PALESTINE POLYTECHNIC UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Graduation Project

Transmitting audio and video using a Free Space Laser Communication

Project Team

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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.

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كلية الهندسة و التكنولوجيا

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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

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توقيع رئيس الدائرة

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Abstract

In this project, a system of transmitting a video signal using a laser beam as a carrier signal will be constructed. This technology is useful where the physical connections are impractical due to high costs or other considerations.

This system is consists in general of two parts, the transmitter where the analog modulation (AM) process happen to the video signal using laser beam as a carrier, and the receiver where the modulated signal can be received by photosensitive resistor LDR which a part from the transmitter by several meters, and then the signal will be processed in the receiver side.

Acknowledgments

We would like to express our greatest gratitude to the following people who help us to accomplish this work. Without their guidance and help the work presented in this project would not have been possible.

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1

Chapter One

Introduction

Chapter contents:

1.1. Introduction.

1.2. Project idea.

1.3. Advantages of the project.

1.4. Project objectives.

1.5. Literature review.

1.6. The Importance of the project.

1.7. Time plane.

1.8. Estimated cost.

1.9. Project contents.

1.1 Introduction.

Free-space optical communication has attracted considerable attention recently for a variety of applications. Because of the complexity associated with phase or frequency modulation, current free space optical communication systems typically use intensity modulation with direct detection (IM/DD).

As the need for a higher bandwidth to transmit the data with 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.

Laser communications systems are wireless connections through the atmosphere. They work similarly to fiber optic links, except the fact that, in lasers, beam is transmitted through free space.

1.2 Project idea.

The main idea in this project is to design and implement a laser communication system which can be used as a wireless communication system to transmit and receive video in free space.

This system is consists in general of two parts, the transmitter where the analoge modulation process happen to the video signal using laser beam as a carrier, and the receiver where the modulated signal can be received by photosensitive resistor LDR which a part from the transmitter by small distance, and then the signal will be processed in the receiver side.

1.3 Advantages of the project.

The main advantages of free space laser communication are:

- 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.
- The very short wavelength of the optical carrier typically of the order of 1 micrometer permits the realization of very small, compact components.
- 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.

Because of the advantages of the optical signals as a carrier over the other types of signals we decided to transmit a video signal with a high speed using a laser beam.

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

1.4 Project objectives.

The project aims to designing a system that consists of a transmitter which transmit a video signal on the laser beam using analoge modulation, then receive the signal after a certain distance and demodulate it to get the video signal again at the receiver side. Also To study the major limitation of free-space laser communication performance, which is due to the atmosphere, since a portion of the atmospheric path always includes turbulence and multiple scattering effects.

1.5 Literature review.

This part is talking about some studies which used a laser beam in communication applications.

This project is depending on laser beam, so theory of laser should be discussed. The principle of laser was first presented in 1917, when physicist Albert Einstein described the theory of stimulated emission. However, it was not until the late 1940s the engineers began to utilize this principle for practical purposes. 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 previous graduation project of the students from Palestine Polytechnic University, it's talking about the transmission of voice signal using laser beam as a carrier. The main objective in that project was to design and implement a system that consists of a transmitter which transmits a voice signal on the laser beam, then receive this signal after a certain distance and demodulate it to get the voice signal a gain at the receiver side.

But in this project the transmission of a video signal will be done, so it should be using a camera to fed a video signal instead of a microphone or any kind of audio input, and using a computer screen or any display screen instead of a speaker.

In reference [2], Applied Sciences Department of University of Technology in Baghdad published an article about free space video laser communication. This article is talking about a system which can transmit and receive an optical video through free space, also about the atmosphere effects of the transmission. The main gap in that system was the transmission range; it was just about 5 m. But in this project the increasing of this distance for a longer range will be taken in consideration if that could be possible.

Finally, the idea of free space laser communication systems is widely spread, and it grown every day.

1.6 The importance of the project.

By improving this system to 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 system in transmitting different kinds of data; this is done by changing the kind of the laser or changing the kind of modulation.

1.7 Time plane

The following table defines the main tasks in the project:

Table (1.1): Time line for finishing the project

T1	Choose a project idea	2 Weeks
T2	Collecting information about the project	14 Weeks
T3	Writing project proposal	3 Weeks
T4	Documentation	10 Weeks
T5	Theoretical calculations	3 Weeks
T6	System Design	8 Weeks
T7	Building and testing the system	4 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													■	■	■	■

1.8 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	20
3	Capacitors	20
4	Transistor	30
5	Potentiometer	25
6	Bred boards	30
7	Printing board	70
8	LDR	5
9	ICs	200
10	Diode	25
11	Oscilloscope	-----
12	كاوي لحام	50
13	Coaxial cable	40
14	MA733CN Amplifier	80
15	Camera	500
16	Display screen(TV)	200
17	Buffers	20
Total cost (NIS)		**1300**

1.9 Project continents

This chapter mainly discussed the definition of the project from multiple sides, its objectives and importance, then it's discussed some studies in using laser beam in communication applications and talking about the time plan and the estimated costs of the system component that needed to implement the design system.

In the following chapter the principle of the laser beam which is used as a carrier in the system will be explain. This includes its definition, characteristic and types.

The analoge modulation process which is the main process in the system will explain in chapter two, which also includes the demodulation process.

In chapter three, which is about the project design, the general block diagram of the system is designed and discussed; also this chapter includes the explanation of circuit that will be in this project.

In chapter four, the testing and the implementation of all parts of the system is discussed, also this chapter includes the explanation of the circuits that were implemented in this project.

Finally, chapter five provides some conclusions and future recommendations to improve the system.

2

Chapter Two

Theoretical Background

2.1 The Definition of Laser.

2.2 Why use a Laser.

2.3 Laser characteristics.

2.4 Laser Classes.

2.5 Types of Lasers.

2.6 Free space optical communication (FSOC).

2.6.1 Applications of (FSOC).

2.6.2 Advantages of (FSOC).

2.6.3 Challenges of (FSOC).

2.7 Modulation process.

2.7.1 Laser modulation.

2.7.2 Amplitude modulation.

2.7.3 Amplitude demodulation.

2.1 The Definition of Laser.

Lasers have been considered for space communications since their realization in 1960.Specific advancements were needed in component performance and system engineering particularly for space qualified hardware. Advances in system architecture, data formatting and component technology over the past three decades have made laser communications in space not only viable but also an attractive approach into inter satellite link applications. [4]

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.

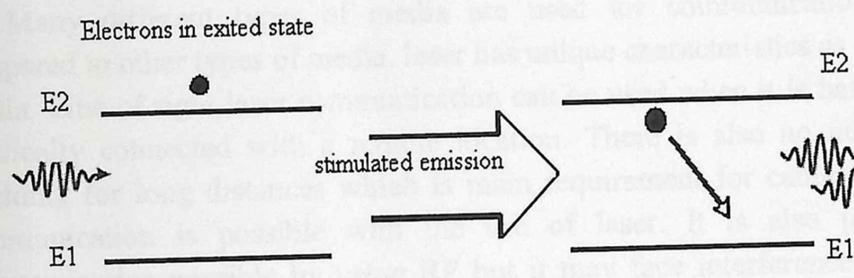

Figure 2.1: The Stimulated Emission.

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 E1 and E2 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 hν, given by:

$$E_2 - E_1 = h\nu$$

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.

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. [1]

2.2 Why use a Laser.

Many different types of media are used for communication purposes. But compared to other types of media, laser has unique characteristics as a communication media. Line of sight laser communication can be used when it is hard for wires to be physically connected with a remote location. There is also no need of laser light shielding for long distances which is main requirement for cables. Longer distance communication is possible with the use of laser. It is also possible to make communication possible by using RF but it may face interference due to other RF transmitters. As diameter of laser is few millimeters and also it is line of sight technology, it is harder to tap the data. Due to this characteristic it makes communication safe and secure. [5]

2.3 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:

- **Directional:** all the atoms in the laser beam travels in the same direction and have the same plane of polarization.
- **Monochromatic**: the light waves have the same wavelength (or the same colors).

- **High intensity**: the light waves in a laser beam have very high frequency. Thus, the energy of the laser beam is also very high.

- **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). [1]

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.

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.

2.4 Laser Classes.

Due to wavelength and maximum output power, lasers have been classified into four classes. This classification categorizes the lasers according to their ability to damage human eye. Classification of laser is dependent on the concept of accessible emission limit (AEL) that defines each laser class. This is normally maximum power and energy that can be emitted about a specific range of wavelengths and time of exposure.

Given below are the main four classes of lasers:

- **Class 1**: Laser of this class is safe one to use under estimated conditions of operation. Safety under every condition is not guaranteed.

- **Class 2**: Lasers of this class have output light in the visible spectrum, which starts from 400 nm and ends at 700 nm. It is assumed that the blink reflex will close the eyes within fraction of a second and it is necessary to provide protection. Long-standing exposure of this class results in damage.

- **Class 3a**: Lasers of this class are safe when viewed by the unaided eye but when viewed by the instruments, result may be unsafe

.

- **Class 3b**: This class of laser is safe for reflected light but direct viewing of light is hazardous. It is directed to users that not use instruments for viewing.

- **Class 4**: Lasers of this class are horribly dangerous. Its direct beam causes fire and skin injury. It is avoided for communication uses.

2.5 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.

- **Gas lasers**: Have a primary output of visible red light (helium and helium-neon, HeNe, are the most common gas lasers). CO2 lasers emit energy in the far-infrared, and are used for cutting hard materials.

- **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.

- **Solid-state lasers:** Have lasing material distributed in a solid matrix (such as the ruby or neodymium: yttrium-aluminum garnet "Yag" lasers). The neodymium-Yag laser emits infrared light at 1,064 nanometers (nm). A nanometer is 1x10-9 meters.

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

Laser diodes consist of a p-n diode with an active region where electrons and holes recombine resulting in light emission. In addition, a laser diode contains an optical cavity where stimulated emission takes 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. The distance between the two mirrors is the cavity length L. [1]

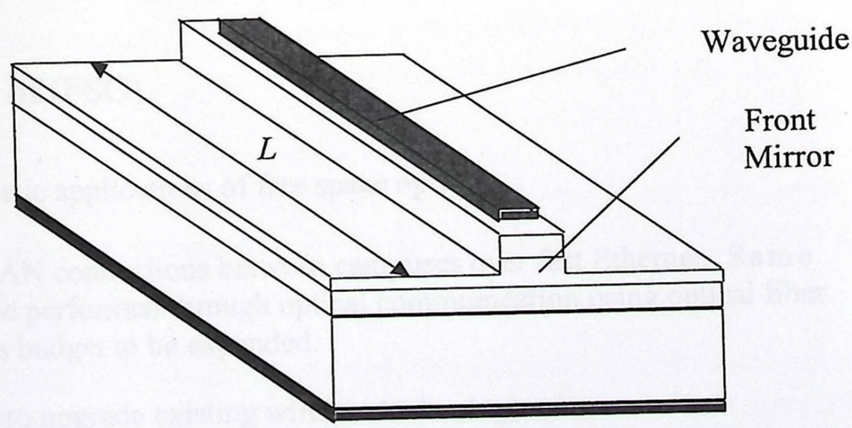

Figure 2.2 Structure of an edge-emitting laser diode.

