic sequence of rectangular pulses. Pulse modulation can itself be of an analog or digital type. In analog pulse modulation, the amplitude, duration, or position of a pulse is varied in accordance with sample values of the message signal. In such case pulse-amplitude modulation (PAM), pulse-duration modulation (PDM), and pulse-position modulation (PPM) are present.

The standard digital form of the pulse modulation is known as pulse-coded modulation (PCM) that has no CW counterpart. PCM starts out essentially as PAM, but with an important modification: the amplitude of each modulated pulse is quantized or rounded off to the nearest value in a prescribed set of discrete amplitude levels and then coded into a corresponding sequence of binary symbols.

In introducing the idea of modulation, there is another important benefit, namely, multiplexing, that results from the use of modulation. Multiplexing is the process of combining several message signals for their simultaneous transmission over the same channel.

2.2.1 Continuous-wave modulation

As mention above, modulation process defined as the process by which some characteristic of a carrier is varied in accordance with a modulating wave. A common form of the carrier is a sinusoidal wave, in which case the continuous-wave modulation process is present. The baseband signal (information signal) is referred to as the modulating wave, and the result of the modulation process is referred to as modulated wave.

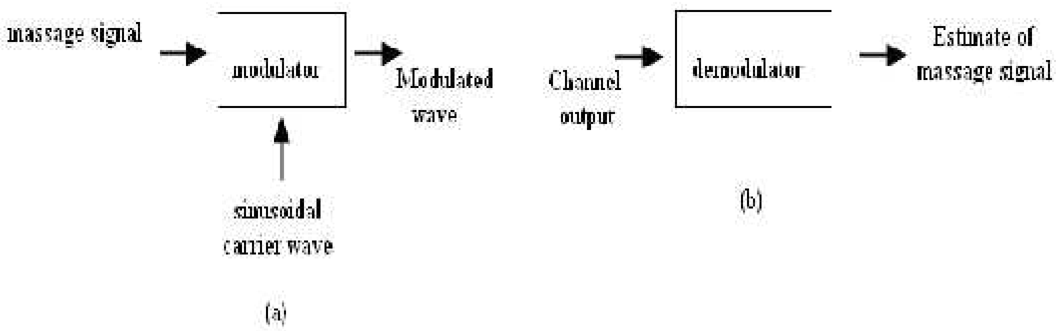


Figure (2.3): Component of a Continuous Wave Modulation System. (a) Transmitter. (b) Receiver

2.2.2 Amplitude modulation

Amplitude modulation (AM) is defined as a process in which the amplitude of the carrier wave is varied about a mean value, linearly with the baseband signal m(t).

The following figures represent the waveforms of the amplitude modulated signals for the case of a single tone.

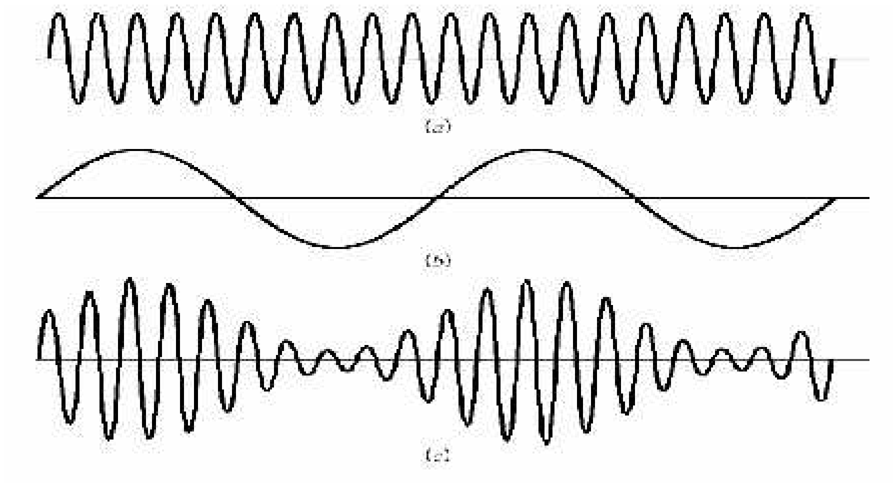


Figure (2.4) AM signals. (a) Carrier wave. (b) Sinusoidal modulating signal. (c) Amplitude modulated signal

An amplitude modulation wave may thus be described, in the most general form, as a function of time as follows:

$$s(t) = A_c[1 + k_a m(t)]\cos(2\pi f_c t) \qquad (2.1)$$

Where k_a is a constant called the amplitude sensitivity of the modulator responsible for the generation of the modulated signal $s(t)$.typically, the carrier amplitude A_c and the message signal $m(t)$ are measured in volts, in which case k_a is measured in $volt^{-1}$ [7].

The envelope of $s(t)$ has essentially the same shape as the baseband signal $m(t)$ provided that two requirements are satisfied:

1.The amplitude of $k_a m(t)$ is less than unity for all t .When the amplitude sensitive of the modulator is large enough to make $|k_a m(t)| > 1$ for any t, the carrier wave becomes over modulated, resulting in carrier phase reversals when ever the factor $1 + k_a m(t)$ crosses zero.

2.The carrier frequency f_c is much greater than the highest frequency component W of the message signal m(t),that is

$$f_c >> W \tag{2.2}$$

W called message bandwidth, and if the condition of equation (2.2) is not satisfied, an envelope cannot be visualized satisfactorily.

A measure of the percentage of possible modulation is the modulation index. The modulation index m is equal to the difference between the maximum voltage and the minimum voltage, divided by the sum of the maximum and minimum voltages. The modulation index varies from m= 0 for no modulation, to m=1 for 100 percent modulation [10].

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} \tag{2.3}$$

Where: m= modulation index

V_{max} = maximum voltage

V_{min}= minimum voltage

The standard form of amplitude modulation defined in equation (2.1) suffers from two major limitations:

1.Amplitude modulation is wasteful of power. The carrier wave c(t) is completely independent of the information- bearing signal $m(t)$. The transmission of the carrier wave therefore represents a waste of power.

2. Amplitude modulation is wasteful of bandwidth. The upper and lower sidebands of an AM wave are uniquely related to each other by virtue symmetry about the carrier frequency, this means that only one sideband is necessary for transmission the information. So, AM is wasteful of bandwidth as it requires a transmission bandwidth equal to twice the message bandwidth.

$$B_T = 2 \times W \tag{2.4}$$

To overcome these limitations, certain modifications are made: suppress the carrier and modify the sideband of the AM wave. This could be done by using one of the following types of AM.

1.Double sideband-suppressed carrier (DEB_SC) modulation, where only the upper and lower sidebands are transmitted.

2. Single sideband (SSB) modulation, where only one sideband (the lower sideband or the upper sideband) is transmitted.

3. Vestigial sideband (VSB) modulation, where only a vestige of one of the sidebands and a correspondingly modified version of the other sideband are transmitted [7].

2.2.2.1 Double sideband-suppressed carrier (DSB_SC) modulation

This form of linear modulation is generated by using a product modulator that simply multiplies the message signal $m(t)$ by the carrier wave $A_c \cos(2®f_c t)$ to produce the modulated signal

$$s(t) = A_c m(t) coc(2®f_c t) \tag{2.5}$$

The transmission bandwidth for the final DSB signal is

$$B_T = 2W \tag{2.6}$$

Thus, the required transmission bandwidth is twice the baseband bandwidth.

2.2.2.2 Single sideband (SSB) modulation

In single-sideband modulation, only the upper or lower sideband is transmitted, such modulated wave may generate by using the frequency-discrimination method that consists of two stages:

1. The first stage is a product modulator, which generates a DSB_SC modulated wave.
2. The second stages is a band-pass filter, which is designed to pass one of the sidebands of this modulated wave and suppress the other.

The transmission bandwidth for SSB is

$$B_T = W \tag{2.7}$$

2.2.2.3 Vestigial sideband (VSB) modulation

In vestigial sideband (VSB) modulation, one of the sidebands is partially suppressed and a vestige of the other sideband is transmitted to compensate for that suppression. A popular method for generating a VSB modulated wave is to use the frequency discrimination method. First, generate a DSB_SC modulated wave and then pass it through a band-pass filter.

The transmission bandwidth op VSB modulation is

$$B_T = W + f_v \tag{2.8}$$

Where W is the message bandwidth, and f_v is the width of the vestigial sideband [1].

2.2.3 Amplitude demodulation

At the receiving end of the system the original baseband signal usually required to be restored. This accomplished by using a process known as demodulation or detection, which is the reverse of the modulation process, the circuit that perform this function is called a detector or demodulator. The detection process normally used for either DSB or SSB is called product detection. Product detection is achieved by mixing a carrier generated at the receiver with the incoming signal in a balanced modulator or mixer circuit, followed by low-pass filtering. If the carrier is locked exactly in phase and frequency with the carrier used for generating the signal, the product-detection process is also referred to as synchronous or coherent detection [5].

2.2.4 Optical carrier and the amplitude modulation

The previous sections discussed the AM modulation concept. The optical carrier in the CW modulation can be treated as a sinusoidal wave too. The wave length of the laser that was used is 650 nm, so the carrier frequency of it was calculated as follow:

$$f_c = \frac{c}{\lambda}$$

$$f_c = \frac{3 \times 10^{8}}{650 \times 10^{-9}} \qquad (2.9)$$

$$f_c = 461.538 THz$$

Where c: is velocity of the light and equal to $3 \times 10^{8}\ {}^{m}\!/_{s}$

λ : is the wave length of the laser and equal to 650 nm.

The carrier signal is:

$$v(t) = V_{\max} \cos(2\pi f_c t) \qquad (2.10)$$

Where V_{max} is the maximum voltage of the carrier signal, which was calculated depending on the characteristics of the laser that was P= 5mW and the I= 40 mA, then:

$$P = VI \qquad (2.11)$$

$$V = \frac{P}{I} = \frac{5mW}{40mA} = 0.125 volts$$

The voice signal is the modulating signal and it could be written as follow:

$$A\cos(2\pi f_m t) \qquad (2.12)$$

Where, f_m is the modulating frequency, and A is the amplitude of the modulating signal. The voice frequency is averaging between 300 Hz and 3400 Hz, and then the average modulating signal is 1350 Hz.

The modulated signal could be expressed as follow:

$$v(t) = (V_{\max} + A\cos(2\pi f_m t))\cos(2\pi f_c t)$$

$$= V_{\max}\cos(2\pi f_c t) + A\cos(2\pi f_m t)\cos(2\pi f_c t)$$

$$= V_{\max}\cos(2\pi f_c t) + \frac{A}{2}\cos 2\pi\left(f_m - f_c\right)t + \frac{A}{2}\cos 2\pi\left(f_m + f_c\right)t \qquad (2.13)$$

from another side, the laser intensity is changing with the current that is delivered to it. As show in the following equation the radiated power from the laser is,

$$p = \int IdA \qquad (2.14)$$

The laser intensity (amplitude) varies with the voltage of the modulating signal, in this project the laser was amplitude modulated in this way. The next chapter is going to discuss the components of the project circuits and how the laser amplitude was modulated with the voice by following the electrical circuit parts.

3

Chapter Three

Project Design

3.1 Introduction

3.2 The Transmitter

3.2.1 Voltage Regulator

3.2.2 Laser Diode Driver

3.2.3 The Transmitter Details

3.3 The Receiver

3.3.1 The photo sensitive diode and the concave mirror

3.3.2 Communication emitter and amplifier

3.3.3 Audio power amplifier

3.3.4 The Receiver Details

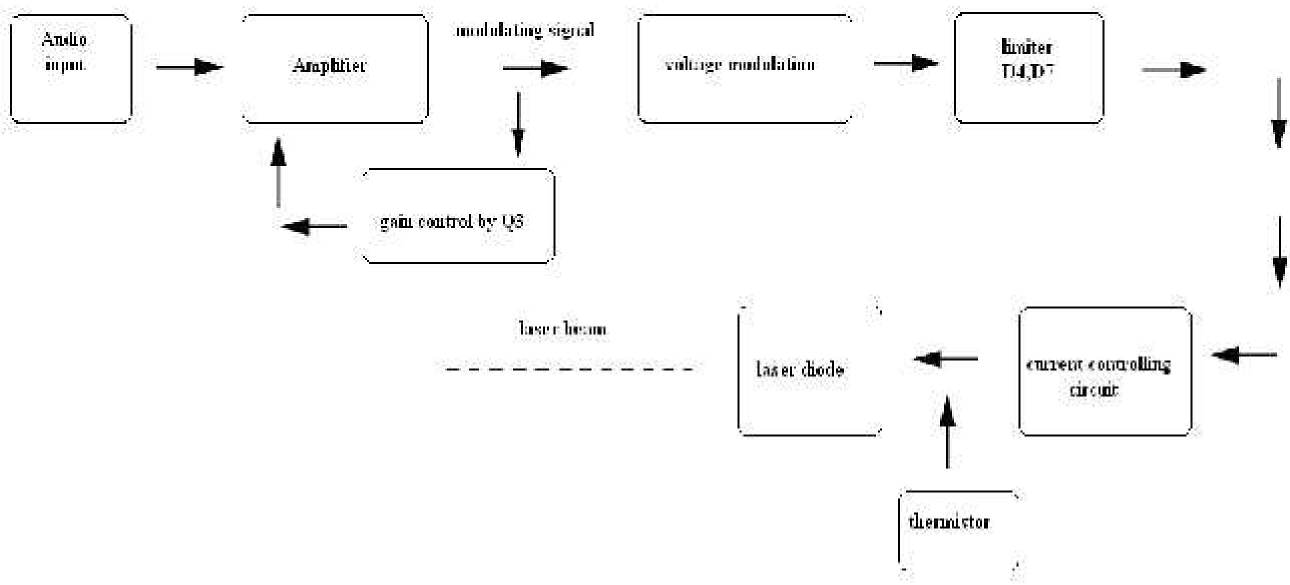
Chapter Three

Project Design

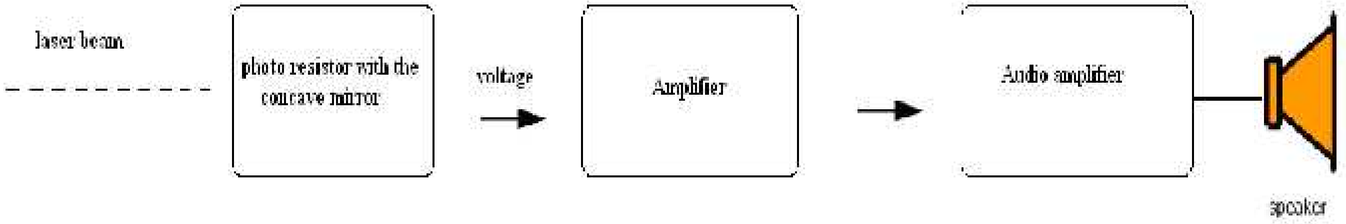
3.1 Introduction

This chapter discusses the main structural design of the whole project in details, showing the main components of the project and their analysis, specification and parameters.

The data transmission system using laser beam consists on general of two main parts: Transmitter, and Receiver, the medium (channel) that was used for transmission the data between the transmitter and the receiver is the free space. That is, the system based on transmission the data (voice) using the laser beam as a carrier from the transmitter to the receiver through the air keep in mind that the distance between the transmitter and the receiver is point to point that is the transmission is line of sight, in the receiver side, the information can be extracted by photo resistor and then the signal will be processed by a power audio amplifier.
The following figure generally views the main component in the system and how they were connected to each other.