2.6 Free space optical communication (FSOC).

Free space optical communication is used to transmit data between two stations. Free space optical communication is the part of technologies used in telecommunication and referred as the line of sight communication which transmits a modulated beam of light in free space. It's a line-of-sight technology that uses invisible beams of light to provide optical bandwidth connections that can send and receive voice, video, and data information as shown in Figure (2.3).

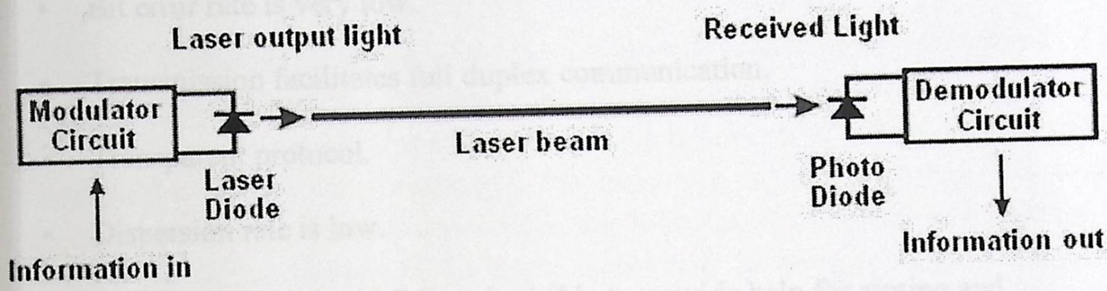

Figure 2.3: Basic overview of FSO communication.

Today, FSO technology has enabled the development of a new category of outdoor wireless products that can transmit voice, data, and video at bandwidths up to 1.25 Gbps. This optical connectivity doesn't require expensive fiber-optic cable or securing spectrum licenses for radio frequency (RF) solutions. FSO technology requires light. The use of light is a simple concept similar to optical transmissions using fiber-optic cables; the only difference is the medium. Light travels through air faster than it does through glass, so it is fair to classify FSO technology as optical communications at the speed of light. [6]

2.6.1 Applications of (FSO).

Following are basic applications of free space optics:

- It facilitates LAN connections between campuses over fast Ethernet. Same function can be performed through optical communication using optical fiber but it demands budget to be expanded.
- It can be used to upgrade existing wireless technologies.
- It may provide help in re-establishment of high speed connections.
- Interconnection between two spacecrafts can be achieved by this technology.

2.6.2 Advantages of (FSOC).

Advantages of free space optical communication are described below:

- Very quick link establishment.
- Requires no security software upgrades
- Requires no RF spectrum licensing
- Bit error rate is very low.
- Transmission facilitates full duplex communication.
- Transparent protocol.
- Dispersion rate is low.
- Light beam may be visible or invisible to provide help for aiming and detection of failures.

2.6.3 Challenges of (FSOC).

While fiber-optic cable and FSO technology share many of the same attributes, they face different challenges due to the way they transmit information. While fiber is subject to outside disturbances from wayward construction backhoes, gnawing rodents, and even sharks when deployed under sea, FSO technology is subject to its own potential outside disturbances. Optical wireless networks based on FSO technology must be designed to combat changes in the atmosphere, which can affect FSO system performance capacity. And because FSO is a line-of-sight technology, the interconnecting points must be free from physical obstruction and able to "see" each other. [6]

All potential disturbances can be addressed through thorough and appropriate network design and planning. Among the issues to be considered when deploying FSO-based optical wireless systems:

Fog: The primary challenge to FSO-based communications is dense fog. Rain and snow have little effect on FSO technology, but fog is different. Fog is vapor composed of water droplets, which are only a few hundred microns in diameter but can modify light characteristics or completely hinder the passage of light through a combination of absorption, scattering, and reflection. The primary answer to counter fog when deploying FSO-based optical wireless products is through a network design that shortens

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FSO link distances and adds network redundancies. FSO installations in extremely foggy cities such as San Francisco have successfully achieved carrier-class reliability.

Absorption: Absorption occurs when suspended water molecules in the terrestrial atmosphere extinguish photons. This causes a decrease in the power density (attenuation) of the FSO beam and directly affects the availability of a system. Absorption occurs more readily at some wavelengths than others. However, the use of appropriate power, based on atmospheric conditions, and use of spatial diversity (multiple beams within an FSO-based unit) helps maintain the required level of network availability.

Scattering: Scattering is caused when the wavelength collides with the scatterer. The physical size of the scatterer determines the type of scattering. When the scatterer is smaller than the wavelength, this is known as Rayleigh scattering. When the scatterer is of comparable size to the wavelength, this is known as Mie scattering. When the scatterer is much larger than the wavelength, this is known as non-selective scattering. In scattering — unlike absorption — there is no loss of energy, only a directional redistribution of energy that may have significant reduction in beam intensity for longer distances.

Physical obstructions: Flying birds or construction cranes can temporarily block a single-beam FSO system, but this tends to cause only short interruptions, and transmissions are easily and automatically resumed. Light Pointe's optical wireless products use multi-beam systems (spatial diversity) to address temporary obstructions, as well as other atmospheric conditions, to provide for greater availability

Building sway/seismic activity: The movement of buildings can upset receiver and transmitter alignment. Light Pointe's FSO-based optical wireless offerings use a divergent beam to maintain connectivity. When combined with tracking, multiple beam FSO-based systems provide even greater performance and enhanced installation simplicity.

Scintillation: Heated air rising from the earth or man-made devices such as heating ducts creates temperature variations among different air pockets. This can cause fluctuations in signal amplitude which leads to "image dancing" at the FSO-based receiver end. Light Pointe's unique multi-beam system is designed to address the effects of this scintillation. Called "Refractive turbulence," this causes two primary effects on optical beams.

Beam Wander: Beam wander is caused by turbulent eddies that are larger than the beam.

Beam Spreading: Beam spreading — long-term and short-term — is the spread of an optical beam as it propagates through the atmosphere

Safety: To those unfamiliar with FSO technology, safety can be a concern because the technology uses lasers for transmission. The proper use and safety of lasers have been discussed since FSO devices first appeared in laboratories more than three decades ago. The two major concerns involve eye exposure to light beams and high voltages within the light systems and their power supplies. Strict international standards have been set for safety and performance, and Light Pointe's optical wireless systems comply with these standards. [6]

2.7 Modulation process.

To deliver a message signal from an information source in recognizable form to a user destination, 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. [1]

The term modulation refers closely to any technique that systematically alters the shape of the waveform by bending its graph a parameter of carrier wave according to the variation of message signal.

Modulation is an important process in any communication system. The purpose of using modulation is:

a. Multiplexed operation of a transmission path.
b. Transfer of signal into a frequency band favorable for signal transfer.
c. Obtaining favorable signal -to- noise ratios when source and noise power are given.

Different modulation formats such as Amplitude Modulation (AM), Frequency Modulation (FM), Phase Modulation (PM), are used in both the analog and digital systems. In all of them the main properties of the beam such as frequency, amplitude, or intensity changes proportional to the input signals.

2.7.1 Laser modulation

Any type of information that can be carried by radio waves can also be carried by laser light beams. Both radio waves and laser beams are electromagnetic waves. This information is called modulation and it includes amplitude modulation (AM),

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Laser modulation aims to modulate the electrical signal on the optical signal intensity. The laser modulation drive circuit is shown in Figure (2.4). Power amplifying circuit can makes sure of supplying enough power to the laser. The voltage stabilizing circuit adopts as low dropout linear regulator, the hybrid wave is filtered by capacitance and acquire stable DC voltage of 3.3V. [3]

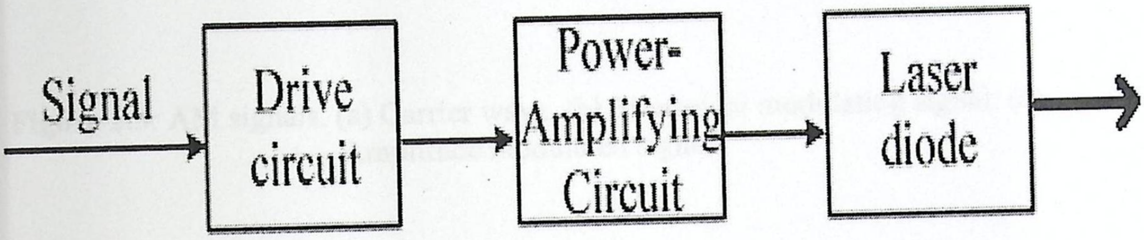

Figure 2.4: Logical diagram for the laser drive circuit.

2.7.2 Amplitude modulation

Conventional amplitude modulation places the message on a carrier whose frequency is much greater than any of the frequency contained in the base band. Amplitude modulation (AM) means that the amplitude of the carrier wave is proportional to the amplitude of the carried wave. The resulting waveform has a spectrum that surrounds the carrier frequency.

The intensity of the laser light is proportional to the amplitude of the sub carrier which depends on the modulation signal (such as audio wave). In essence, (AM) shifts the base band to anew region of the electromagnetic spectrum.

The following figures represent the waveforms of the amplitude modulated signals for the case of sinusoidal modulation.

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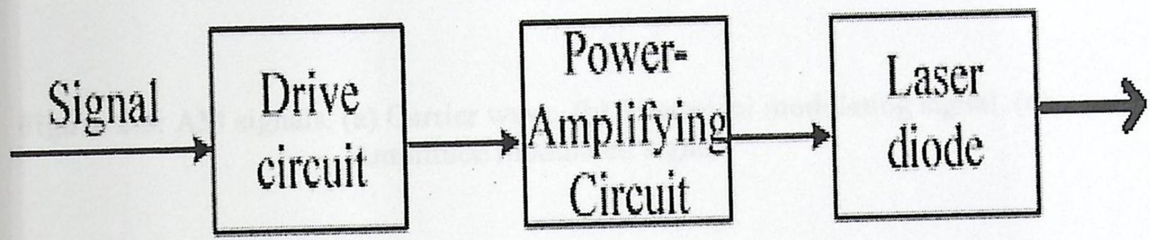

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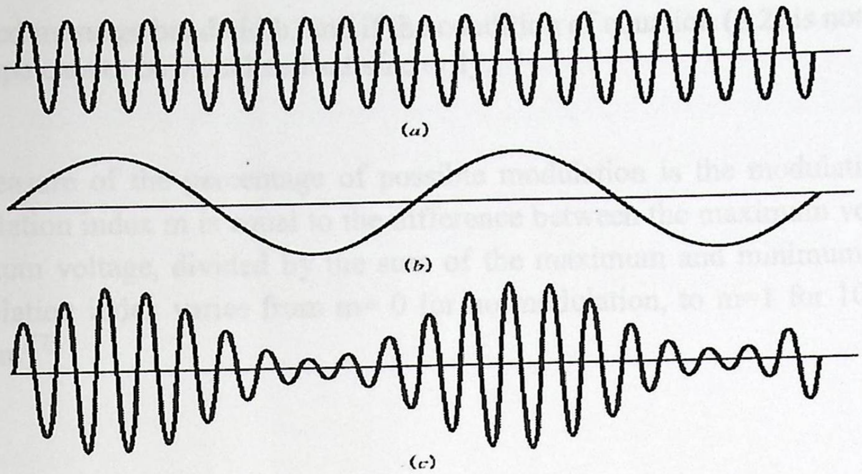

Figure 2.5: AM signals. (a) Carrier wave. (b) Sinusoidal modulating signal. (c) Amplitude modulated signal

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

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

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 $volt^{-1}$.

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 whenever 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. [7]

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} \quad (2.3)$$

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. [8]

$$B_T = 2 \times W \quad (2.4)$$

2.7.3 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. [9]

3

Chapter Three

Project Design

3.1 Introduction.

3.2 General Block Diagram.

3.3 The Transmitter.

3.3.1 Coaxial Cable.

3.3.2 Driver Circuit.

3.3.3 Modulation Process.

3.3.3.1 Modulation Circuit Operation

3.3.4 Laser Diode.

3.3.4.1 Laser Diode Divergence Angle Measurements.

3.3.4.2 Measurement of laser diode Intensity with the Distance.

3.3.5 The transmitter detailed circuit diagram.

3.4 The Receiver.

3.4.1 Light detector.

3.4.1.1 PIN photodiode.

3.4.2 Driver circuit.

3.4.3 Amplifier.

3.4.4 Coaxial Cable.

3.4.5 Display.

3.4.6 The receiver detailed circuit diagram.

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 optical communication system consists of a transmitter uses a laser beam of a wavelength 650 nm as a carrier in free space, and a receiver uses PIN diode as a detector. The transmitted signal amplified and converted to a modulated intensity of laser beam and sent to the receiver, the receiver converts the laser signal to a weak electrical signal by the detector; the signal will be amplified and converted back to an analogue signal to produce the original transmitted signal. [2]

3.2 General block diagram.

The general block diagram of the project is shown below in figure (3.1).

Figure (3.1): free space laser communication general block diagram.

Optical video link using laser beam in free space is shown in Figure (3.2). The optical transmitter (OT) converts the camera signal (through the 75Ω coax cable) into proportional light variations which are sent through the free space. The optical Receiver (OR) converts the modulated laser light back into a video signal which is sent to the monitor (TV set) through the (75Ω) coax cable. [14]

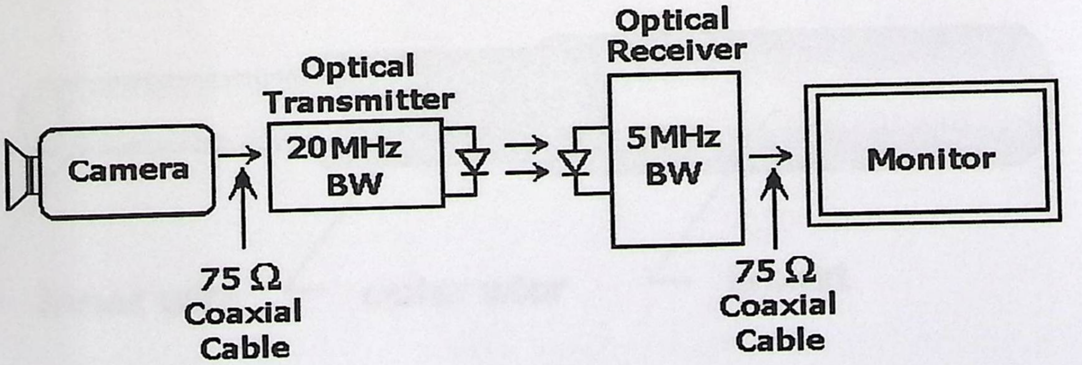

Figure (3.2): Analog communications optical video link in free space.

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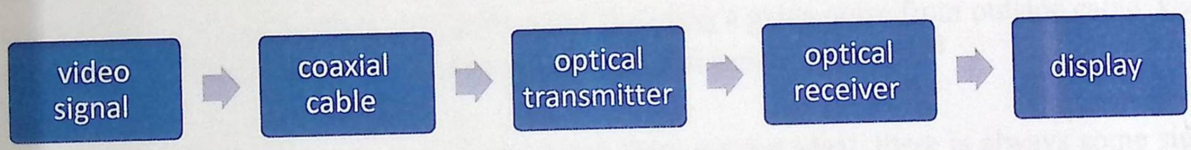

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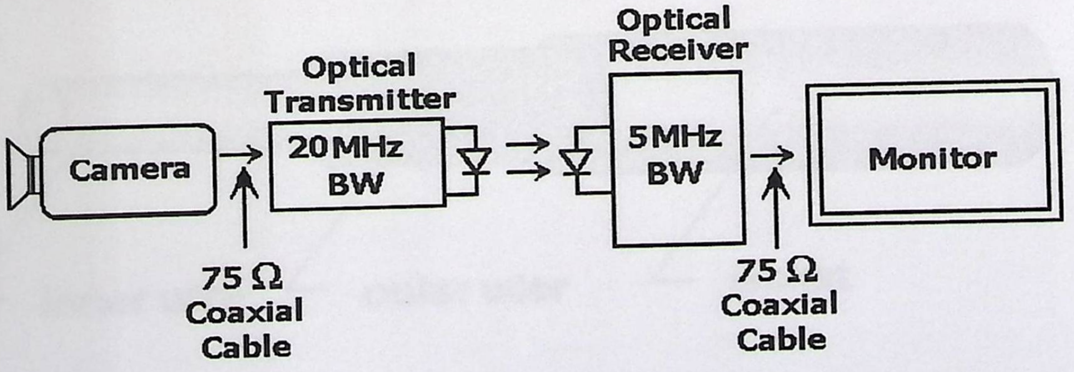

Figure (3.2): Analog communications optical video link in free space.

3.3 The transmitter.

The general block diagram of the optical transmitter is shown in the figure (3.3) below.

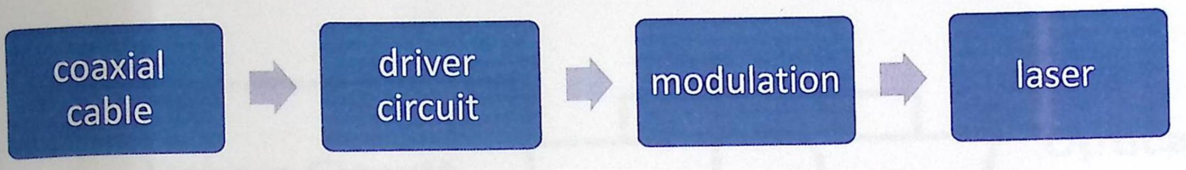

Figure (3.3): Optical transmitter block diagram.

3.3.1 Coaxial Cable.

A coaxial cable is a cable type used to carry radio signals, video signals, measurement signals and data signals. It consists of two conductors that share a common axis. The inner conductor is typically a straight wire, either solid or stranded and the outer conductor is typically a shield that might be braided or a foil. It consists of an insulated center conductor which is covered with a shield. The signal is carried between the cable shield and the center conductor. This arrangement give quite good shielding a gains noise from outside cable, keeps the signal well inside the cable and keeps cable characteristics stable. [10]

Coaxial cables and systems connected to them are not ideal, there is always some signal radiating from coaxial cable. Hence, the outer conductor also functions as a shield to reduce coupling of the signal into adjacent wiring. More shield coverage means less radiation of energy (but it does not necessarily mean less signal attenuation).

75Ω Coaxial Cable: The characteristic impedance 75 ohms is an international standard, based on optimizing the design of long distance coaxial cables. 75 ohms video cable is the coaxial cable type widely used in video, audio and telecommunications applications. Generally all baseband video applications that use coaxial cable (both analogue and digital) are matched for 75 ohm impedance cable. Also RF video signal systems like antenna signal distribution networks in houses and cable TV systems are built from 75 ohms coaxial cable. [11]

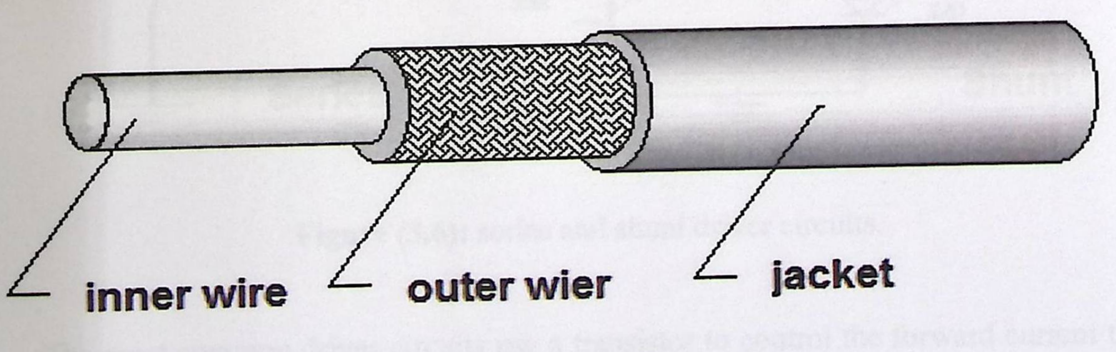

Figure (3.4): Coaxial cable structure.

3.3.2 Driver Circuit.

Optical transmitter requires electronic circuitry called the driver circuit; Figure (3.5), to control the electrical input to its light source.

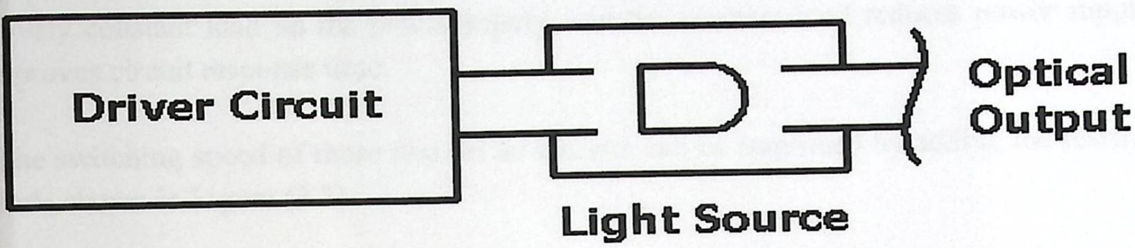

Figure (3.5): Optical transmitter driver circuit.

Driver Circuits can be driven by different types of signals: DC, AC. And pulse. Power and speed (switching speed) are important characteristic of optical–transmitter driver circuit .Without overheating; a driver circuit must apply enough electrical power to a light source so enough optical power is produced for the system .A driver must also be fast enough to pass a Signal with minimum distortion. There are two basic types of driver circuits that are commonly used for optical transmitters, series and shunt as in Figure (3.6).