(a)



(b)

Figure 3.1: General Block Diagram of the System (a) the transmitter (b) the receiver

3.2 The transmitter

In the transmitter side, An AM process would happen to modulate the voice signal with laser beam as carrier. Then, this modulated signal will transmits over the free space to the receiver side where the Amplitude demodulation will happen to extract the voice signal from the carrier signal.

Some of the transmitter parts details will be shown, after that, the whole transmission process and the effect of each part will be discussed according to the detailed circuit.

3.2.1 Voltage Regulator

The first part of the transmitter is voltage regulator which is a device that converts varying input voltage and produces a constant regulated output voltage.

In this project IC LM7805 is used as voltage regulator and associated components which supply the circuit with steady regulated +5 V.

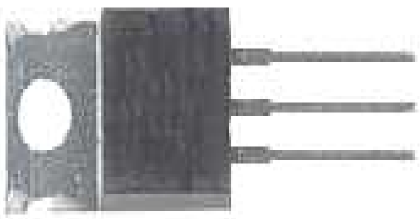


Figure (3.2) The Regulator IC

The LM 78XX series typically has the ability to derive current up to 1A. For application requirements up to 150mA, 78XX can be use. From figure (4.3), the component has three legs: input leg which can hold up to 36VDC, common leg (GND) and output leg with the regulator voltage. For maximum voltage regulation, adding a capacitor in parallel between the common leg and the output is usually recommended. Typically a 0.1MF capacitor is used. This eliminates any high frequency AC voltage that could otherwise combine with the output voltage. See below circuit diagram which represents a typical use of a voltage regulator.

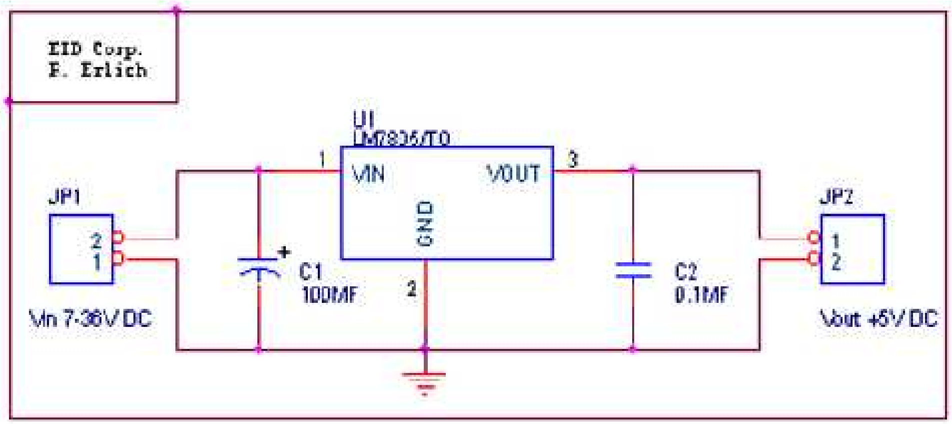


Figure (3.3) The LM 7805 Voltage Regulator Circuit (see appendix 1)

3.2.2 Laser Diode Driver

As mentioned above, laser beam used as carrier instead of the sinusoidal waves**,** so laser diode is used as source of the laser beam. The basic idea of a laser diode is to use a mirrored resonant chamber that reinforces the emission of light waves at a single frequency of the same phase. Because of the resonance, a laser diode produces a narrow beam of light that is very intense, focused, and pure.

Laser diodes produce visible light (red, green, or blue) and invisible light (infrared). They are used in consumer products and broadband communication.

In this project laser diode type sld-650 is used as a source of the laser beam, it deliver 5mW when it conducts 40 mA, the relation between current and output power is linear, so, it reflect input signal typically and clearly. (see appendix 2)

3.2.3 The transmitter details:

A laser diode needs a certain value of current, called the threshold current, before it emits laser light. A further increase in this current produces a greater light output.

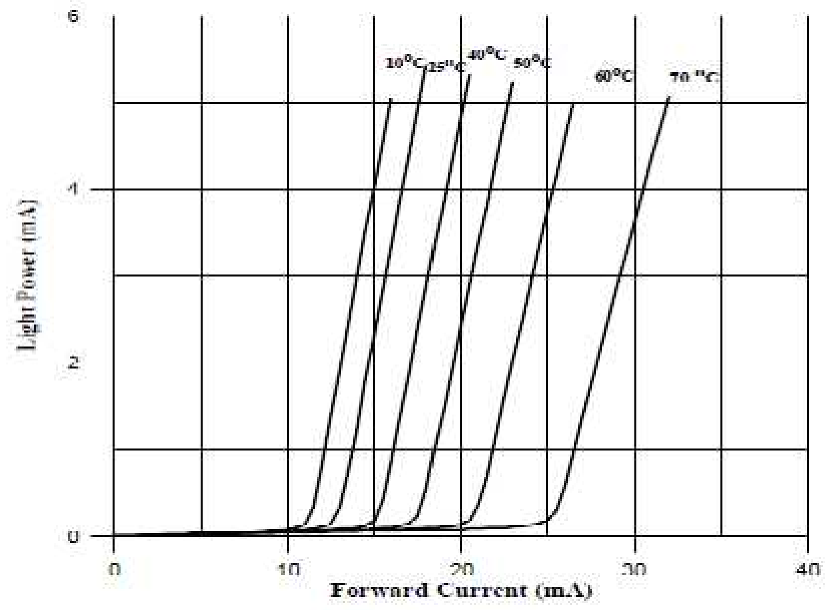


Figure (3.4): light power vs. forward current

The relationship between output power and current figure in a laser diode is very linear figure (3.4), once the current is above the threshold, giving a low distortion when the beam is amplitude modulated. For example, the 65Onm 5mW laser diode used in this project has a typical threshold current of 3OmA and produces its full output when the current is raised by approximately 1OmA above the threshold to 4OmA. Further increasing the current will greatly reduce the life of the laser diode, and exceeding the absolute maximum of 8OmA will destroy it instantly.

However, if used within specifications, the typical life of one of these lasers is around 20,000 hours. In the transmitter circuit bellow Figure (3.5), the laser diode is supplied via an adjustable constant-current source. Since the lasing threshold also varies with temperature, a 68ohm NTC (thermistor) is included to compensate for changes in ambient temperature. Note that the metal housing for the laser diode and the lens also acts as a heat sink. The laser diode should not be powered without the metal housing in place. The quiescent laser diode current is controlled by Q2 (current controlling circuit), in turn driven by the buffer stage of 1C2b. The DC voltage as set by VR2 appears at the base of Q2, which determines the current through the transistor and therefore the laser diode.

Increasing the voltage at VR1 reduces the laser current. The setting of VR1 determines the quiescent brightness of the laser beam, and therefore the overall sensitivity of the system.

The audio modulation voltage is applied to the cathode of the laser diode, which varies the laser current around its set point by around +/-3mA. The (modulation voltage) is from the emitter of Q 1, which is an emitter follower stage driven by the audio amplifier stage of 1C2a. Diodes D4 to D7 limit the modulating voltage to +/-2V (limiter), while C4 and C5 block the DC voltages at the emitter of Q 1 and the cathode of the laser diode. The audio signal is coupled to the laser diode via R10, which limits the maximum possible variation in the laser diode current to a few milliamps.

LED1 gives an indication of the modulating voltage. Diodes D2, D3 and resistor R8 limit the current through the LED and enhance the brightness changes so the modulation is obvious. The LED flickers in sympathy with the sound received by the microphone, giving an indication that a modulating voltage is present.

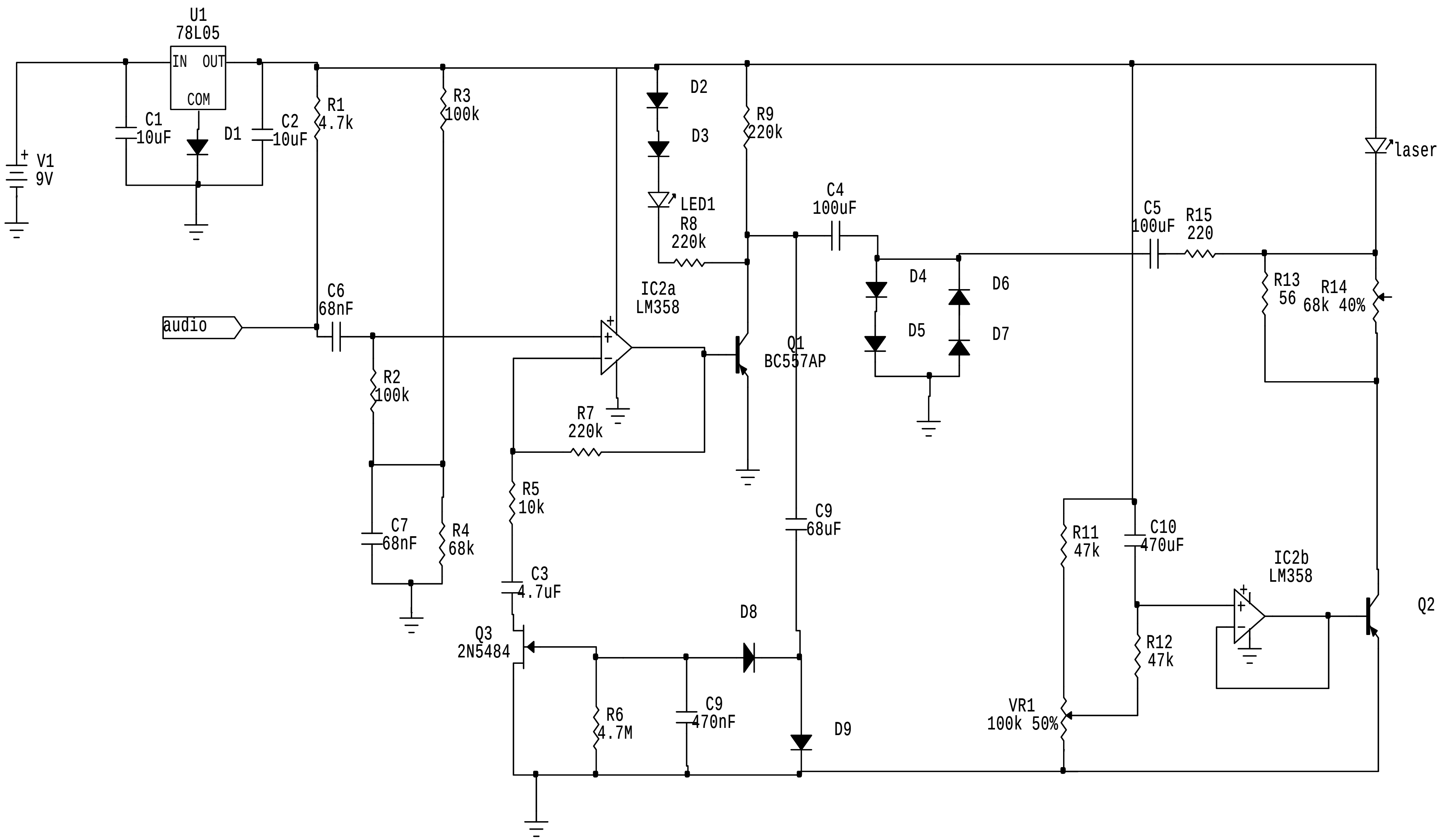


Figure (3.5): The transmitter detailed circuit

The inverting amplifier of 1C2a includes a form of compression, in which the output level is relatively constant and independent of how soft or loud the audio level is at the microphone. This is achieved by FET Q3 and its associated circuitry.

The cascaded voltage doubler of C9, D8, D9 and C8 rectifies the audio signal at the emitter of Ql, and the resulting negative DC voltage that is fed to the gate of Q3 (gain control). An increase in the audio signal will increase the negative bias to Q3, increasing its drain-source resistance. Because the gain of 1C2a is determined by R7 and the series resistance of R5 and Q3, increasing the effective resistance of Q3 will lower the gain.

Since the compression circuit takes time to respond, the clamping network of D4-D7 is still needed to protect against sudden voltage increases. This system is rather similar to the compression used in portable tape recorders.

The electrets' microphone is powered through R1 and is coupled to the non inverting input of 1C2a via C6. This input is held at a fixed DC voltage to give a DC output to bias Ql. The supply voltage to the transmitter circuit is regulated by ICI, a 5V three terminal regulator.

Now the modulated signal which is a variation in the laser intensity depending on the audio modulating signal is travelling in a direct way to the receiver side (line of sight).

3.3 The Receiver

In this part the signal would be received and demodulated to have the audio signal as an output of the circuit. Now, the following subsections are talking about the receiver components that were connected as shown in the block diagram, figure (3.1-b).

3.3.1 The photo resistor and the concave mirror

When the beam of the laser was received, the radius of its cross section was bigger than the form that was transmitted with. The received signal would have a noise because of the broaden of the beam along the transmission distance. So, to get back the laser beam focused and having the signal without distortion, a concave mirror behind the sensitive photo resistor was used, to collect back the beam in the focus point of the mirror as shown in the figure below:

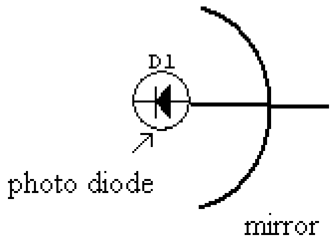


Figure (3.6): The Photo Diode and the Mirror

The focus point of the concave mirror was calculated as follow:

- **The concave mirror**

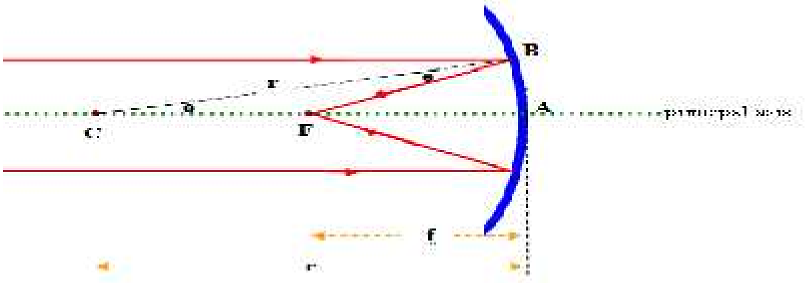


Figure (3.7): The Concave Mirror

Consider the beam of the laser failed on the concave mirror parallel to the principal axis, as shown in the above figure. the beam would reflects back at the point F. the previous figure shows that CB is equal to r (the radius of the concave mirror) and C is the center of the curvature CB is perpendicular on the mirror at point B. Also, CF is equal to FB, and FB is equal to FA. While FA is the equal to the length f. CA is equal to 2FA, that is;

$$r = 2f$$

$$f = \frac{r}{2} \tag{3.1}$$

The mirror that would be used in this project has an optical focusing point at an 18 mm distance from the center of the mirror, which has a diameter of 45 mm.

- **The photo resistor LDR:**

A photo resistor or light dependent resistor or cadmium sulfide (CdS) cell is a resistor whose resistance decreases with increasing incident light intensity. It can also be referred to as a photoconductor.

A photo resistor is made of a high resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance.