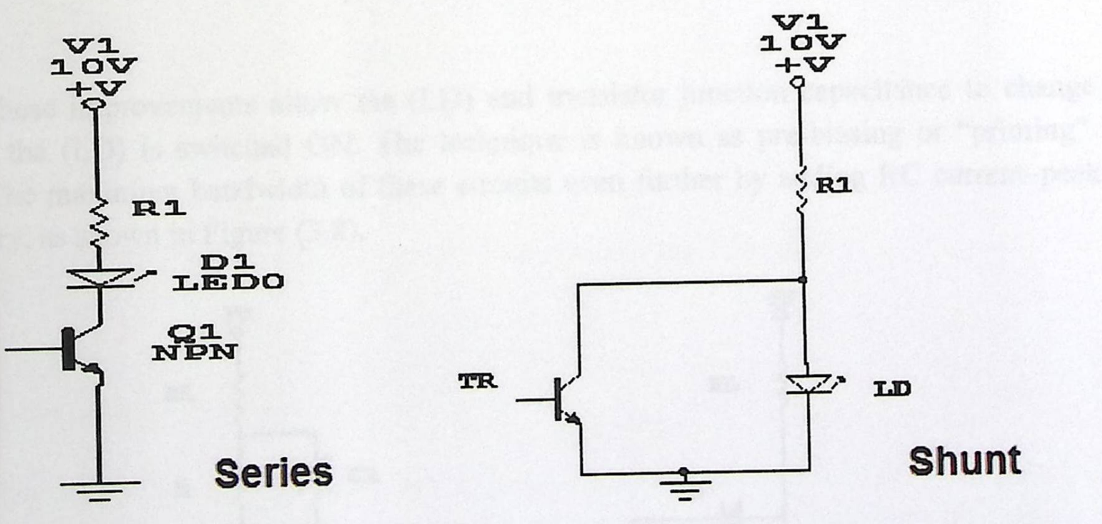

Figure (3.6): series and shunt driver circuits.

The most common driver circuits use a transistor to control the forward current through an LD light source. A series driver circuit has its active device (transistor) connected in series with the light source (LD). A shunt driver circuit has its active device (transistor) connected in

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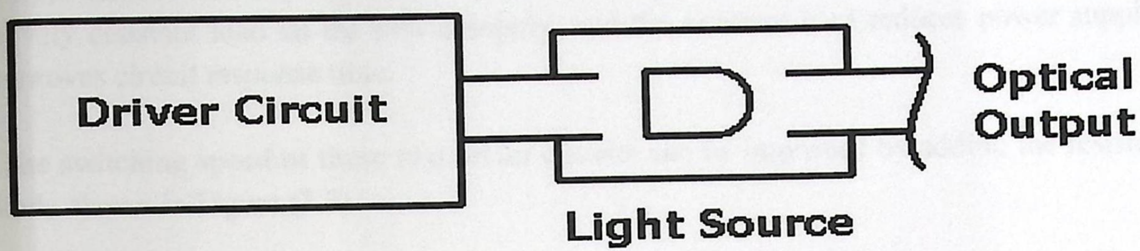

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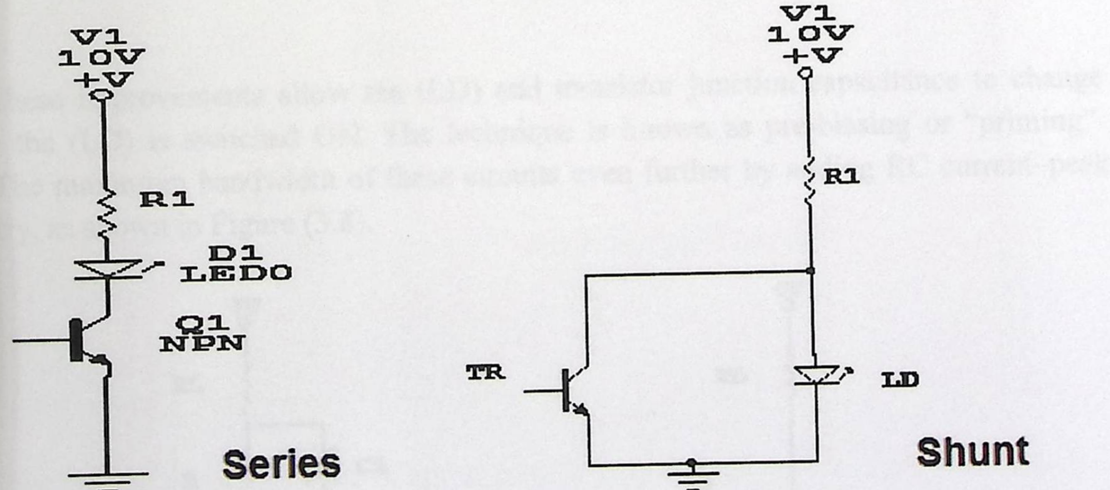

Figure (3.6): series and shunt driver circuits.

The most common driver circuits use a transistor to control the forward current through an LD light source. A series driver circuit has its active device (transistor) connected in series with the light source (LD). A shunt driver circuit has its active device (transistor) connected in parallel with the light source (LD). The series driver circuit is a simple voltage switch that only draws significant supply current when the LD is ON; this reduces the average power supply current. [2]

The shunt (parallel) driver is a simple current switch that draws significant current when the (LD) is off, because current is drawn by the driver even after it turns the (LD) off, there is a relatively constant load on the power supply, and the constant load reduces power supply and improves circuit response time.

The switching speed of these two driver circuits can be improved by adding the resister and diode shown in Figure (3.7).

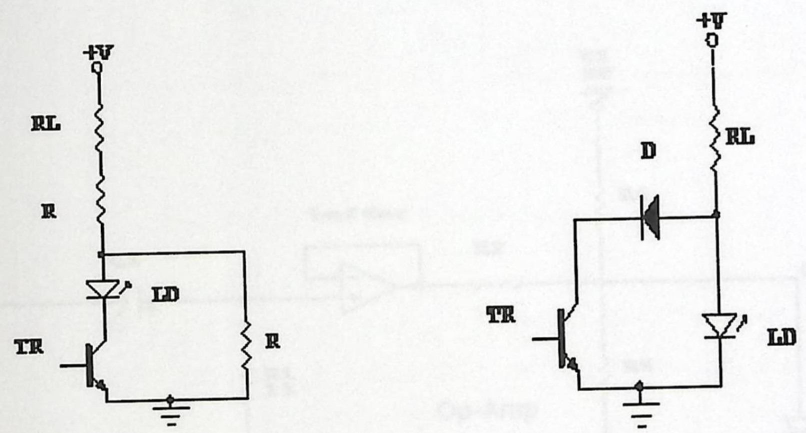

Figure (3.7): Switching Speed Improvement.

These improvements allow the (LD) and transistor junction capacitance to change up before the (LD) is switched ON. The technique is known as pre-biasing or "priming" the (LD).The maximum bandwidth of these circuits even further by adding RC current–peaking circuitry, as shown in Figure (3.8).

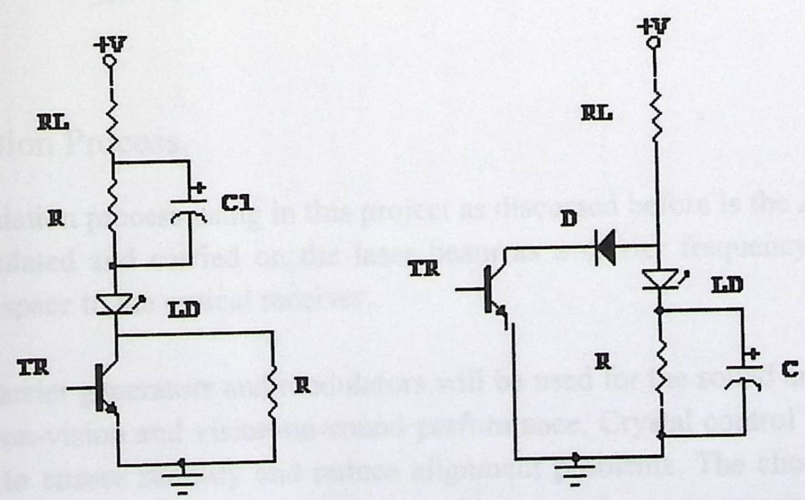

Figure (3.8): Maximum Bandwidth.

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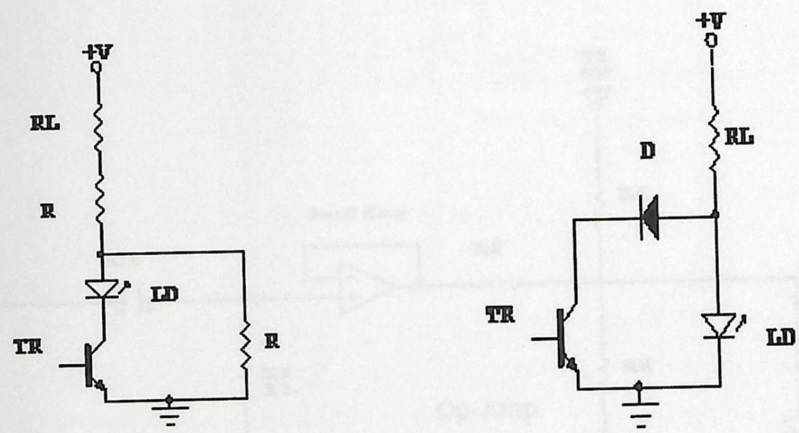

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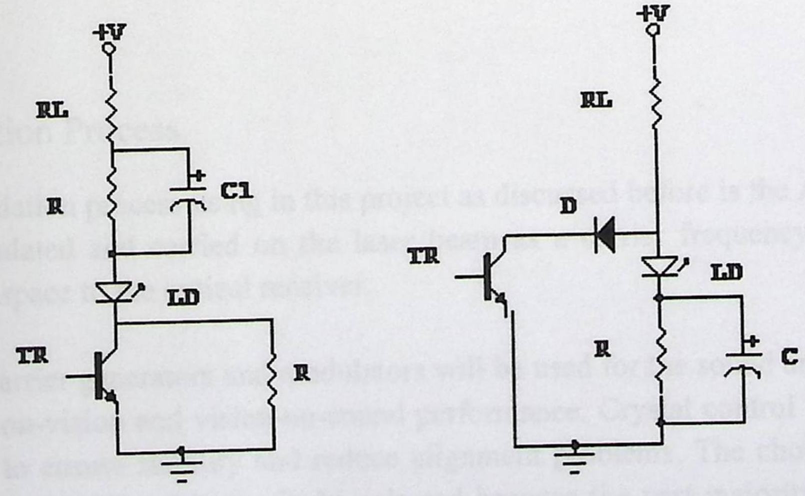


Figure (3.8): Maximum Bandwidth.

The forward current waveform is frequency compensated by the current-peaking circuitry to improve the wave shape of the optical output signal. Maximum bandwidth can be obtained by selecting R and C values for optimum current–peaking .The Analog Video Transmitter shown in figure (3.9), Uses a buffer amplifier in its driver circuit as a voltage to current converter, and R2. The circuit also uses feedback. The Feedback Maintains a stable bias voltage at the amplifier input that is equal to the (LD) forward voltage. An AC input voltage creates an AC. current through the (LD) that modulates the emitted optical power. The low cutoff frequency for the analog transmitter is determined by a high–pass filter consisting of C1, and R1 in union with low–pass filter C2 .The input signal at point (A) is fed through capacitor C1 to the input of the voltage-to-current converter Q1 , this point include feedback, from Q2 that maintains stable bias at the amplifier input .

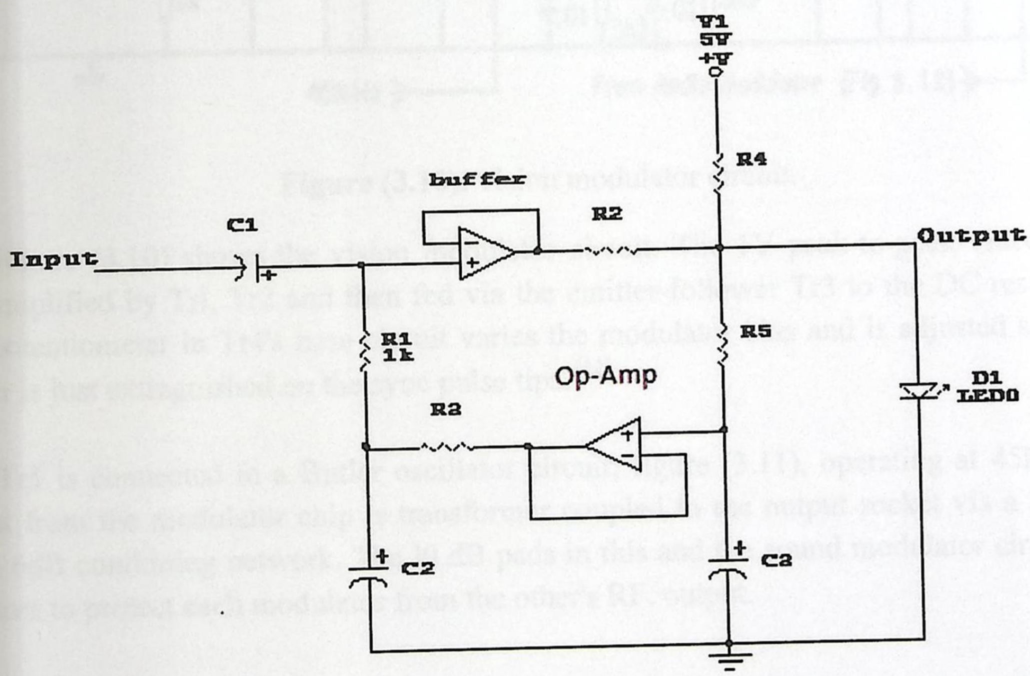


Figure (3.9): Optical Video Analogue Transmitter.

3.3.3 Modulation Process.

The modulation process using in this project as discussed before is the AM modulation , the signal modulated and carried on the laser beam as a carrier frequency the signal then transmit in free space to the optical receiver.

Separate carrier generators and modulators will be used for the sound and vision for best possible sound-on-vision and vision-on-sound performance. Crystal control of the oscillators will be chosen to ensure stability and reduce alignment problems. The choice of Channel 1 (41.5MHz sound, 45MHz vision) will be selected because the vast majority of 405-line TV sets, including all pre-war models, can operate on this channel.

3.3.3.1 Modulation Circuit Operation.

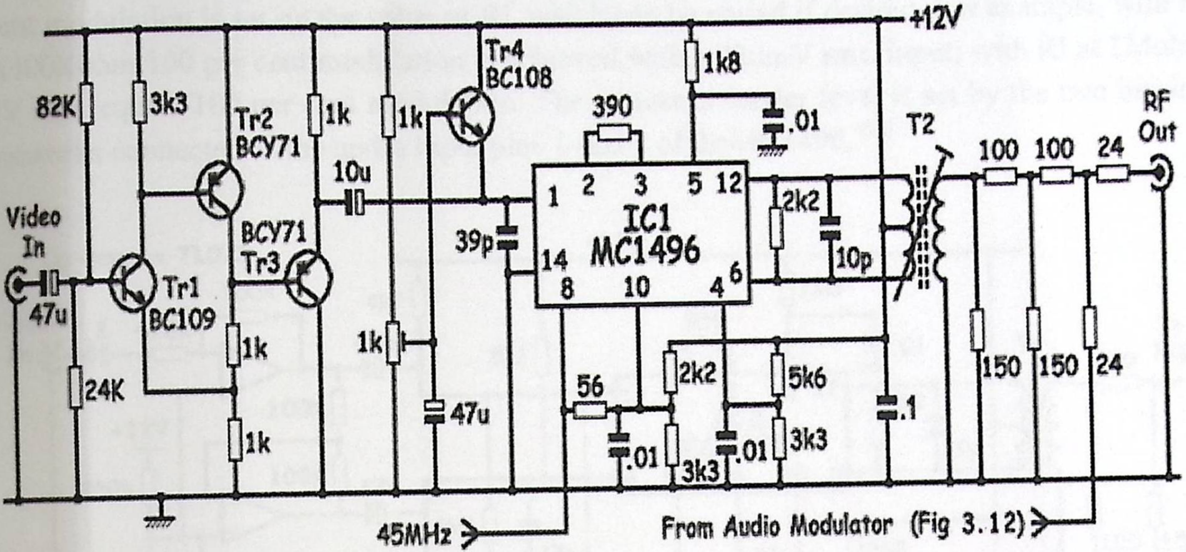


Figure (3.10): vision modulator circuit.

Figure (3.10) shows the vision modulator circuit. The 1V peak-to-peak video input is first amplified by Trl, Tr2 and then fed via the emitter-follower Tr3 to the DC restorer Tr4. The potentiometer in Tr4's base circuit varies the modulator bias and is adjusted so that the carrier is just extinguished on the sync pulse tips. [12]

Tr5 is connected in a Butler oscillator circuit; figure (3.11), operating at 45MHz. The output from the modulator chip is transformer coupled to the output socket via a l0 dB pad and a 6dB combining network. The l0 dB pads in this and the sound modulator circuit act as isolators to protect each modulator from the other's RF. output.

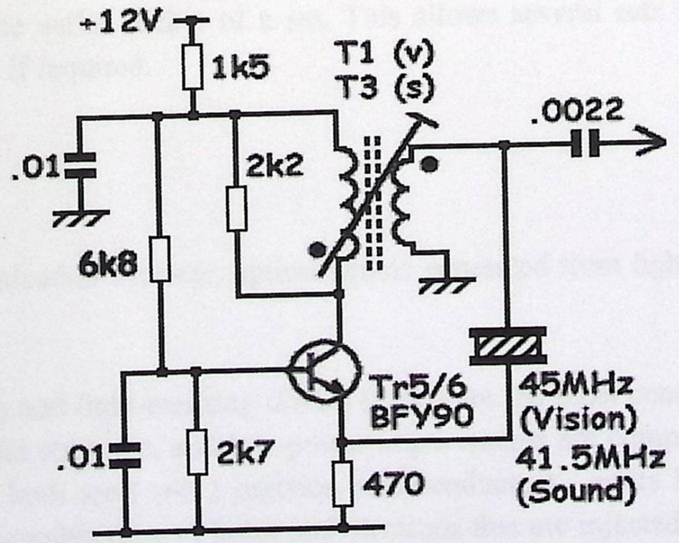


Figure (3.11): Butler oscillator circuit.

The audio modulator circuit; figure (3.12), is similar, with IC2 driving the modulator chip in push-pull to reduce distortion to a minimum. The audio sensitivity of 1Vrms = 100 per cent modulation is set by the value of Rl, which can be varied if desired. For example, with Rl at l00Kohm 100 per cent modulation is achieved with a 200mV rms. input; with Rl at 1Mohm 2V rms. equals 100 per cent modulation. The quiescent carrier level is set by the two biasing networks connected to the audio input pins 1 and 4 of theMC1496. [12]

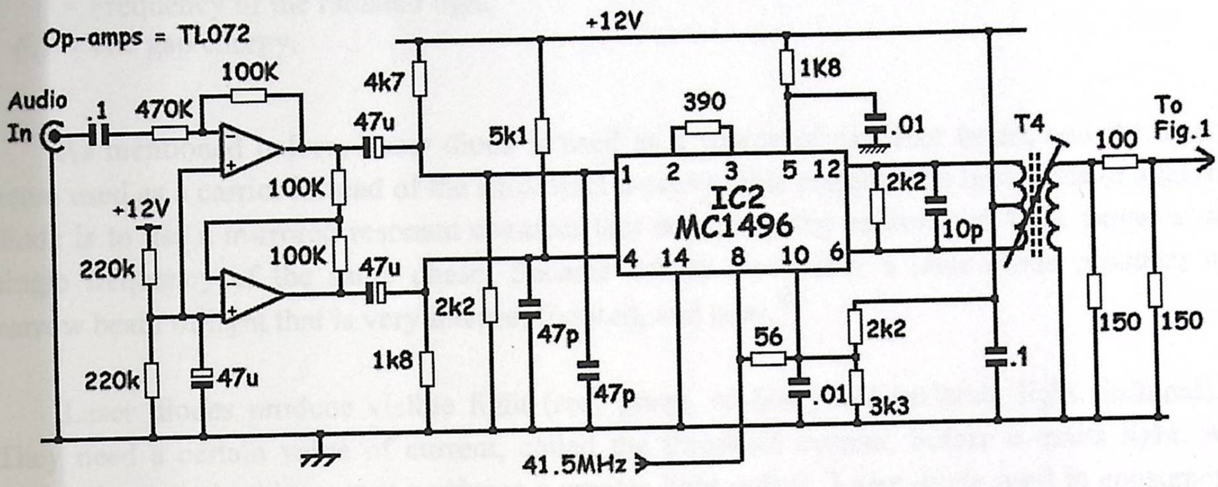


Figure (3.12): Audio modulator circuit.

Both modulators generate 800mV of RF. across the secondary windings of the output transformers T2 and T4 under maximum modulation conditions (peak white for video and the positive peak of a 1V sine wave for audio). Each modulator thus produces about 130mV of RF. at the output socket, so about 20dB of extra attenuation will be needed when this is connected directly to the aerial socket of a set. This allows several sets to be driven via a passive splitter network if required.

3.3.4 Laser diode.

In optical communication systems, optical beams generated from light sources carry the information.

Laser diodes (LD) and light-emitting diodes (LED) are the most common sources, their small size and their solid structure, and low power requirements are compatible with modern solid state electronics, both are (p-n) junction semiconductors , emits light when forward biased , which cause recombination of holes and electrons that are injected in to the junction , the energy lost in the transition is converted to optical energy in the form of a photon . Photon energy and frequency are related by (E= hv). The radiated wave length is then:

$$\lambda = \frac{hv}{Eg}$$

Where:

λ = Wavelength of radiation or emitted laser beam.

h = Blanks constant=6.626*10-34 J.s

v = Frequency of the radiated light.

Eg = The gap energy.

As mentioned before, Laser diode is used as a source of the laser beam, and the laser beam used as a carrier instead of the sinusoidal waves in this project. 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. [2]

Laser diodes produce visible light (red, green, or blue) and invisible light (infrared). They need a certain value of current, called the threshold current, before it emits light. A further increase in this current produces a greater light output. Laser diode used in consumer products and broadband communication.

In this project laser diode type that used as a source of the laser beam is uses a laser beam of a wavelength 650 nm as a carrier in free space.