A photoelectric device can be either intrinsic or extrinsic. An intrinsic semiconductor has its own charge carriers and is not an efficient semiconductor, e.g. silicon. In intrinsic devices the only available electrons are in the valence band, and hence the photon must have enough energy to excite the electron across the entire band gap. Extrinsic devices have impurities, also called dopants, and added whose ground state energy is closer to the conduction band; since the electrons do not have as far to jump, lower energy photons (i.e., longer wavelengths and lower frequencies) are sufficient to trigger the device. If a sample of silicon has some of its atoms replaced by phosphorus atoms (impurities), there will be extra electrons available for conduction. This is an example of an extrinsic semiconductor [12].

Figure (3.8):The photo resistor (see appendix 3)

3.3.2 The amplifier stage

This stage consists of common emitter transistor amplifier, which receives the detected signal from photo diode then amplifies it about 20 times, and then it was coupled to the next amplifying stage by variable resistance (50kΩ trim pot) for controlling the out put volume and matching between the stages.

3.3.3Audio power amplifier

An audio amplifier is an electronic amplifier that amplifies low-power audio signals (signals composed primarily of frequencies between 20 hertz to 20,000 hertz, the human range of hearing) to a level suitable for driving loudspeakers and is the final stage in a typical audio playback chain.

The preceding stages in such a chain are low power audio amplifiers which perform tasks like pre-amplification, equalization, tone control, mixing/effects, or audio sources like record players, CD players, and cassette players. Most audio amplifiers require these low-level inputs to adhere to line levels [12].

The audio power amplifier that was used in this project is IC LM386 which its full description is shown in appendix 4.

3.3.4: The receiver details:

After transmitting the laser signal beam to the receiver side, the radius of the cross section of the laser beam was increased, this means that the signal is less coherent than the transmitter side. So, to collect back the beam a concave mirror was used behind the photo resistor LDR which was positioned in the optical focusing point of the mirror, to catch the focused signal.

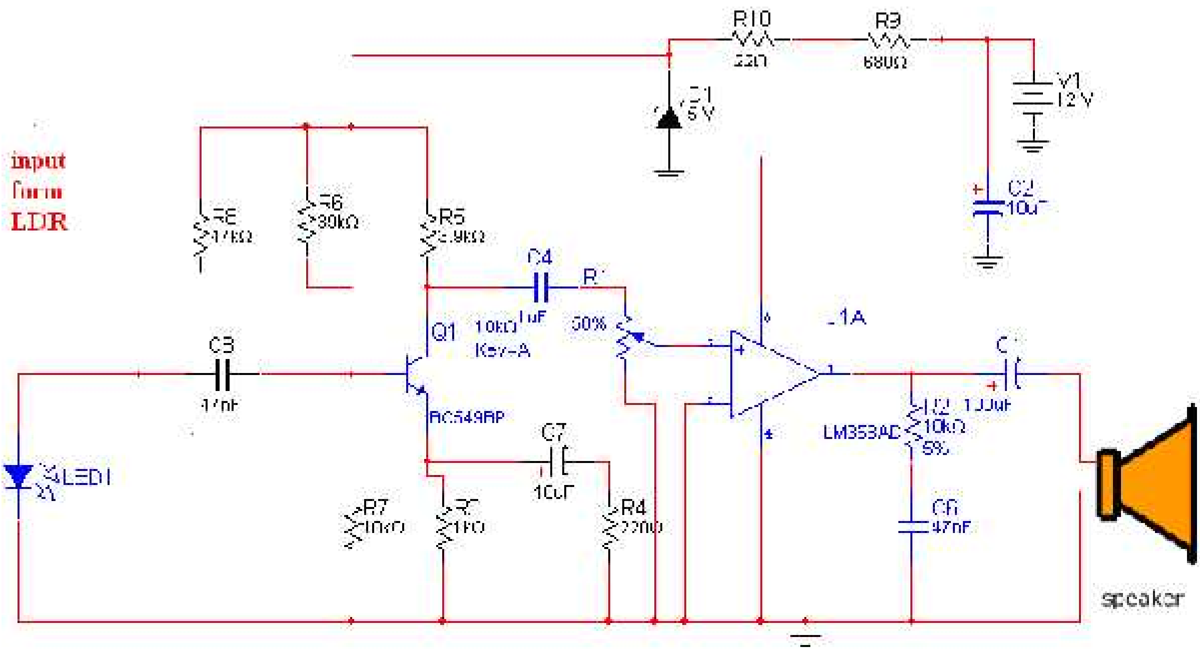


Figure (3.9): The receiver detailed circuit.

The transmitted signal is picked up by the photo resistor in the receiver (shown in Figure 3.9). The output voltage of this photo resistor is amplified by the common emitter amplifier around Ql. This amplifier has a gain of 20 or so, and connects via VRI to U1A, an LM386 basic power amplifier IC with a gain internally set to 20.

This IC can drive a speaker with a resistance as low as four ohms, and 35OmW when the circuit is powered from a 9V supply. Increasing the supply voltage will increase the output power marginally. The voltage to the transistor amplifier stage is regulated by ZD I to 5.6V, and decoupled from the main supply by R9 and C2.

4

Chapter Four

Implementation and Testing

Chapter Four

Implementation and Testing

4.1 Introduction

In this chapter the construction and testing processes for the system would be shown, the construction and testing processes are very important to insure that the system work successfully. After collecting all the necessary information related to the project and analyze them, the group starts to build the system using all the ICs that depicted in the design chapter and after build each part of the system the group tested it to get the wanted results, and when the whole system has been finished a complete testing process had been done over the whole system.

4.2 Construction

The implementation process is synchronized with the testing operation, since each implementation process will take many testing steps to insure that were no errors.

As the photos show bellow, both the transmitter and the receiver are built on silk-screened PCBS. As usual fitting the resistors, pots and capacitors first, taking care with the polarity of the electrolytic. IC sockets are not essential, although servicing is obviously made easier if they are used. In which case, fitting these next, followed by the transistors, diodes and the LED.

By taking care of using the right diodes for D8 and D9. These are larger than the 1N4148 types, and have two black bands (the cathode end) around a glass package. Note that the regulator IC has the tab facing outwards. The laser diode is sensitive to heat, so it wasn't soldered directly to the receiver; it was connected by wires lead to it.

The photo resistor is mounted on the focusing point of the mirror, and then connected to the circuit as shown in figure 4.2-a.

The microphone element wires were connected to the transmitter board. Finally, connecting the speaker and 9V battery clips, then checking over the boards for any soldering errors or incorrectly installed components.

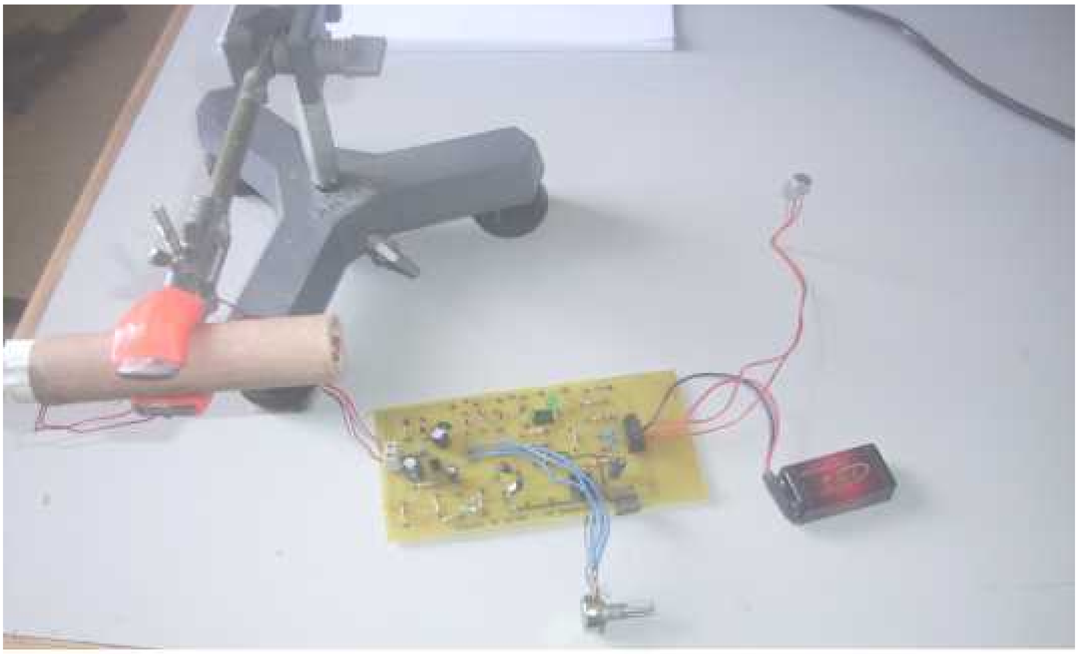
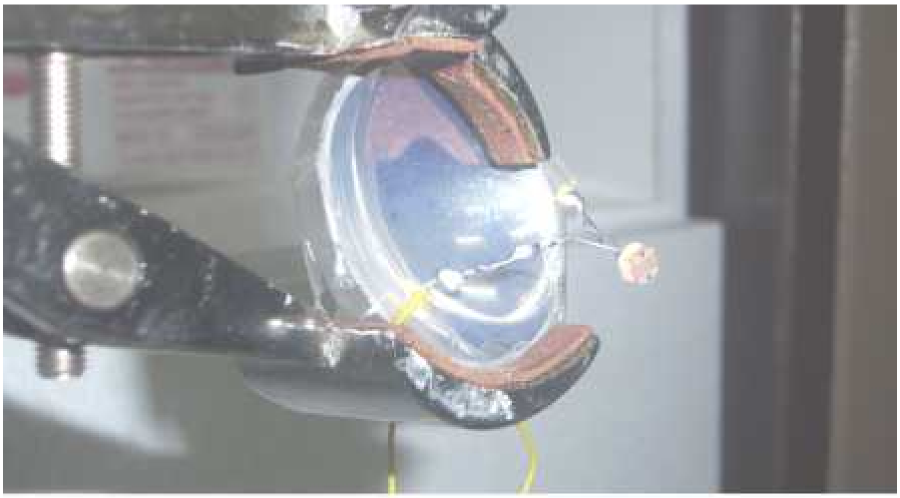
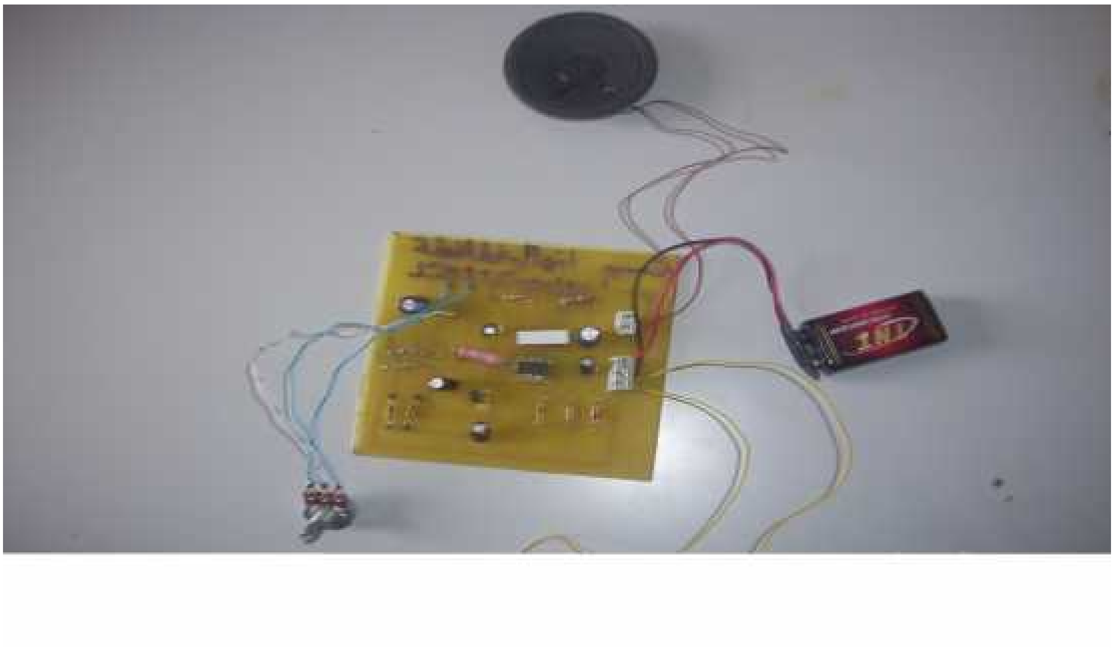


Figure (4.1) Transmitter circuit image



(a)



(b)

Figure (4.2) Receiver circuit: (a): the concave mirror and LDR (b): the receiver circuit

4.3 Testing

First of all, it's most important that not to look directly into the laser beam. If one does, it could cause permanent eye damage. Also, the responsibility for the safety of others near the laser, which means you must stop others from also looking into the beam, and take all necessary safety steps. This is covered by legislation.

Both the receiver and the transmitter can be powered by separate 9V batteries or suitable DC supplies. Before applying power to the transmitter PCB, VRI was set to its halfway position, to make sure the laser current is not excessive. To be totally sure, it could be set fully anticlockwise, as this setting will reduce the laser current to zero.

Then apply power to the board. If the laser doesn't produce light, slowly adjust VRI clockwise. The laser diode should emit a beam with intensity adjustable with VRI. At this stage, keep the beam intensity low, but high enough to clearly see. If you are not getting an output, check the circuit around IC2b.
You should also find that LED 1 should flickers if one runs his finger over the microphone. If so, it indicates that the amplifier section is working and that there's a modulation voltage to the laser diode. You won't see the laser beam intensity couldn't be seen changing with the modulating signal.

To check that the system is working, place the two PCBs is placed on the workbench, spaced a meter or go apart. A sheet of paper would be used in front of the photo resistor to know the laser beam position and sitting up a direct link between the both sides.

Move the laser diode so the beam points at the receiver's concave mirror. You should now be able to hear the speaker reproducing any audio signal picked up by the microphone, but after a delay time that could be calculated as follow,

$$T_d = \frac{D}{c} \tag{4.1}$$

Where D: the distance between the transmitter and the receiver

c: the speed of the light (EM wave)

Assuming the distance between the transmitter and the receiver is 20 m, then the time delay will be 0.667 nsec. This is an acceptable value. By increasing the distance between the two sides, the time delay will increase. If the transmitted power P_t was 5mW then the received signal power density S_R will be calculated as using isotropic approximation,

$$S_R = \frac{P_t}{4®R^2} = \frac{5mW}{4®(20m)^2} = 0.995mW \tag{4.2}$$

Because of this the concave mirror was used, to get a part of the power back by collecting the beam on its focusing point. So the received power P_r will be,

$$P_r = S_R.\pm_{eff.} \tag{4.3}$$

Where $\pm_{eff.}$: is the effective area of the mirror which equal to R^2 ® = 1589.625 mm^2.

So calculated received power was 1.5 mW.

To insure that the efficiency of the system is acceptable the group decreases the voice source at the transmitter side. In the receiver side they found that the voice is clear and with acceptable efficiency.

5

Future Suggestions and Results

5.1 Conclusion

5.2 Future work

5.2.1 Improvement by changing the modulation

5.2.2 Improvement by changing the laser type

Chapter five

Future Suggestions Results and

After building the circuits of the system, as was shown in chapter four and five. The project could be concluded as follow.

5.1: Conclusions

Many experiences were added to the team cognitive knowledge through this project. The most significant and important conclusions are described as follow:

Many problems which the laser beam suffered from were improved by adding external equipments such as the concave mirror. Also the data is in each part of the laser beam, but the more collected beam the more signal strength.