3.3.4.1 Laser Diode Divergence Angle Measurements.

The laser beam has been transmitted from a distance point; the radius of the laser beam spot was measured at different locations from laser diode to the target. The result is shown in Figure (3.13) as shown below:

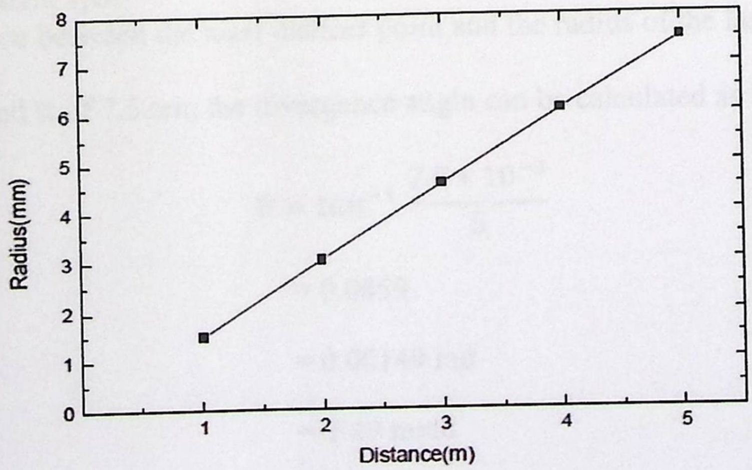


Figure (3.13): The radiuses of laser spot with the distance from the laser diode.

The previous figure illustrates the relation between the radius of laser spot with the distance from the laser diode to the receiver. In this project, a laser beam will transmitted from distinct point, and the radius of the laser beam spot will measure at many distances from the system starting with (1 m).

A typical free space optical system will have half angle divergence equal to (θ). This results a cone radius of (r). A typical shape of the laser spot will be elliptical of minor axis 2r as shown in figure (3.14).[2]

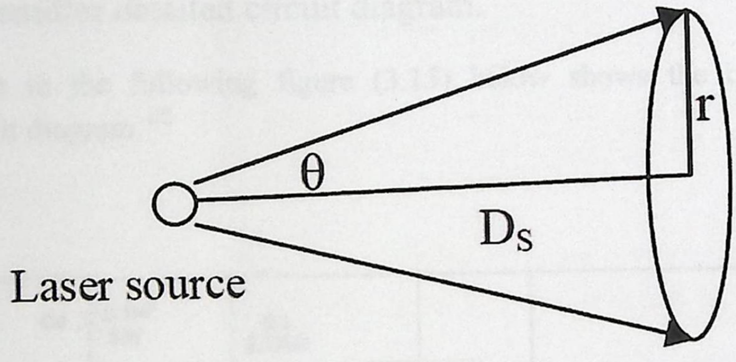


Figure (3.14): Laser Diode Divergence Angle Measurements.

Then divergence (θ) can be given by:

$$\boldsymbol{\theta = tan^{-1}\frac{R}{Ds}}$$

Where:

R = the laser beam spot.
DS = the distance between the laser distinct point and the radius of the laser beam spot.

For DS of 5 m and R of 7.5 cm, the divergence angle can be calculated as the following:

$$\theta = tan^{-1}\frac{7.5 * 10^{-3}}{5}$$

= 0.0859

= 0.00149 rad

= 1.49 mrad

3.3.4.2 Measurement of laser diode Intensity with the Distance.

The laser diode intensity inversely proportional to the distance, this means that the laser intensity is reduced rapidly when the distance increased.

The most important factor on the intensity of laser beam is the solar radiation background noise. The results are taken at daytime, where the background noise is at maximum value. It is possible to reduce this effect by taking the measurements at night. [2]

3.3.5 The transmitter detailed circuit diagram.

The circuit in the following figure (3.15) below shows the overall optical video transmitter circuit diagram. [2]

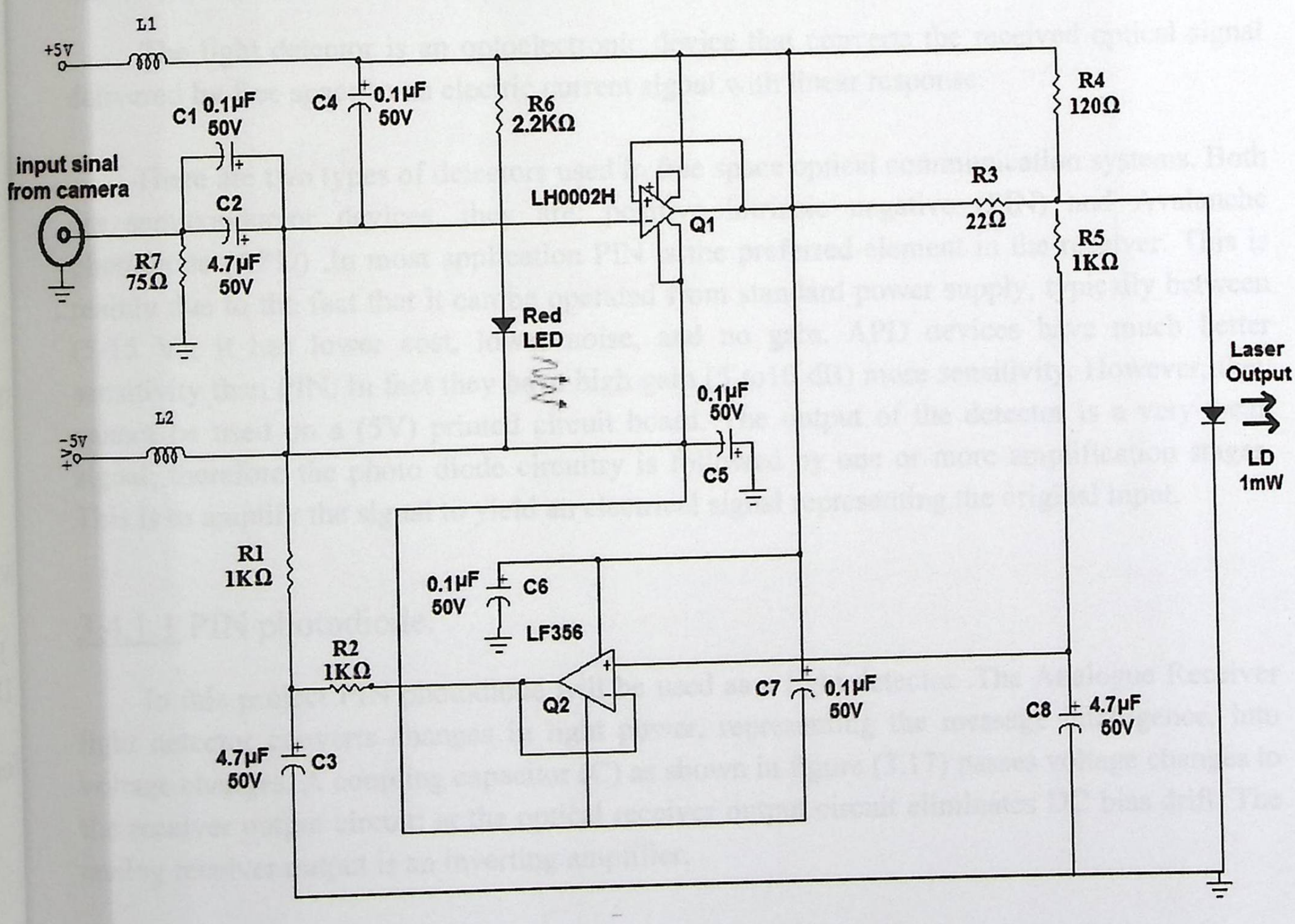


Figure (3.15): The Transmitter detailed circuit diagram.

3.4 The Receiver.

The general block diagram of the optical receiver is shown in the figure (3.16) below.

Figure (3.16): Optical receiver block diagram.

3.4.1 Light detector

The light detector is an optoelectronic device that converts the received optical signal delivered by free space to an electric current signal with linear response.

There are two types of detectors used in free space optical communication systems. Both are semiconductor devices, they are: positive intrinsic negative (PIN) and Avalanche photodiode (APD) .In most application PIN is the preferred element in the receiver. This is mainly due to the fact that it can be operated from standard power supply, typically between (5-15 V); it has lower cost, lower noise, and no gain. APD devices have much better sensitivity than PIN. In fact they have high gain (5 to10 dB) more sensitivity. However, they cannot be used on a (5V) printed circuit board. The output of the detector is a very weak signal; therefore the photo diode circuitry is followed by one or more amplification stages. This is to amplify the signal to yield an electrical signal representing the original input.

3.4.1.1 PIN photodiode.

In this project PIN photodiode will be used as a light detector .The Analogue Receiver light detector converts changes in light power, representing the message intelligence, into voltage changes. A coupling capacitor (C) as shown in figure (3.17) passes voltage changes to the receiver output circuit; at the optical receiver output circuit eliminates DC bias drift. The analog receiver output is an inverting amplifier.

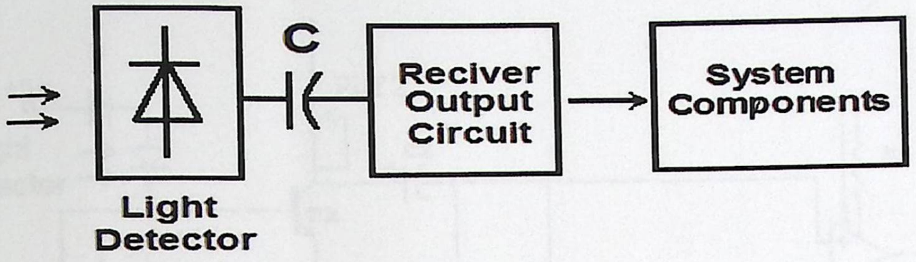


Figure (3.17): Optical Analogue Receive Block diagram.

3.4.2 Driver circuit.

The light that comes from the light detector is controlled by a driver circuit as discussed before in the optical transmitter. Optical receiver circuit consists of a light detector, and an output circuit, as shown in the following figure (3.18):

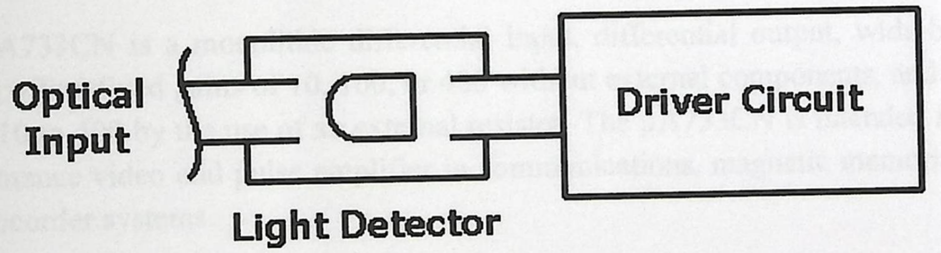


Figure (3.18): Optical Analogue Receiver Output Circuit

3.4.3 Amplifier

The analogue receiver output is an inverting amplifier that corrects the signal amplitude, impedance, phase, and bandwidth as shown in figure (3.19). In this project, µA733CN differential video amplifier will be used as an inverting amplifier.

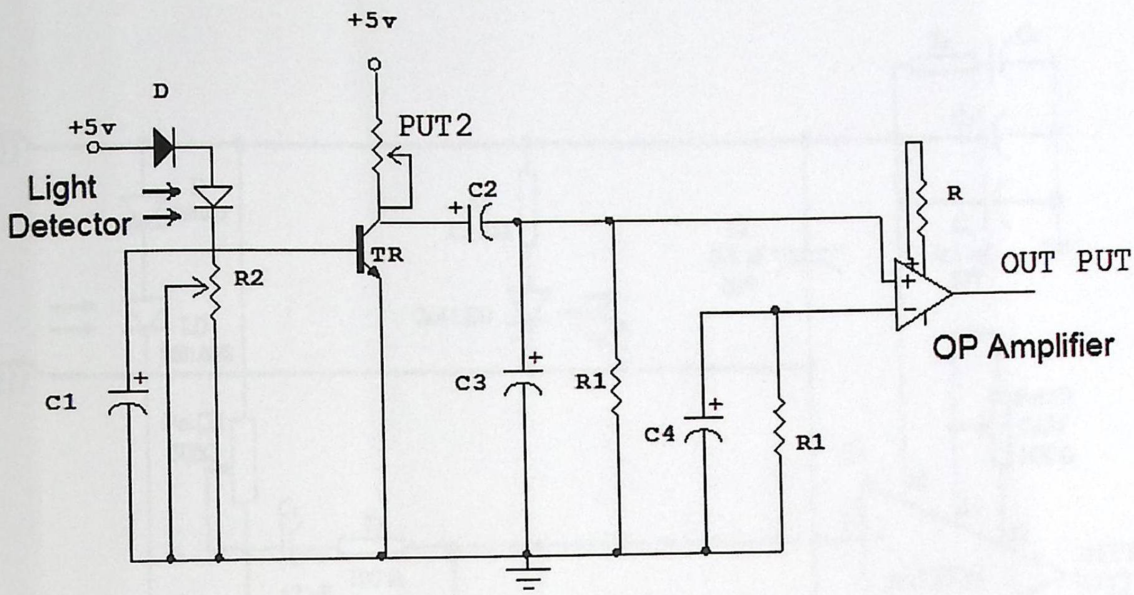


Figure (3.19): optical analogue receiver circuit of an inverting amplifier.

The μA733CN is a monolithic differential input, differential output, wide-band video amplifier. It offers fixed gains of 10, 100, or 400 without external components, and adjustable gains from 10 to 400 by the use of an external resistor. The μA733CN is intended for use as high performance video and pulse amplifier in communications, magnetic memories, display and video recorder systems.

3.4.4 Coaxial Cable.

As mentioned before in the transmitter description part of this chapter, the 75Ω coaxial cable is used to carry the video signals. In receiver part it used to carry the video signal between the driver circuit and display screen.

3.4.5 Display.

A TV screen is a Compatible display screen can be used to display the transmitted video signal, that because of using the coaxial cables.

3.4.6 The receiver detailed circuit diagram.

The circuit in the following figure (3.20) below shows the overall optical video receiver circuit diagram.

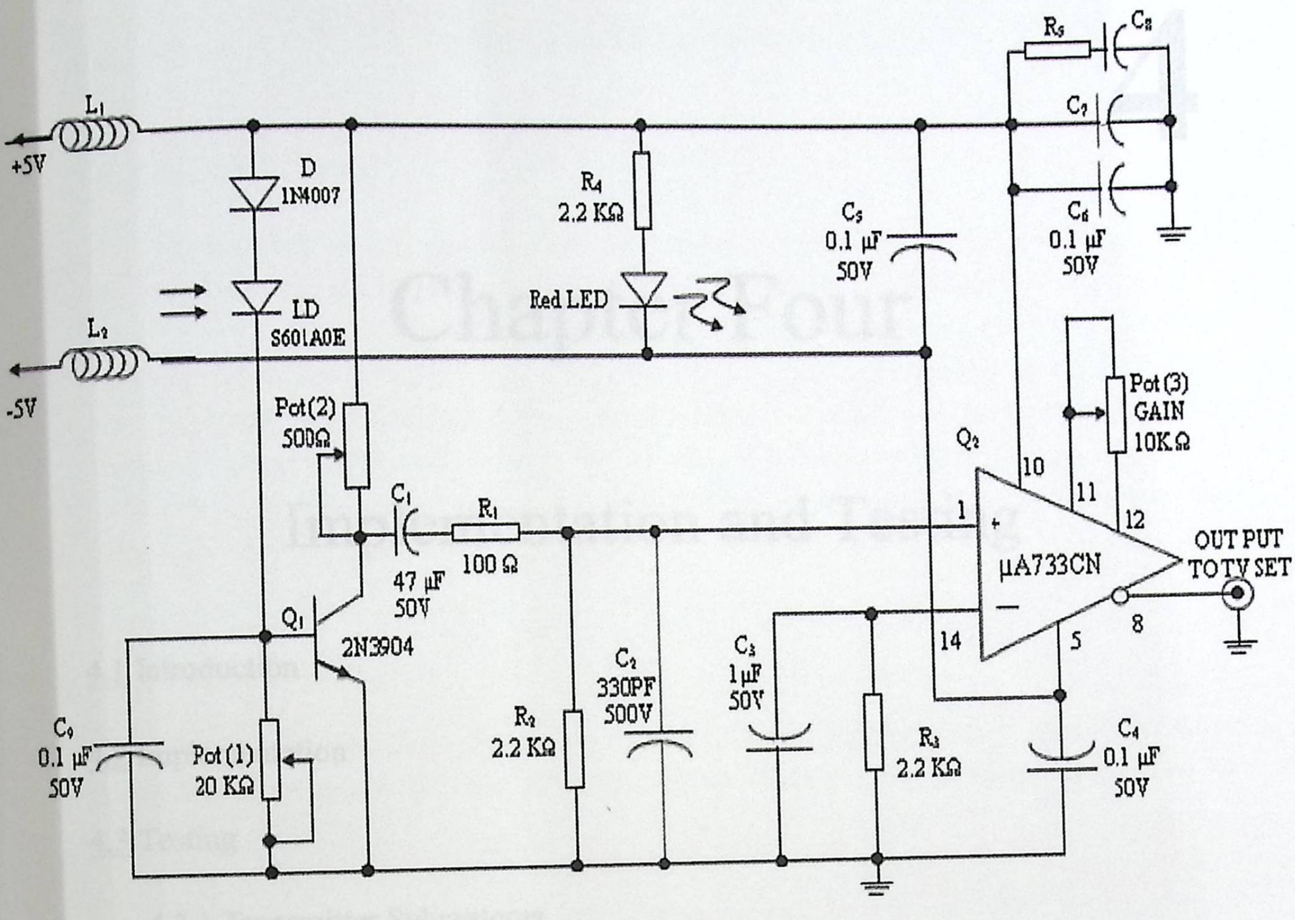


Figure (3.20): The receiver detailed circuit diagram.

4

Chapter Four

Implementation and Testing

4.1 Introduction

4.2 Implementation

4.3 Testing

4.3.1 Transmitter Subsystems.

4.3.1.1 First transmitter subsystem.

4.3.1.2 second transmitter subsystem.

4.3.2 Receiver Subsystem.

4.3.2.1 First receiver subsystem.

4.3.2.2 Second receiver subsystem.

4.3.3 General Illustration of an oscilloscope testing.

Chapter Four

Implementation and Testing

4.1 Introduction.

In this chapter the construction and testing processes for whole system will be shown, the implementation and testing processes are very important to insure that the system work successfully or not. 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 to insure it work successfully, and when the whole system has been finished a complete testing process had been done over the whole system using the specific devices.

4.2 Implementation.

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

The first step of the system construction is done through building the transmitter and receiver circuits on the bred board using all the require ICs and electronic devices, and insure they work successfully by a testing with digital multimeter device to test the inputs and the outputs voltages and currents on several points and junctions on the circuits . also it was necessary to use an oscilloscope to see the transmitted and received signals waveforms on the transmitter and receiver sides, respectively.

As usual, the construction processes is done first by places the appropriate and suitable resistors, capacitors, transistors, diodes, LEDs and ICs on the associated transmitter and receiver boards, taking care with the polarity of the electrolytic.

The second step is done by connecting a 650nm,1mW red laser with the transmitter circuit, which is responsible for emitting the laser beam to the receiver side. Therefore the receiver side is connected with a suitable photo diode to receive that beam of laser.

Finally, the camera is connected with the transmitter side, and a TV screen is connected with receiver side.

The following figures show the circuit diagrams and their implemented circuits for the transmitter and the receiver, respectively.

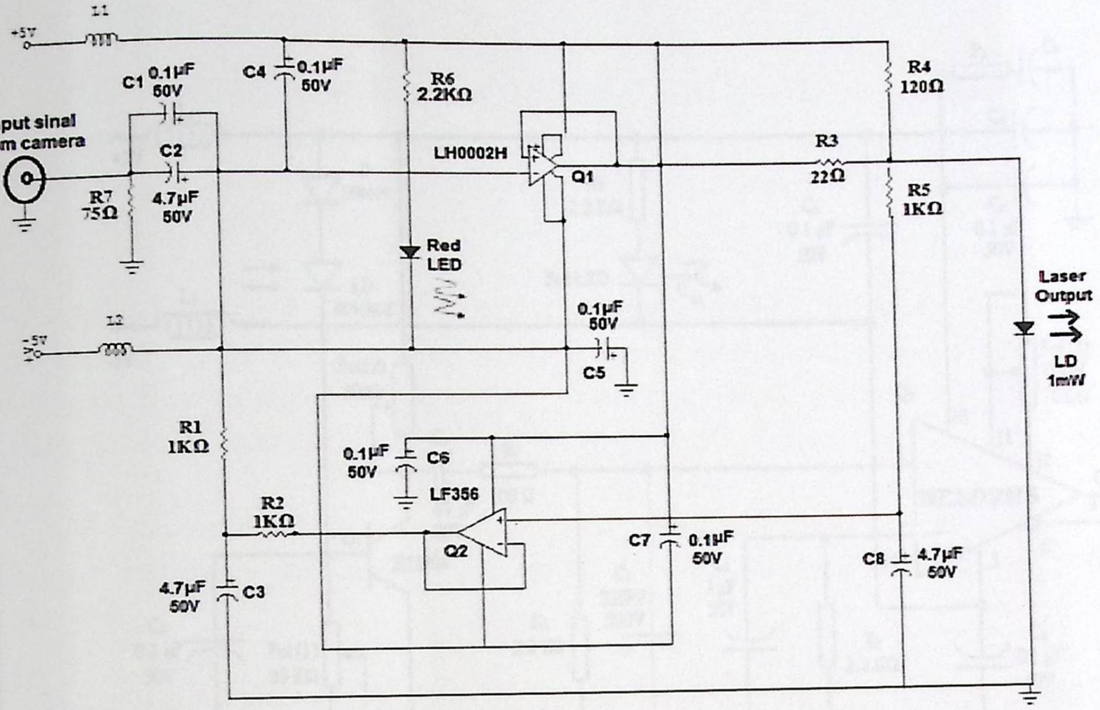


Figure (4.1): The Transmitter circuit diagram.