A normal mirror could be used to change the direction of the laser beam; this can be done if we don't have a direct line of site. As the distance between the transmitter and the receiver increases, the efficiency of the system decreases, so intensity laser beam must use.

After concluding the project we can suggest other future implementations of the system.

5.2: Future work

For implementing this system more and more, the type of modulation could be changed or the color of the laser as it will be shown in the following subsections.

5.2.1 Improvement by changing the modulation:

In this project the type of modulation that was used is the AM modulation, because the sound wave is continues. The circuit of this type of modulation was easy to build and do the wanted job, but also the AM has its disadvantages. So, one can use the Frequency modulation FM. The main advantages of FM over AM are:

1. Improved signal to noise ratio.
2. Smaller geographical interference between neighboring stations.
3. Less radiated power.
4. Well defined service areas for given transmitter power.

A general description of a laser transmission system using the FM is as follow. The audio signal enters the transmitter circuit, and passes through a LPF then an amplifier. Then it goes to a selection followed by the FM modulation circuit, and finally the laser diode.

At the receiver side, a laser sensor is located to get the modulated beam, then the signal enters to a BPF which followed by an FM demodulator, then to a selection circuits that leads to an audio amplifier, and finally the speaker [4].

The disadvantages of FM transmission systems are:

1. Much more Bandwidth.
2. More complicated receiver and transmitter.
3. More complicated receiver and transmitter.

Another types of modulation could be used, but also the circuits of them would be more complicated than the AM or FM modulation. Sending digital data using the Laser beam also could be done.

Changing of the modulation including a change in the band width, the change of the band width needs a change in the color of the laser. Also the power could be changed, which what the next subsection well discuss

Another types of modulation could be used, but also the circuits of them would be more complicated than the AM or FM modulation. Sending digital data using the Laser beam also could be done.

Changing of the modulation including a change in the band width, so changing the band width needs a change in the type of the laser also to change the wave length and the power, which what the next subsection well discuss.

5.2.2 Improvement by changing the laser type:

In this project the type of laser that was used is a laser diode type sld-650(in the range of the visible light 400 -700 nm) which delivers 5 mW had been used. The color of it was red and the frequency was 461.538 THz.

According to the stimulated emission definition, the quantum energy is equal to the energy difference between its present level and a lower level. So the power of the laser is changing between its types depending on the energy that the photon generates.

Here some continuous or average power required for some uses:

- less than 1 mW – laser pointers
- 5 mW – CD-ROM drive
- 5–10 mW – DVD player or DVD-ROM drive
- 100 mW – High-speed CD-RW burner
- 250 mW – Consumer DVD-R burner
- 1 W – green laser in current Holographic Versatile Disc prototype development
- 1–20 W – output of the majority of commercially available solid-state lasers used for micro machining
- 30–100 W – typical sealed CO_2 surgical lasers
- 100–3000 W (peak output 1.5 kW) – typical sealed CO_2 lasers used in industrial laser cutting
- 1 kW – Output power expected to be achieved by a prototype 1 cm diode laser bar.

As it was noticed from the above points, when the power of the laser increases, the application is become higher level.

When changing the wave length of the laser and changing the power, one can transmit more data with higher transmission rate. For example, create an internet connection between two buildings using the laser.

References

[1] Kishi, Walid. *"Data Transmission via Laser Beam"*, Graduation Project, January 2008.

[2] Hyper physics group. *"The LASER"*, Georgia state university, article, 2006

[3] Tuominen, Juha. and Ailon Oy, Patria. *"Wireless Power Transmission Using Laser"*, U.S. Oct. 31, 2001.

[4] Muhi, Samer. *"Laser transmits audio signal using frequency modulation".* Graduation project, May,2009.

[5] D-stanley, William. *"Electric Communication, Principles and system"*, 2nd Edition.

[6] Malvino, Albert. *"Electronic Principle"*, 6th Edition.

[7] Haykin, Simon. *"Communication systems"*, 4th Edition.

[8] Agrawal, Govind P. *"Fiber-Optic Communication Systems"*, 3rd Edition,(2002).

[9] L-flyd, Themas. *"electronic devices"*, 5th Edition.

[10] Hund , Edgar. *"Microwave Communication, components and circuits"*, 1st edition.

[11] www.ALLDATASHEET.com

[12] www.en.wikipedia.org

[13] http://www.kigre.com/files/historylasers.pdf

August 2005

National Semiconductor

LM341/LM78MXX Series 3-Terminal Positive Voltage Regulators

General Description

The LM341 and LM78MXX series of three-terminal positive voltage regulators employ built-in current limiting, thermal shutdown, and safe-operating area protection which makes them virtually immune to damage from output overloads.

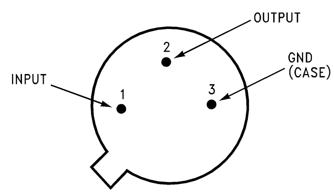
With adequate heatsinking, they can deliver in excess of 0.5A output current. Typical applications would include local (on-card) regulators which can eliminate the noise and degraded performance associated with single-point regulation.

Features

- Output current in excess of 0.5A
- No external components
- Internal thermal overload protection
- Internal short circuit current-limiting
- Output transistor safe-area compensation
- Available in TO-220, TO-39, and TO-252 D-PAK packages
- Output voltages of 5V, 12V, and 15V

Connection Diagrams

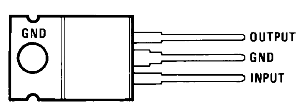
TO-39 Metal Can Package (H)



01048405

Bottom View
Order Number LM78M05CH, LM78M12CH or LM78M15CH
See NS Package Number H03A

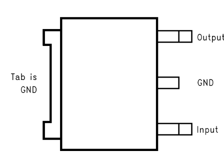
TO-220 Power Package (T)



01048406

Top View
Order Number LM341T-5.0, LM341T-12, LM341T-15, LM78M05CT, LM78M12CT or LM78M15CT
See NS Package Number T03B

TO-252



01048419

Top View
Order Number LM78M05CDT
See NS Package Number TD03B

Absolute Maximum Ratings (Note 1)

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

Lead Temperature (Soldering, 10 seconds)	
TO-39 Package (H)	300˚C
TO-220 Package (T)	260˚C
Storage Temperature Range	−65˚C to +150˚C
Operating Junction Temperature Range	−40˚C to +125˚C
Power Dissipation (Note 2)	Internally Limited
Input Voltage	
$5V \le V_O \le 15V$	35V
ESD Susceptibility	TBD

Electrical Characteristics

Limits in standard typeface are for T_J = 25˚C, and limits in **boldface type** apply over the −40˚C to +125˚C operating temperature range. Limits are guaranteed by production testing or correlation techniques using standard Statistical Quality Control (SQC) methods.

LM341-5.0, LM78M05C

Unless otherwise specified: V_{IN} = 10V, C_{IN} = 0.33 µF, C_O = 0.1 µF

Symbol	Parameter	Conditions		Min	Typ	Max	Units
V_O	Output Voltage	I_L= 500 mA		4.8	5.0	5.2	V
		$5 mA \le I_L \le 500 mA$ $P_D \le 7.5W$, $7.5V \le V_{IN} \le 20V$		**4.75**	**5.0**	**5.25**	
$V_{R\ LINE}$	Line Regulation	$7.2V \le V_{IN} \le 25V$	I_L = 100 mA			50	mV
			I_L = 500 mA			100	
$V_{R\ LOAD}$	Load Regulation	$5 mA \le I_L \le 500 mA$				100	
I_Q	Quiescent Current	I_L = 500 mA			4	10.0	mA
ΔI_Q	Quiescent Current Change	$5 mA \le I_L \le 500 mA$				0.5	
		$7.5V \le V_{IN} \le 25V$, I_L = 500 mA				1.0	
V_n	Output Noise Voltage	f = 10 Hz to 100 kHz			40		µV
$\frac{\Delta V_{IN}}{\Delta V_O}$	Ripple Rejection	f = 120 Hz, I_L = 500 mA			78		dB
V_{IN}	Input Voltage Required to Maintain Line Regulation	I_L = 500 mA		7.2			V
ΔV_O	Long Term Stability	I_L = 500 mA				**20**	mV/khrs

Electrical Characteristics

Limits in standard typeface are for T_J = 25˚C, and limits in **boldface type** apply over the −40˚C to +125˚C operating temperature range. Limits are guaranteed by production testing or correlation techniques using standard Statistical Quality Control (SQC) methods. (Continued)

LM341-12, LM78M12C

Unless otherwise specified: V_{IN} = 19V, C_{IN} = 0.33 µF, C_O = 0.1 µF

Symbol	Parameter	Conditions		Min	Typ	Max	Units
V_O	Output Voltage	I_L= 500 mA		11.5	12	12.5	V
		5 mA ≤ I_L ≤ 500 mA P_D ≤ 7.5W, 14.8V ≤ V_{IN} ≤ 27V		**11.4**	**12**	**12.6**	
$V_{R\ LINE}$	Line Regulation	14.5V ≤ V_{IN} ≤ 30V	I_L = 100 mA			120	mV
			I_L = 500 mA			240	
$V_{R\ LOAD}$	Load Regulation	5 mA ≤ I_L ≤ 500 mA				240	
I_Q	Quiescent Current	I_L = 500 mA			4	10.0	mA
ΔI_Q	Quiescent Current Change	5 mA ≤ I_L ≤ 500 mA				0.5	
		14.8V ≤ V_{IN} ≤ 30V, I_L = 500 mA				1.0	
V_n	Output Noise Voltage	f = 10 Hz to 100 kHz			75		µV
$\frac{\Delta V_{IN}}{\Delta V_O}$	Ripple Rejection	f = 120 Hz, I_L = 500 mA			71		dB
V_{IN}	Input Voltage Required to Maintain Line Regulation	I_L = 500 mA		14.5			V
ΔV_O	Long Term Stability	I_L = 500 mA				**48**	mV/khrs

LM341-15, LM78M15C

Unless otherwise specified: V_{IN} = 23V, C_{IN} = 0.33 µF, C_O = 0.1 µF

Symbol	Parameter	Conditions		Min	Typ	Max	Units
V_O	Output Voltage	I_L= 500 mA		14.4	15	15.6	V
		5 mA ≤ I_L ≤ 500 mA P_D ≤ 7.5W, 18V ≤ V_{IN} ≤ 30V		**14.25**	**15**	**15.75**	
$V_{R\ LINE}$	Line Regulation	17.6V ≤ V_{IN} ≤ 30V	I_L = 100 mA			150	mV
			I_L = 500 mA			300	
$V_{R\ LOAD}$	Load Regulation	5 mA ≤ I_L ≤ 500 mA				300	
I_Q	Quiescent Current	I_L = 500 mA			4	10.0	mA
ΔI_Q	Quiescent Current Change	5 mA ≤ I_L ≤ 500 mA				0.5	
		18V ≤ V_{IN} ≤ 30V, I_L = 500 mA				1.0	
V_n	Output Noise Voltage	f = 10 Hz to 100 kHz			90		µV
$\frac{\Delta V_{IN}}{\Delta V_O}$	Ripple Rejection	f = 120 Hz, I_L = 500 mA			69		dB
V_{IN}	Input Voltage Required to Maintain Line Regulation	I_L = 500 mA		17.6			V
ΔV_O	Long Term Stability	I_L = 500 mA				**60**	mV/khrs

Note 1: Absolute maximum ratings indicate limits beyond which damage to the component may occur. Electrical specifications do not apply when operating the device outside of its rated operating conditions.

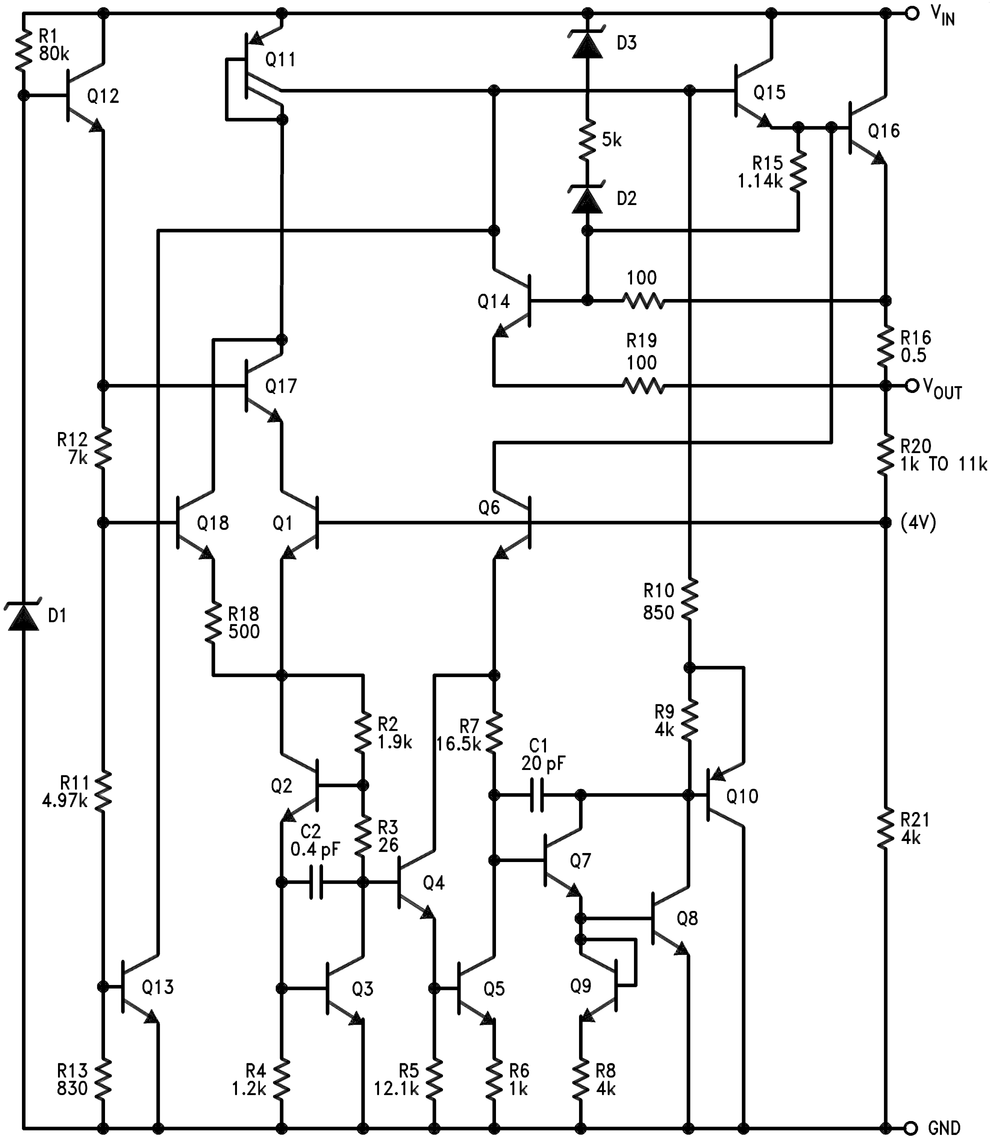
Note 2: The typical thermal resistance of the three package types is:

T (TO-220) package: $\theta_{(JA)}$ = 60 ˚C/W, $\theta_{(JC)}$ = 5 ˚C/W

H (TO-39) package: $\theta_{(JA)}$ = 120 ˚C/W, $\theta_{(JC)}$ = 18 ˚C/W

DT (TO-252) package: $\theta_{(JA)}$ = 92 ˚C/W, $\theta_{(JC)}$ = 10 ˚C/W

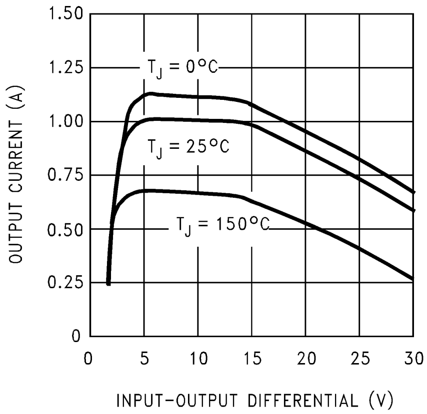
Schematic Diagram



01048401

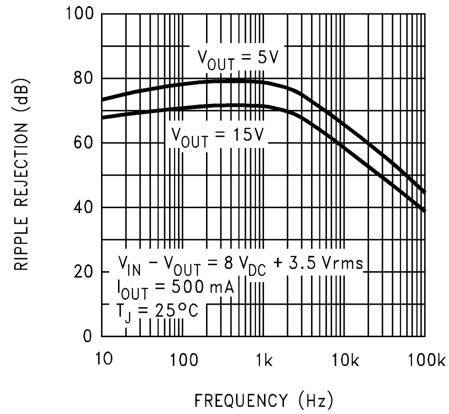
Typical Performance Characteristics

Peak Output Current



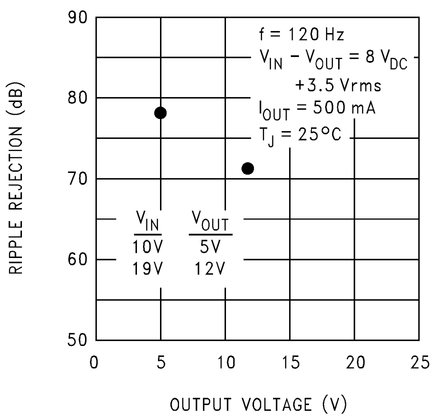
01048410

Ripple Rejection



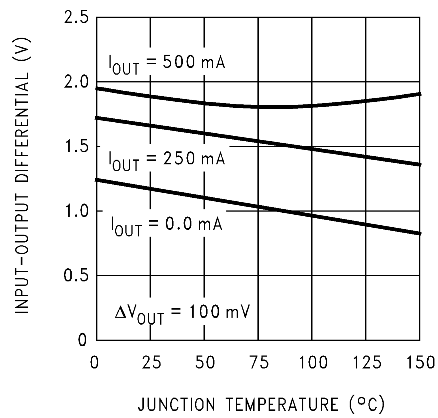
01048411

Ripple Rejection



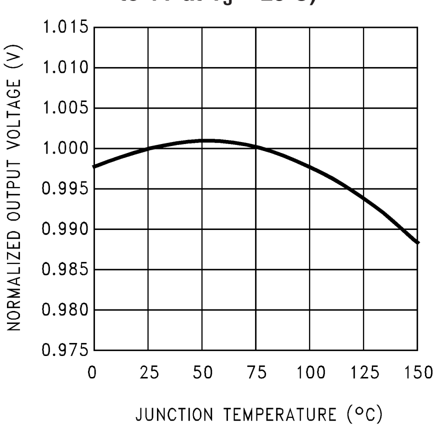
01048412

Dropout Voltage



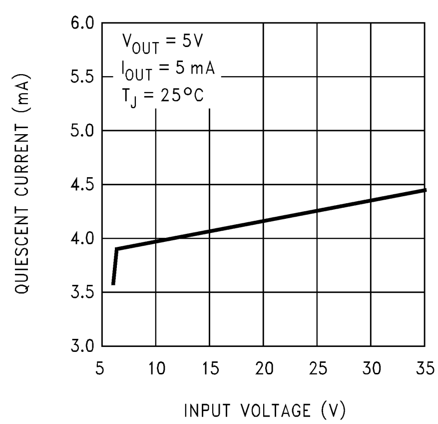
01048413

Output Voltage (Normalized to 1V at T_J = 25˚C)



01048414

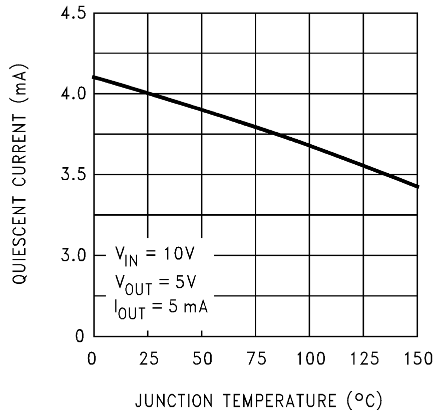
Quiescent Current



01048415

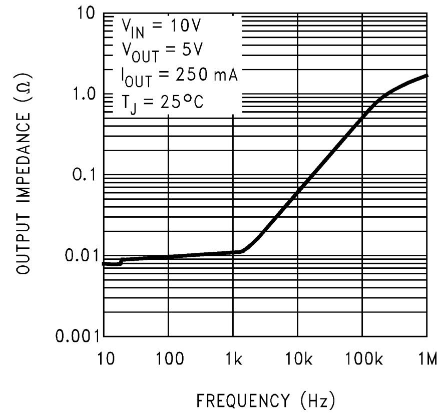
Typical Performance Characteristics (Continued)

Quiescent Current



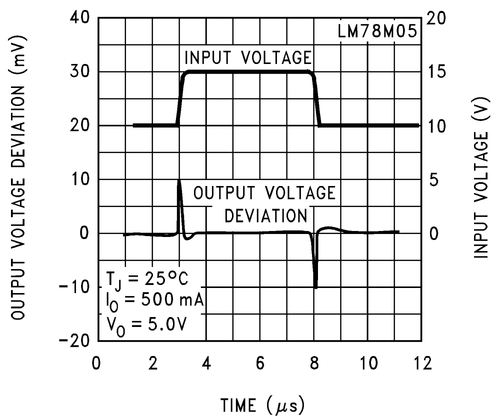
01048416

Output Impedance



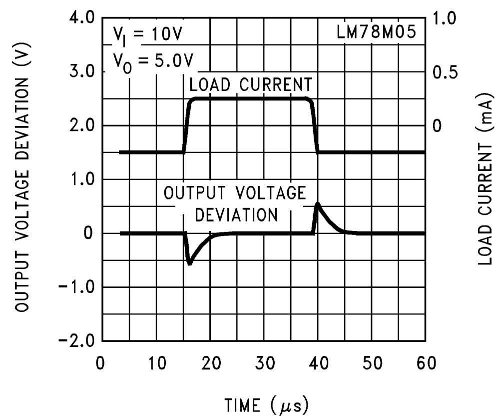
01048417

Line Transient Response



01048407

Load Transient Response



01048408

Design Considerations

The LM78MXX/LM341XX fixed voltage regulator series has built-in thermal overload protection which prevents the device from being damaged due to excessive junction temperature.

The regulators also contain internal short-circuit protection which limits the maximum output current, and safe-area protection for the pass transistor which reduces the short-circuit current as the voltage across the pass transistor is increased.

Although the internal power dissipation is automatically limited, the maximum junction temperature of the device must be kept below +125˚C in order to meet data sheet specifications. An adequate heatsink should be provided to assure this limit is not exceeded under worst-case operating conditions (maximum input voltage and load current) if reliable performance is to be obtained).

1.0 HEATSINK CONSIDERATIONS

When an integrated circuit operates with appreciable current, its junction temperature is elevated. It is important to quantify its thermal limits in order to achieve acceptable performance and reliability. This limit is determined by summing the individual parts consisting of a series of temperature rises from the semiconductor junction to the operating environment. A one-dimension steady-state model of conduction heat transfer is demonstrated in The heat generated at the device junction flows through the die to the die attach pad, through the lead frame to the surrounding case material, to the printed circuit board, and eventually to the ambient environment. Below is a list of variables that may affect the thermal resistance and in turn the need for a heatsink.

$R^{\theta JC}$(Component Variables)	**$R^{\theta CA}$(Application Variables)**
Leadframe Size & Material	Mounting Pad Size, Material, & Location
No. of Conduction Pins	Placement of Mounting Pad
Die Size	PCB Size & Material
Die Attach Material	Traces Length & Width
Molding Compound Size and Material	Adjacent Heat Sources
	Volume of Air
	Air Flow
	Ambient Temperature
	Shape of Mounting Pad

Application Information

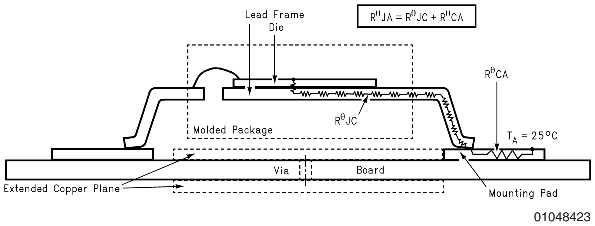


FIGURE 1. Cross-sectional view of Integrated Circuit Mounted on a printed circuit board. Note that the case temperature is measured at the point where the leads contact with the mounting pad surface

The LM78MXX/LM341XX regulators have internal thermal shutdown to protect the device from over-heating. Under all possible operating conditions, the junction temperature of the LM78MXX/LM341XX must be within the range of 0˚C to 125˚C. A heatsink may be required depending on the maximum power dissipation and maximum ambient temperature of the application. To determine if a heatsink is needed, the power dissipated by the regulator, P_D, must be calculated:

$I_{IN} = I_L + I_G$

$P_D = (V_{IN}–V_{OUT})\ I_L + V_{IN}I_G$

shows the voltages and currents which are present in the circuit.

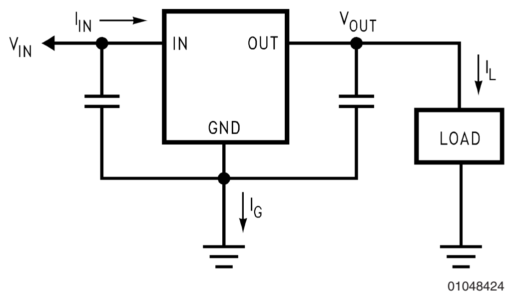


FIGURE 2. Power Dissipation Diagram

The next parameter which must be calculated is the maximum allowable temperature rise, T_R(max):

θ_{JA} = TR (max)/P_D

If the maximum allowable value for θ_{JA}˚C/w is found to be ≥60˚C/W for TO-220 package or ≥92˚C/W for TO-252 package, no heatsink is needed since the package alone will dissipate enough heat to satisfy these requirements. If the calculated value for θ_{JA} fall below these limits, a heatsink is required.

As a design aid, *Table 1* shows the value of the θ_{JA} of TO-252 for different heatsink area. The copper patterns that we used to measure these θ_{JA} are shown at the end of the Application Note Section. reflects the same test results as what are in the *Table 1*

shows the maximum allowable power dissipation vs. ambient temperature for theTO-252 device. shows the maximum allowable power dissipation vs. copper area (in^2) for the TO-252 device. Please see AN1028 for power enhancement techniques to be used with TO-252 package.

Application Information (Continued)

TABLE 1. θ_{JA} Different Heatsink Area

Layout	Copper Area		Thermal Resistance
	Top Sice (in^2)*	Bottom Side (in^2)	(θ_{JA}, ˚C/W) TO-252
1	0.0123	0	103
2	0.066	0	87
3	0.3	0	60
4	0.53	0	54
5	0.76	0	52
6	1	0	47
7	0	0.2	84
8	0	0.4	70
9	0	0.6	63
10	0	0.8	57
11	0	1	57
12	0.066	0.066	89
13	0.175	0.175	72
14	0.284	0.284	61
15	0.392	0.392	55
16	0.5	0.5	53

*Tab of device attached to topside copper

Application Information (Continued)

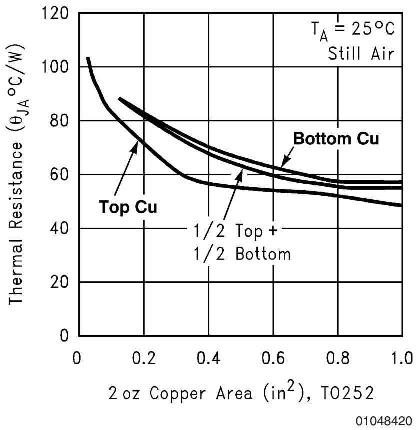


FIGURE 3. θ_{JA} vs. 2oz Copper Area for TO-252

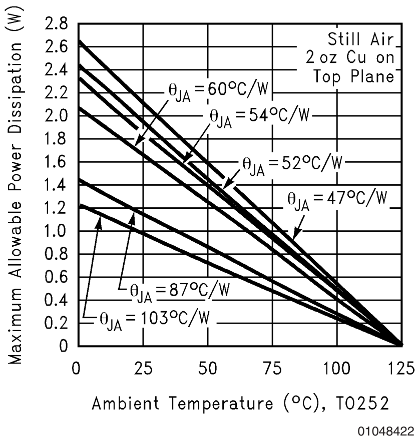


FIGURE 4. Maximum Allowable Power Dissipation vs. Ambient Temperature for TO-252

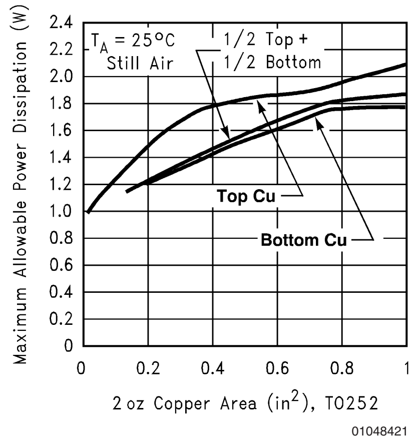
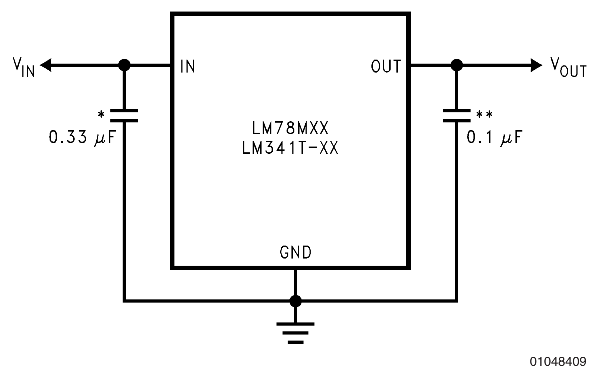


FIGURE 5. Maximum Allowable Power Dissipation vs. 2oz. Copper Area for TO-252

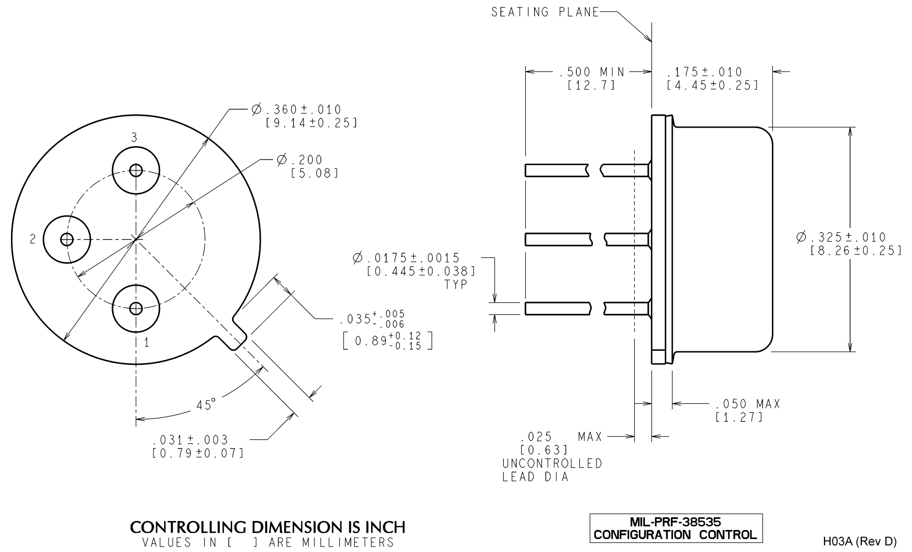
Typical Application



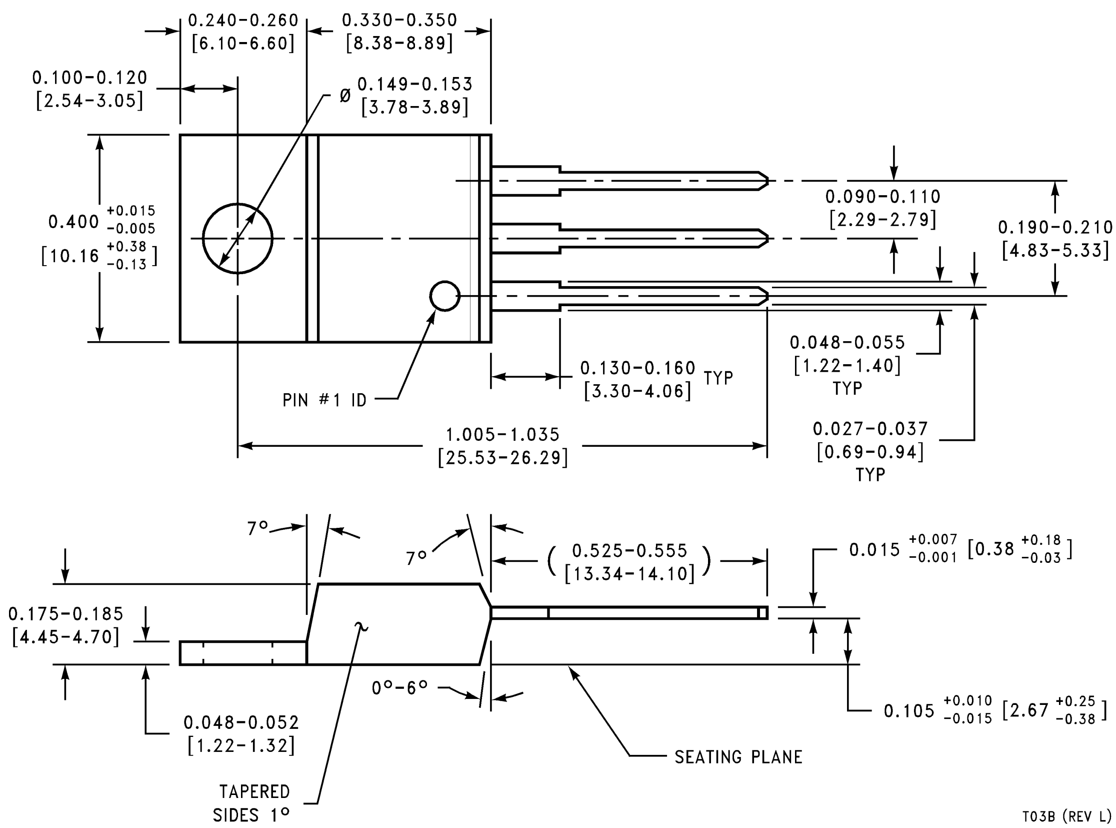
*Required if regulator input is more than 4 inches from input filter capacitor (or if no input filter capacitor is used).

**Optional for improved transient response.

Physical Dimensions inches (millimeters) unless otherwise noted

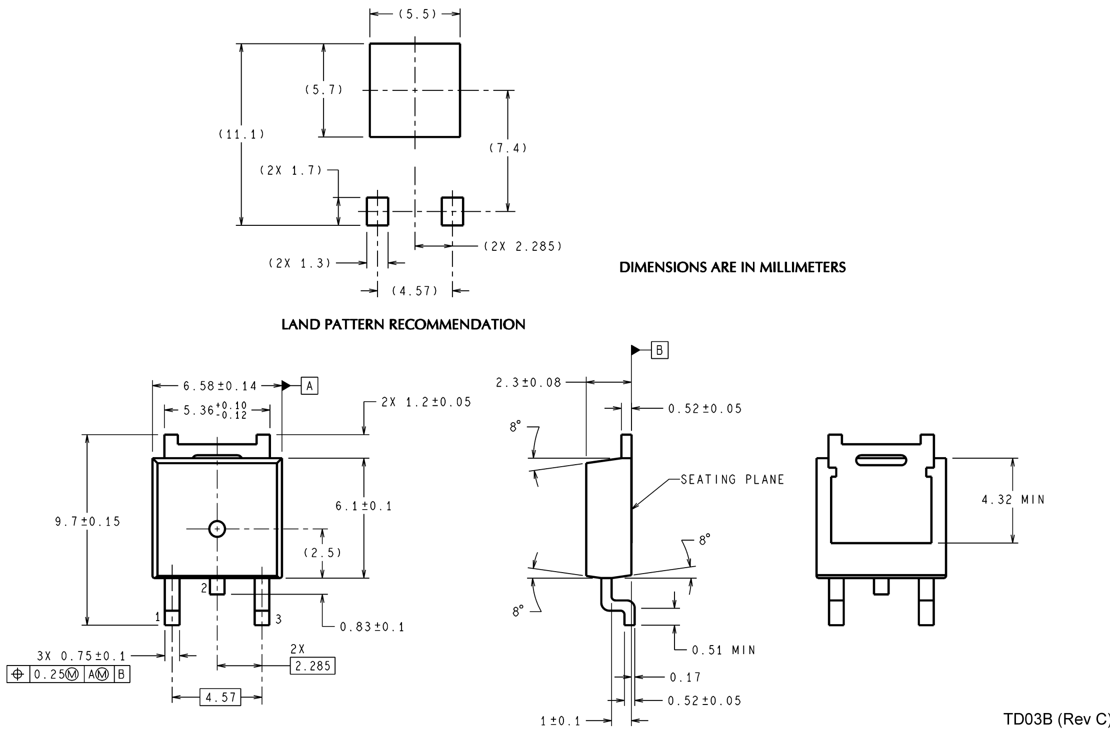


TO-39 Metal Can Package (H)
Order Number LM78M05CH, LM78M12CH or LM78M15CH
NS Package Number H03A



TO-220 Power Package (T)
Order Number LM341T-5.0, LM341T-12, LM341T-15, LM78M05CT, LM78M12CT or LM78M15CT
NS Package Number T03B

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



TO-252
Order Number LM78M05CDT
NS Package Number TD03B

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.

For the most current product information visit us at www.national.com.

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

BANNED SUBSTANCE COMPLIANCE

National Semiconductor manufactures products and uses packing materials that meet the provisions of the Customer Products Stewardship Specification (CSP-9-111C2) and the Banned Substances and Materials of Interest Specification (CSP-9-111S2) and contain no ''Banned Substances'' as defined in CSP-9-111S2.

Leadfree products are RoHS compliant.

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

www.national.com

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

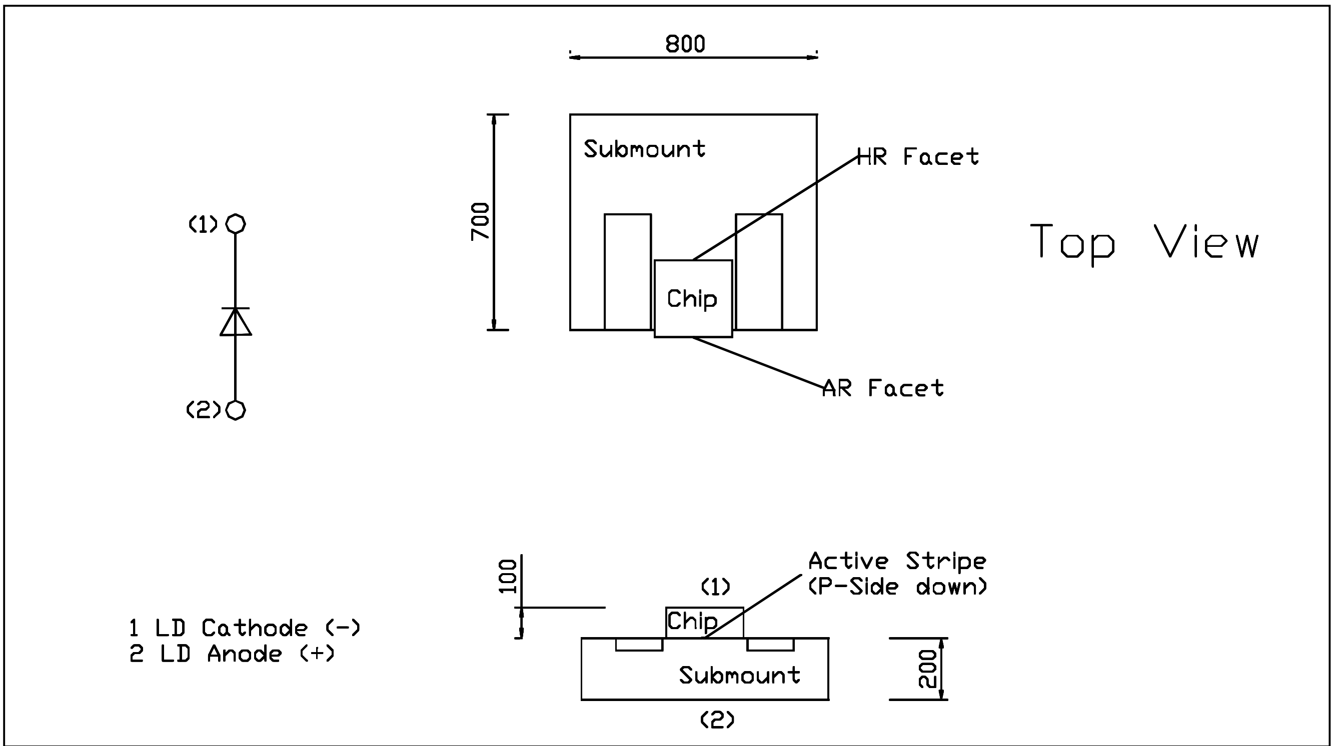
National Semiconductor
Asia Pacific Customer
Support Center
Email: ap.support@nsc.com

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

650nm Red Laser Diode chip on Submount
SLD-650-P5-CS-HR4-04

Descriptions 650nm Laser Diode Chip on Submount
Features Un-cooled Laser chip on submount with MQW structure
Gold coated copper submount

External dimensions (Unit : μ m)



Maxmum ratings (Tc = 25^{0}C)

Characteristic	Symbol	Rating	Unit
Optical Output Power	Po	7	mW
LD Reverse Voltage	Vr (LD)	2	V
Operation Case Temperature	Top	-10 ~ +40	^{o}C
Storage Temperature	Tstg	-15 ~ +85	^{o}C

友嘉科技股份有限公司
UNION OPTRONICS CORP.
桃園縣楊梅鎮3鄰高獅路156號
No, 156 Kao-Shy Road Yang-Mei, Tao-Yuan, Taiwan, R.O.C.
TEL : 886-3-485-2687 FAX : 886-3-475-4378
E-mail : sales@uocnet.com

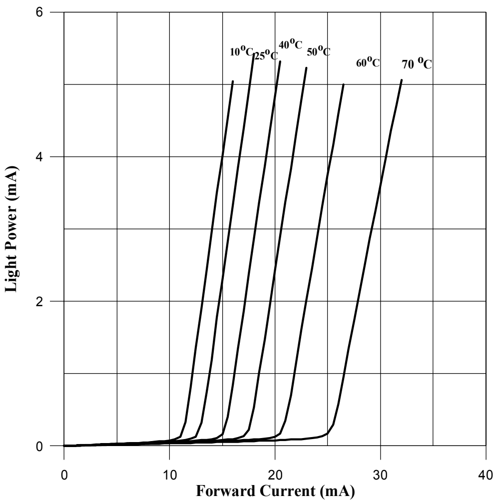
Revise by 2006/03/01

Optical-electrical characteristics (Tc = 25^0C)

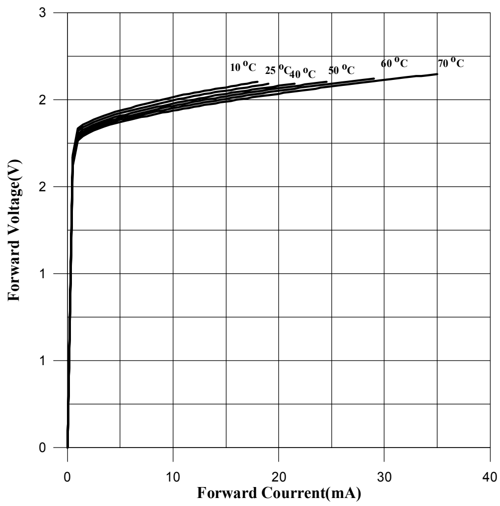
Characteristic	Symbol	Test Condition	Min.	Typ.	Max.	Unit
Threshold Current	Ith	-	-	13	22	mA
Operation Current	Iop	Po = 5mW	-	18	22	mA
Operation Voltage	Vop	Po = 5mW	2.0	2.3	2.5	V
Slope Efficiency	SE	Po = 1 to 4mW	0.6	0.8	-	W/A
Beam Divergence (horizontal)	$\theta_{//}$	Po = 5mW	5	7	12	deg.
Beam Divergence (vertical)	$\theta_{\perp}$	Po = 5mW	32	38	42	deg.
Lasing Wavelength	λ	Po = 5mW	640	652	660	nm

Typical characteristics

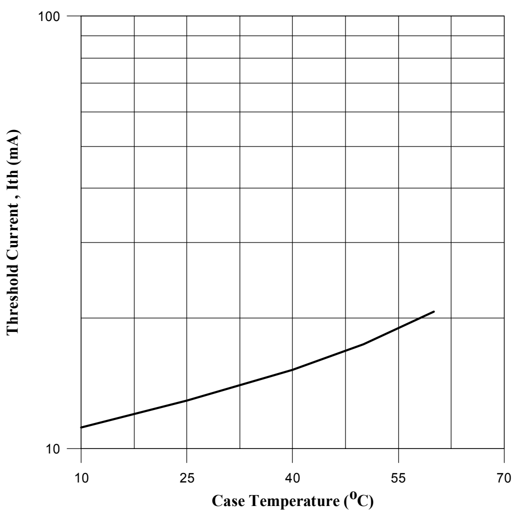
Light Power vs.Forward Current

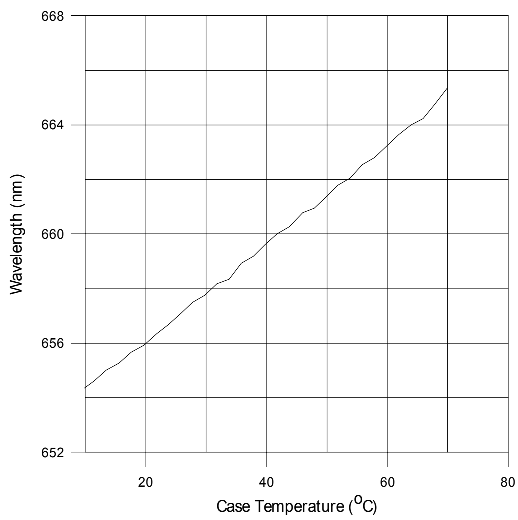


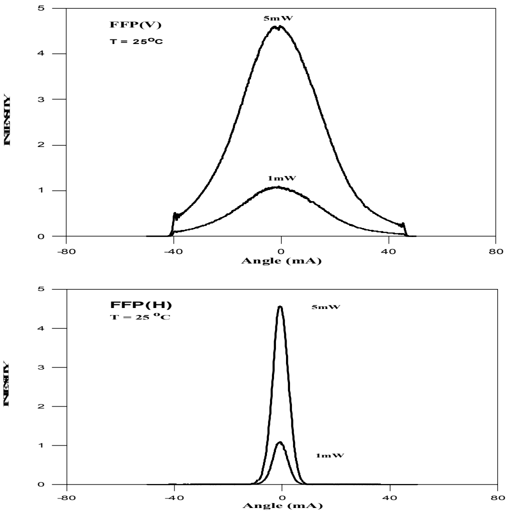
Forward Voltage vs. Forward Current

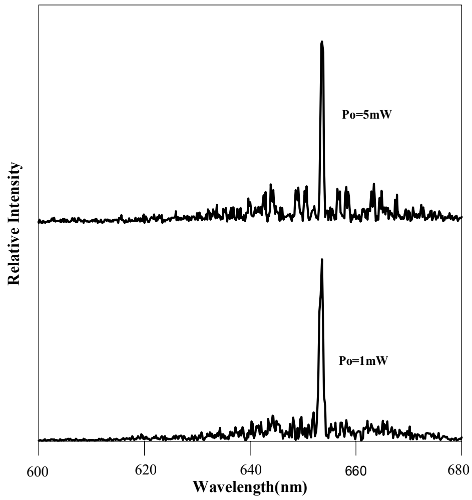


Ith (mA) vs. Case Temperature









■Precautions

QUALITY ASSURANCE

After any processing of laser chip or laser diode TO-CAN (LD) by the customer, the performance, yield and reliability of the product, in which the chip or LD is applied, are subject to change due to customer's handling, assembly, testing, and processing. Because laser chip and LD are strongly affected by environmental conditions, physical stress, and chemical stresses imposed by customer that are not in Union Optronics Corp. (UOC) control and hence no guarantee on the characteristics and the reliability at all after the shipment. Also, UOC does not have any responsibility for field failures in a customer product. When attaching a heat sink to laser chip or LD, be careful not to apply excessive force to the device in the process.

SAFETY PRECAUTIONS

Although Union Optronics Corp. (UOC) keeps improving quality and reliability of its laser chip and laser diode TO-CAN (LD), semiconductor devices in general can malfunction or fail due to their intrinsic characteristics. Hence, it is required that the customer's products are designed with full regard to safety by incorporating the redundancy, fire prevention, error prevention so that any problems or error with UOC laser chip or LD does not cause any accidents resulting in injury, death, fire, property damage, economic damage, or environmental damage. In case customer wants to use UOC laser chip or LD in the systems requiring high safety, customer is requested to confirm safety of entire systems with customer's own testing.

SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE.

The information provided by Union Optronics Corp. (UOC), including but not limited t technical specifications, recommendations, and application notes relating to laser chip or laser diode TO-CAN (LD) is believed to be reliable and accurate and is subject to change without notice. UOC reserves the right to change its assembly, test, design, form, specification, control, or function without notice.

National Semiconductor

August 2000

LM386
Low Voltage Audio Power Amplifier

General Description

The LM386 is a power amplifier designed for use in low voltage consumer applications. The gain is internally set to 20 to keep external part count low, but the addition of an external resistor and capacitor between pins 1 and 8 will increase the gain to any value from 20 to 200.

The inputs are ground referenced while the output automatically biases to one-half the supply voltage. The quiescent power drain is only 24 milliwatts when operating from a 6 volt supply, making the LM386 ideal for battery operation.

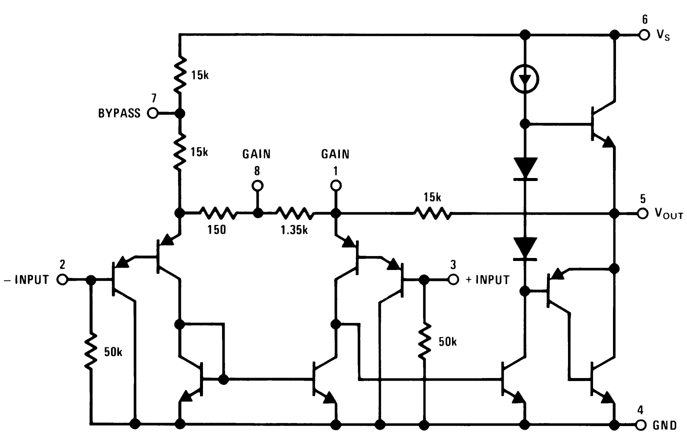
Features

- Battery operation
- Minimum external parts
- Wide supply voltage range: 4V–12V or 5V–18V
- Low quiescent current drain: 4mA
- Voltage gains from 20 to 200
- Ground referenced input
- Self-centering output quiescent voltage
- Low distortion: 0.2% (A_V = 20, V_S = 6V, R_L = 8Ω, P_O = 125mW, f = 1kHz)
- Available in 8 pin MSOP package

Applications

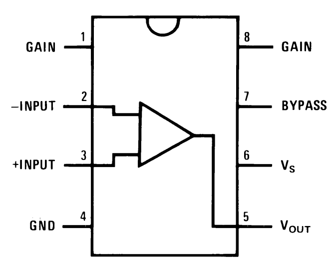
- AM-FM radio amplifiers
- Portable tape player amplifiers
- Intercoms
- TV sound systems
- Line drivers
- Ultrasonic drivers
- Small servo drivers
- Power converters

Equivalent Schematic and Connection Diagrams



DS006976-1

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



DS006976-2

Top View
Order Number LM386M-1, LM386MM-1, LM386N-1, LM386N-3 or LM386N-4
See NS Package Number M08A, MUA08A or 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	
(LM386N-1, -3, LM386M-1)	15V
Supply Voltage (LM386N-4)	22V
Package Dissipation (Note 3)	
(LM386N)	1.25W
(LM386M)	0.73W
(LM386MM-1)	0.595W
Input Voltage	±0.4V
Storage Temperature	−65˚C to +150˚C
Operating Temperature	0˚C to +70˚C
Junction Temperature	+150˚C
Soldering Information	
Dual-In-Line Package	
Soldering (10 sec)	+260˚C
Small Outline Package	
(SOIC and MSOP)	
Vapor Phase (60 sec)	+215˚C
Infrared (15 sec)	+220˚C

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

Thermal Resistance	
θ_{JC} (DIP)	37˚C/W
θ_{JA} (DIP)	107˚C/W
θ_{JC} (SO Package)	35˚C/W
θ_{JA} (SO Package)	172˚C/W
θ_{JA} (MSOP)	210˚C/W
θ_{JC} (MSOP)	56˚C/W

Electrical Characteristics (Notes 1, 2)

T_A = 25˚C

Parameter	Conditions	Min	Typ	Max	Units
Operating Supply Voltage (V_S)					
LM386N-1, -3, LM386M-1, LM386MM-1		4		12	V
LM386N-4		5		18	V
Quiescent Current (I_Q)	V_S = 6V, V_{IN} = 0		4	8	mA
Output Power (P_{OUT})					
LM386N-1, LM386M-1, LM386MM-1	V_S = 6V, R_L = 8Ω, THD = 10%	250	325		mW
LM386N-3	V_S = 9V, R_L = 8Ω, THD = 10%	500	700		mW
LM386N-4	V_S = 16V, R_L = 32Ω, THD = 10%	700	1000		mW
Voltage Gain (A_V)	V_S = 6V, f = 1 kHz		26		dB
	10 µF from Pin 1 to 8		46		dB
Bandwidth (BW)	V_S = 6V, Pins 1 and 8 Open		300		kHz
Total Harmonic Distortion (THD)	V_S = 6V, R_L = 8Ω, P_{OUT} = 125 mW f = 1 kHz, Pins 1 and 8 Open		0.2		%
Power Supply Rejection Ratio (PSRR)	V_S = 6V, f = 1 kHz, C_{BYPASS} = 10 µF Pins 1 and 8 Open, Referred to Output		50		dB
Input Resistance (R_{IN})			50		kΩ
Input Bias Current (I_{BIAS})	V_S = 6V, Pins 2 and 3 Open		250		nA

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 operation in ambient temperatures above 25˚C, the device must be derated based on a 150˚C maximum junction temperature and 1) a thermal resistance of 107˚C/W junction to ambient for the dual-in-line package and 2) a thermal resistance of 170˚C/W for the small outline package.

Application Hints

GAIN CONTROL

To make the LM386 a more versatile amplifier, two pins (1 and 8) are provided for gain control. With pins 1 and 8 open the 1.35 kΩ resistor sets the gain at 20 (26 dB). If a capacitor is put from pin 1 to 8, bypassing the 1.35 kΩ resistor, the gain will go up to 200 (46 dB). If a resistor is placed in series with the capacitor, the gain can be set to any value from 20 to 200. Gain control can also be done by capacitively coupling a resistor (or FET) from pin 1 to ground.

Additional external components can be placed in parallel with the internal feedback resistors to tailor the gain and frequency response for individual applications. For example, we can compensate poor speaker bass response by frequency shaping the feedback path. This is done with a series RC from pin 1 to 5 (paralleling the internal 15 kΩ resistor). For 6 dB effective bass boost: $R \simeq 15$ kΩ, the lowest value for good stable operation is $R = 10$ kΩ if pin 8 is open. If pins 1 and 8 are bypassed then R as low as 2 kΩ can be used. This restriction is because the amplifier is only compensated for closed-loop gains greater than 9.

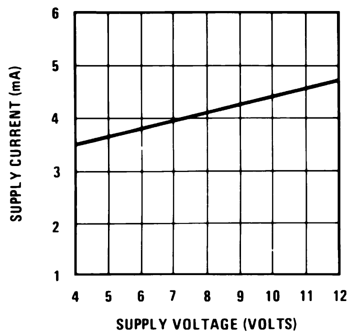
INPUT BIASING

The schematic shows that both inputs are biased to ground with a 50 kΩ resistor. The base current of the input transistors is about 250 nA, so the inputs are at about 12.5 mV when left open. If the dc source resistance driving the LM386 is higher than 250 kΩ it will contribute very little additional offset (about 2.5 mV at the input, 50 mV at the output). If the dc source resistance is less than 10 kΩ, then shorting the unused input to ground will keep the offset low (about 2.5 mV at the input, 50 mV at the output). For dc source resistances between these values we can eliminate excess offset by putting a resistor from the unused input to ground, equal in value to the dc source resistance. Of course all offset problems are eliminated if the input is capacitively coupled.

When using the LM386 with higher gains (bypassing the 1.35 kΩ resistor between pins 1 and 8) it is necessary to bypass the unused input, preventing degradation of gain and possible instabilities. This is done with a 0.1 µF capacitor or a short to ground depending on the dc source resistance on the driven input.

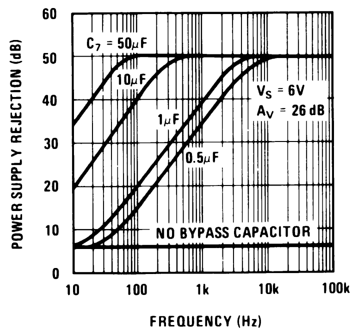
Typical Performance Characteristics

Quiescent Supply Current vs Supply Voltage



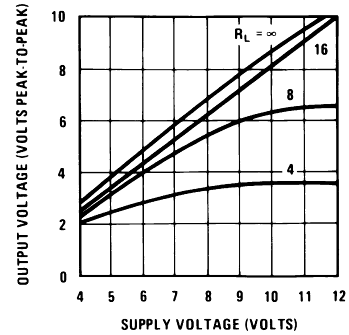
DS006976-5

Power Supply Rejection Ratio (Referred to the Output) vs Frequency



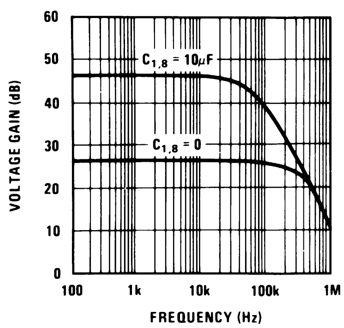
DS006976-12

Peak-to-Peak Output Voltage Swing vs Supply Voltage



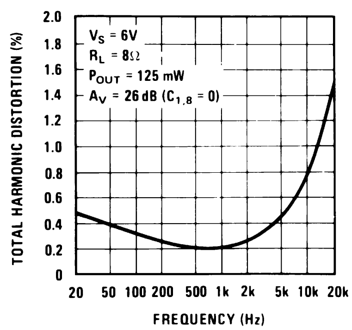
DS006976-13

Voltage Gain vs Frequency



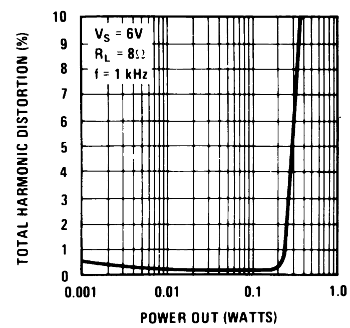
DS006976-14

Distortion vs Frequency



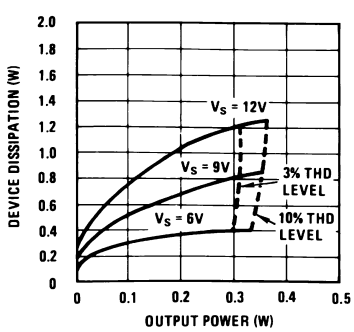
DS006976-15

Distortion vs Output Power



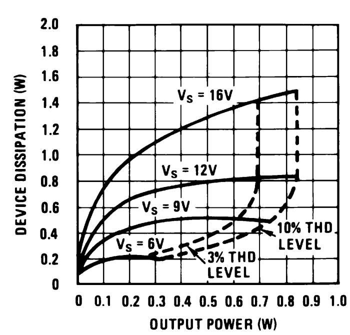
DS006976-16

Device Dissipation vs Output Power—4Ω Load



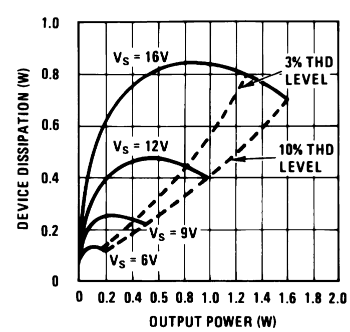
DS006976-17

Device Dissipation vs Output Power—8Ω Load



DS006976-18

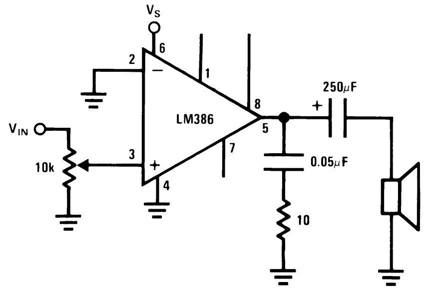
Device Dissipation vs Output Power—16Ω Load



DS006976-19

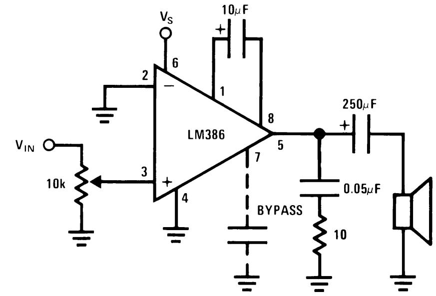
Typical Applications

**Amplifier with Gain = 20
Minimum Parts**



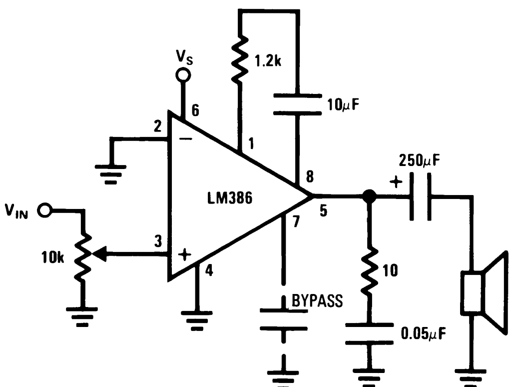
DS006976-3

Amplifier with Gain = 200



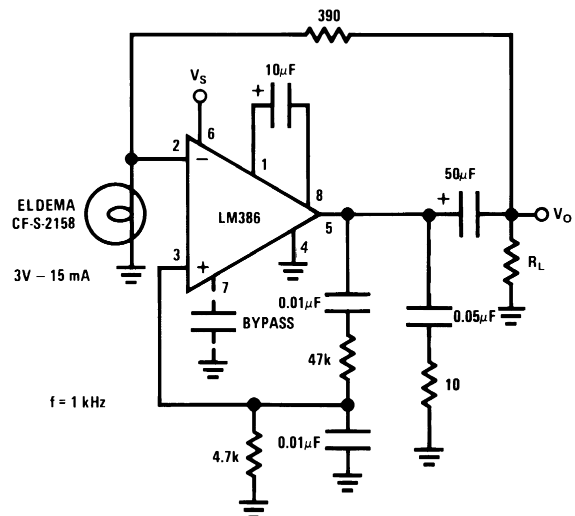
DS006976-4

Amplifier with Gain = 50



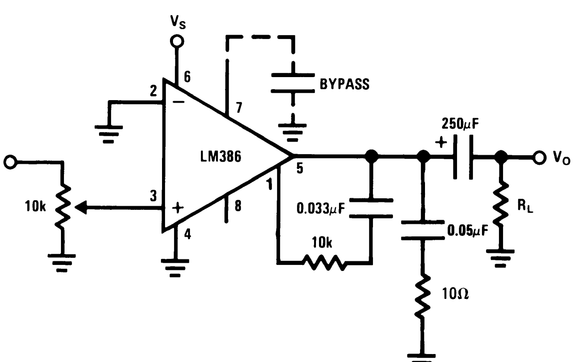
DS006976-6

Low Distortion Power Wienbridge Oscillator



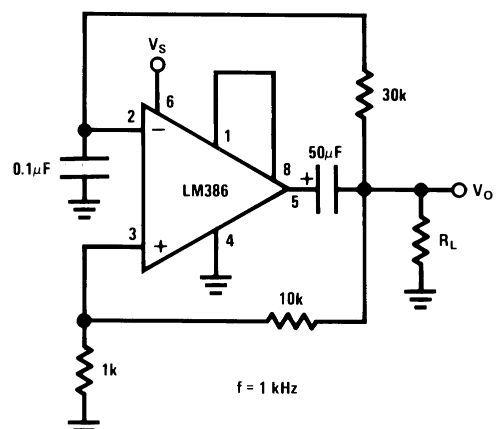
DS006976-7

Amplifier with Bass Boost



DS006976-8

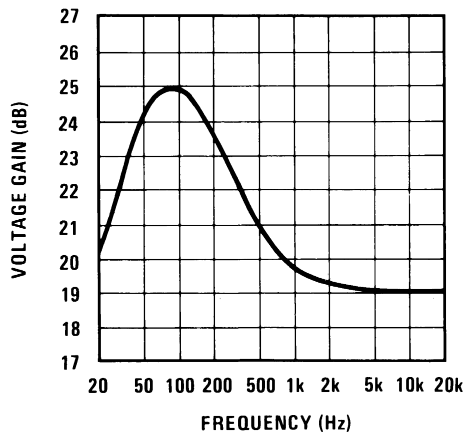
Square Wave Oscillator



DS006976-9

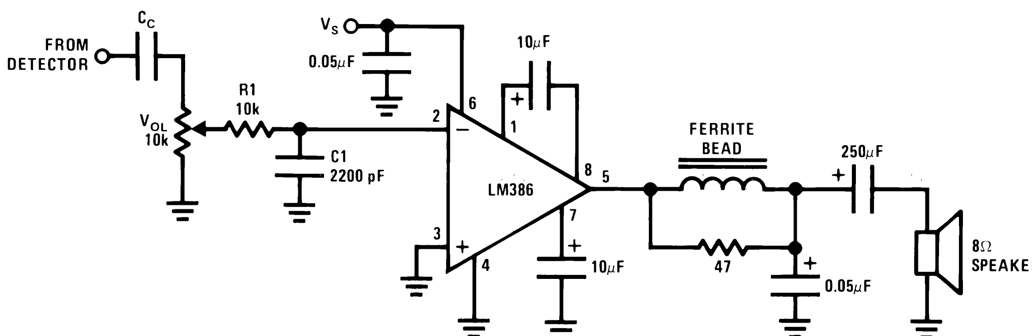
Typical Applications (Continued)

Frequency Response with Bass Boost



DS006976-10

AM Radio Power Amplifier



DS006976-11

Note 4: Twist Supply lead and supply ground very tightly.

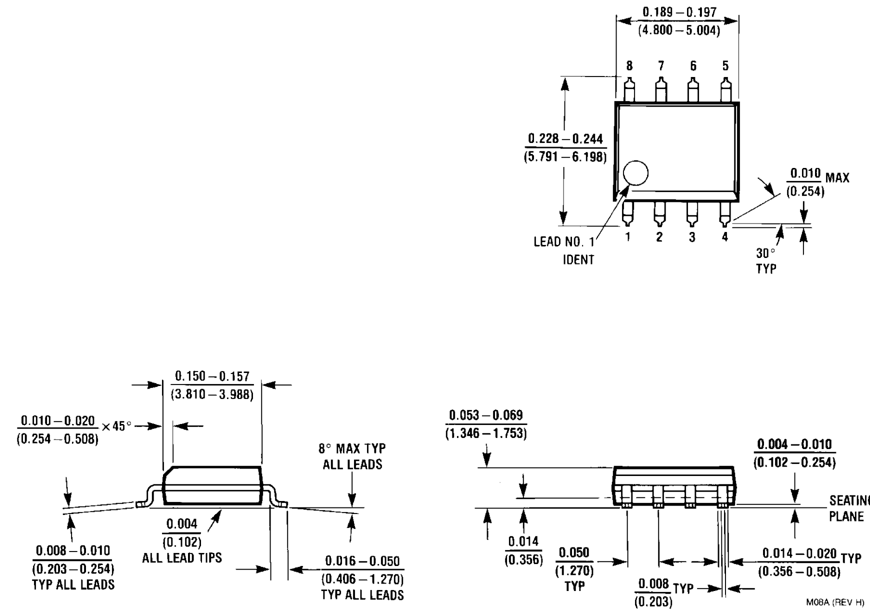
Note 5: Twist speaker lead and ground very tightly.

Note 6: Ferrite bead in Ferroxcube K5-001-001/3B with 3 turns of wire.

Note 7: R1C1 band limits input signals.

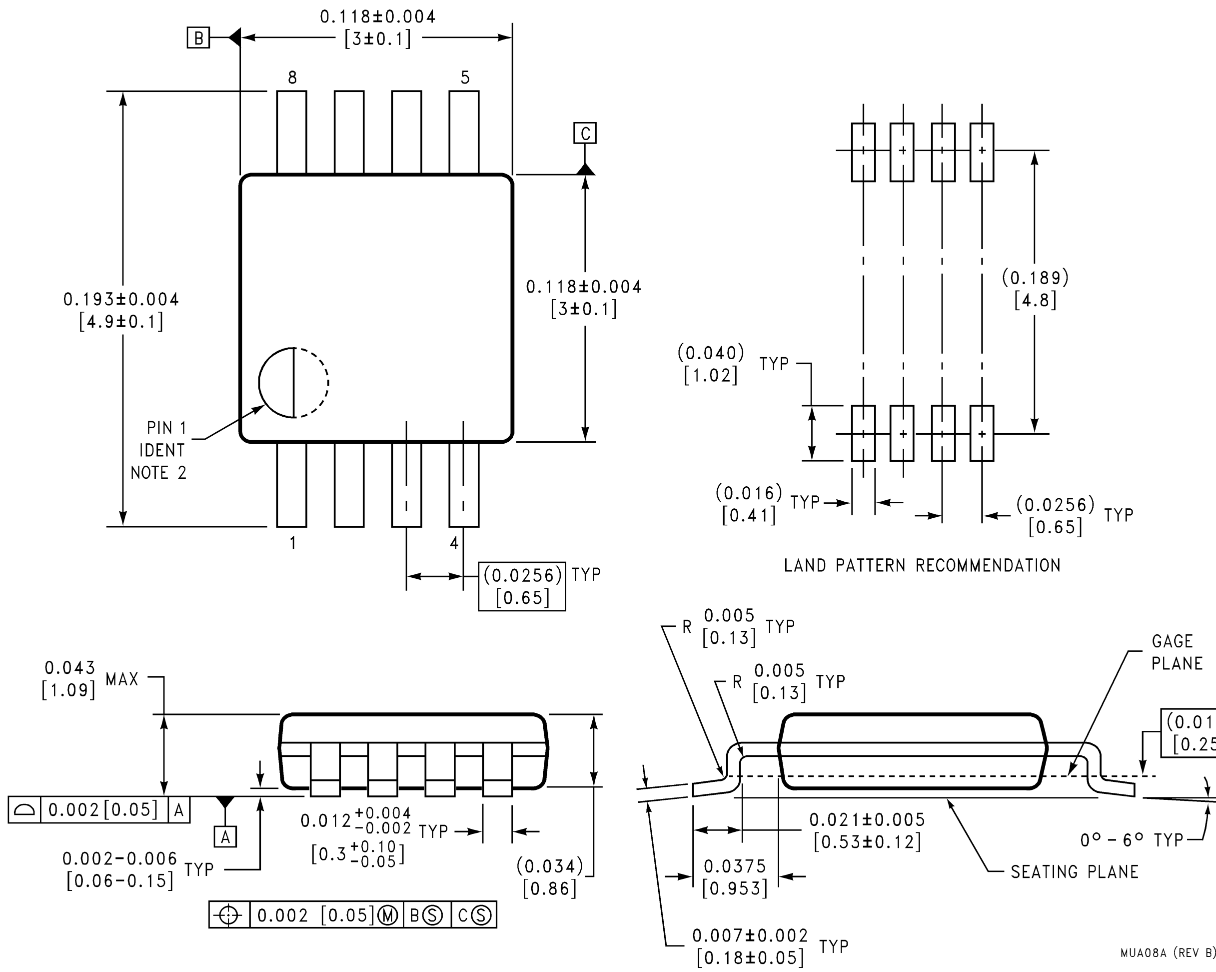
Note 8: All components must be spaced very closely to IC.

Physical Dimensions inches (millimeters) unless otherwise noted



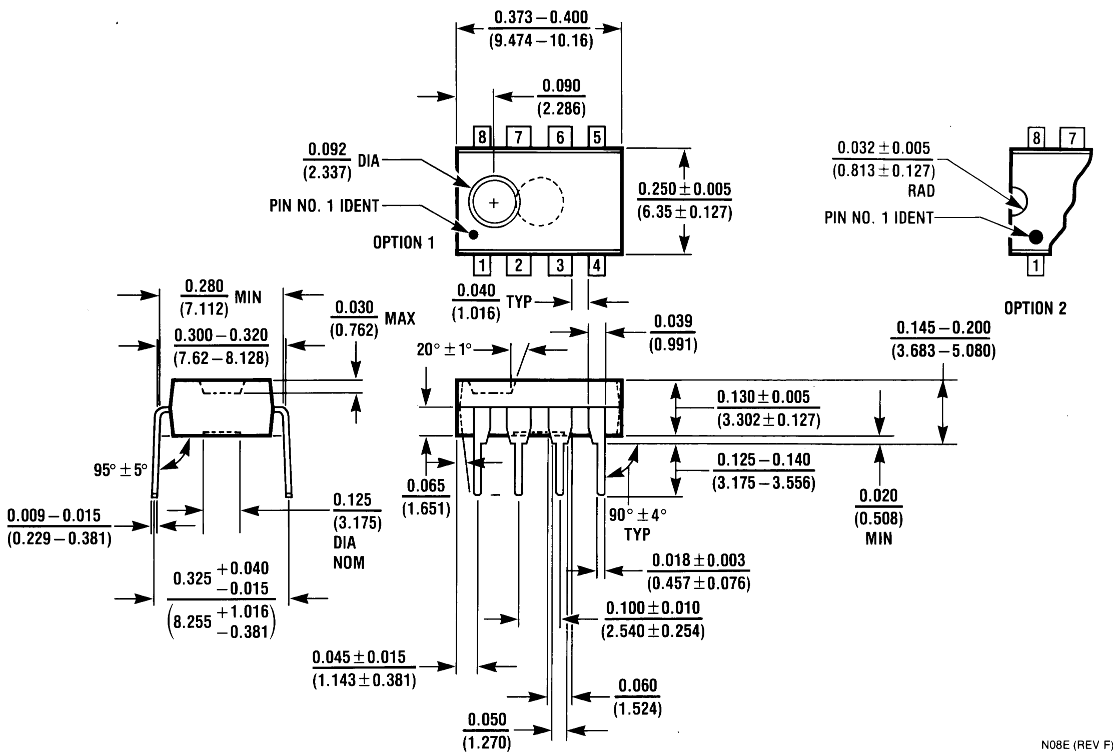
SO Package (M)
Order Number LM386M-1
NS Package Number M08A

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



8-Lead (0.118" Wide) Molded Mini Small Outline Package
Order Number LM386MM-1
NS Package Number MUA08A

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



Dual-In-Line Package (N)
Order Number LM386N-1, LM386N-3 or LM386N-4
NS Package Number N08E

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

National Semiconductor Corporation
Americas
Tel: 1-800-272-9959
Fax: 1-800-737-7018
Email: support@nsc.com
www.national.com

National Semiconductor Europe
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 Response Group
Tel: 65-2544466
Fax: 65-2504466
Email: ap.support@nsc.com

National Semiconductor Japan Ltd.
Tel: 81-3-5639-7560
Fax: 81-3-5639-7507