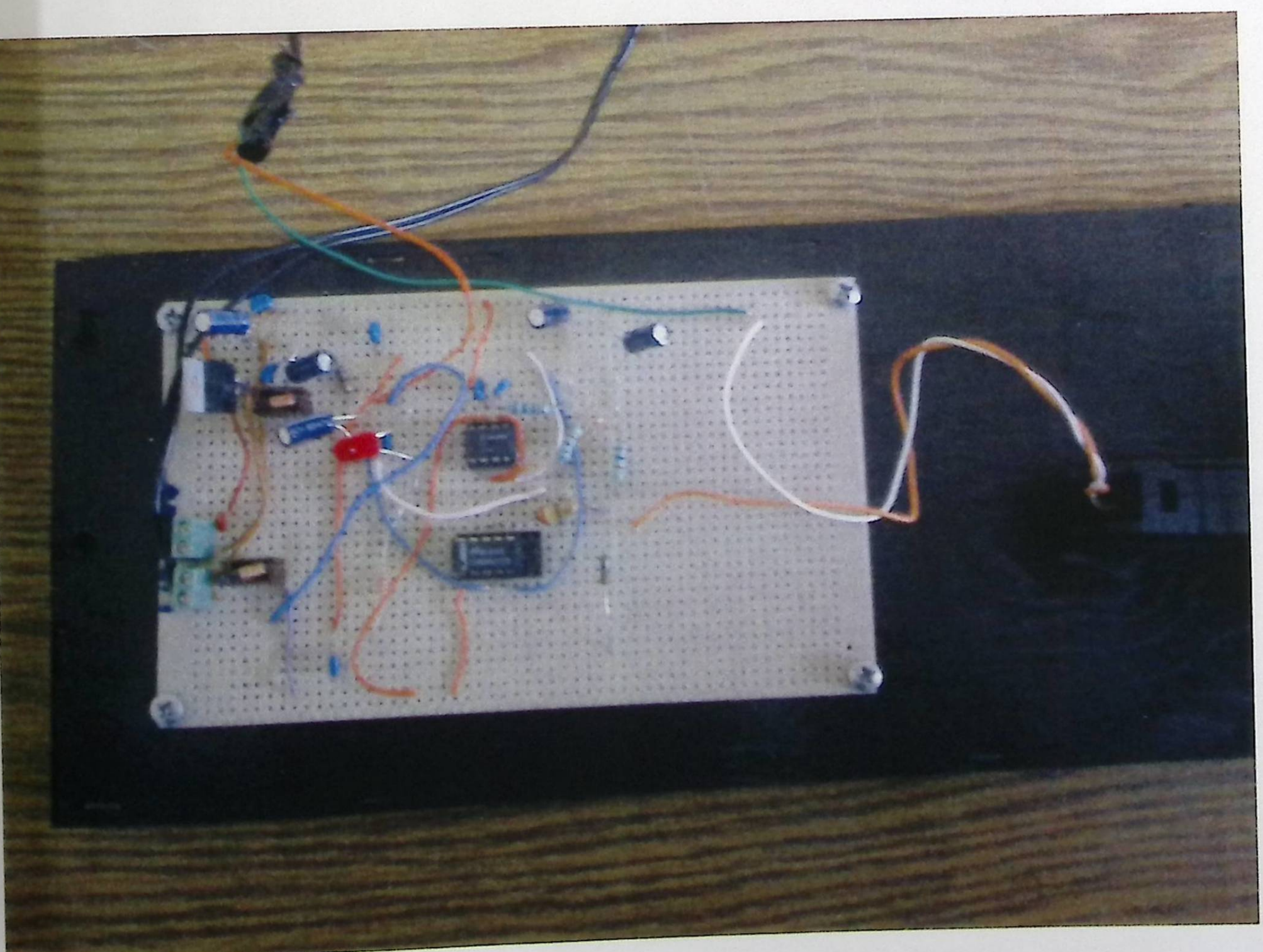


Figure (4.2): The Transmitter implemented circuit.

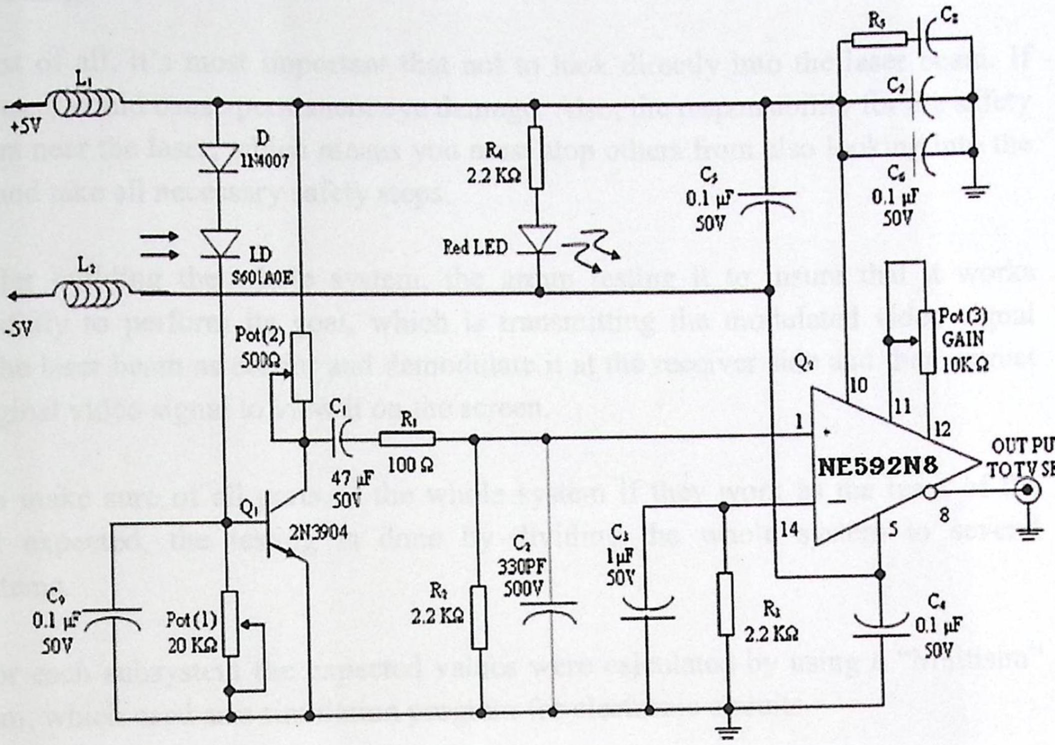


Figure (4.3): The Receiver circuit diagram.

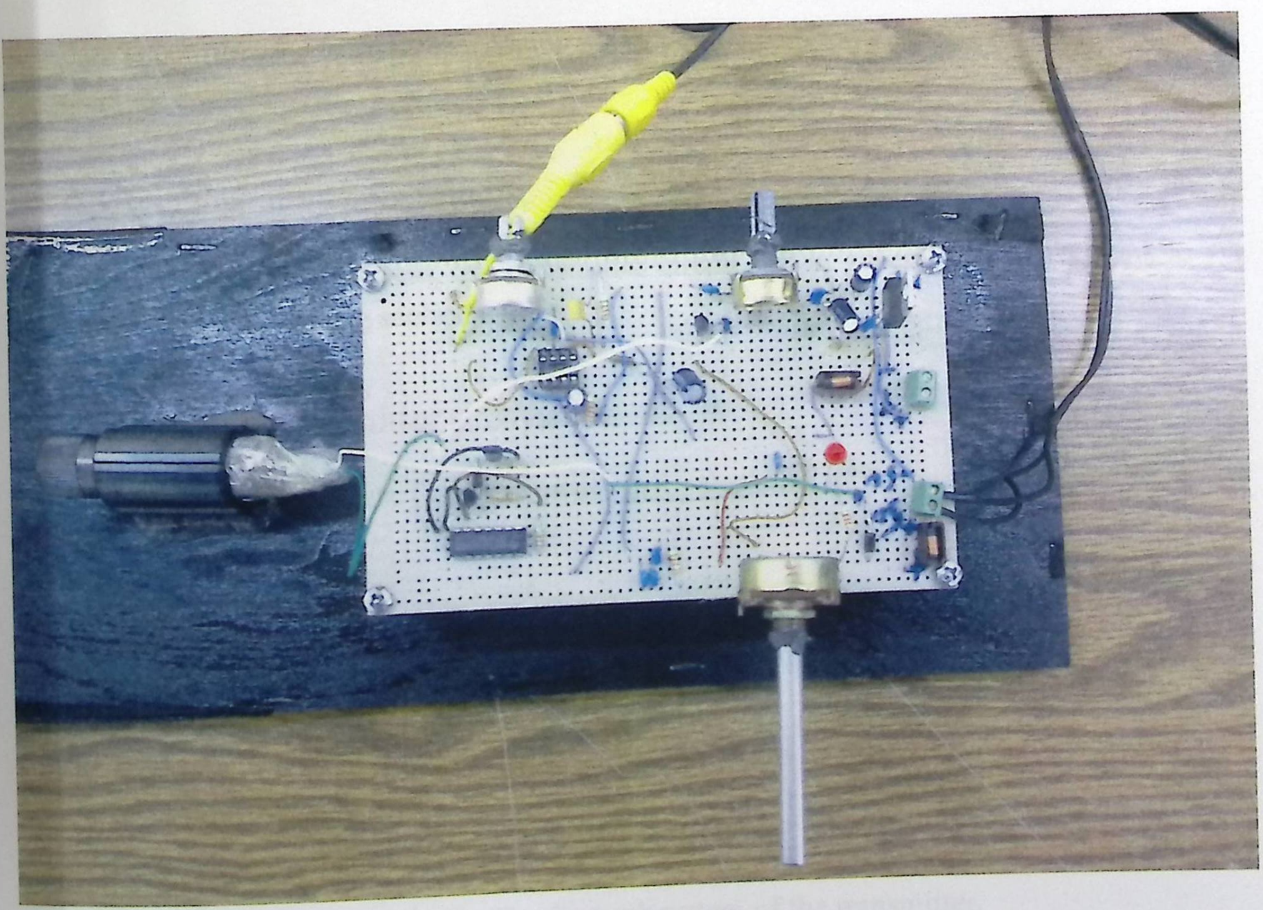


Figure (4.4): The Receiver implemented circuit.

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.

After building the whole system, the group testing it to insure that it works successfully to perform its goal, which is transmitting the modulated video signal using the laser beam as carrier and demodulate it at the receiver side and then extract the original video signal to view it on the screen.

To make sure of all parts of the whole system if they work as the team of the project expected, the testing is done by dividing the whole system to several subsystems.

For each subsystem the expected values were calculated by using a "Multisim" program, which used as a simulation program for electronic circuits.

The real values were taken by using an oscilloscope device and a digital multemeter on different points for each subsystem.

The following subsections show the subsystems figures of the transmitter and receiver circuits.

4.3.1 Transmitter Subsystems.

For the testing process, the transmitter circuit has in general two subsystems as shown in the following sections.

4.3.1.1 First transmitter subsystem.

The following figure (4.5) shows the first subsystem of the transmitter circuit:

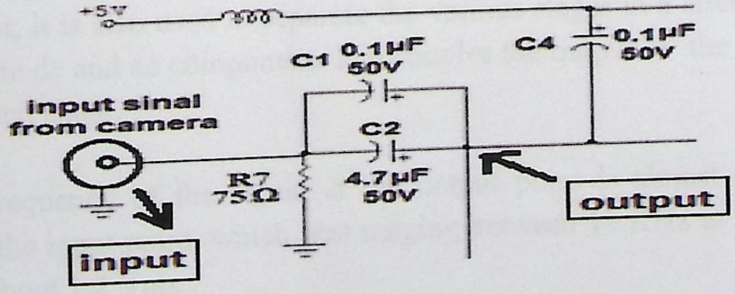
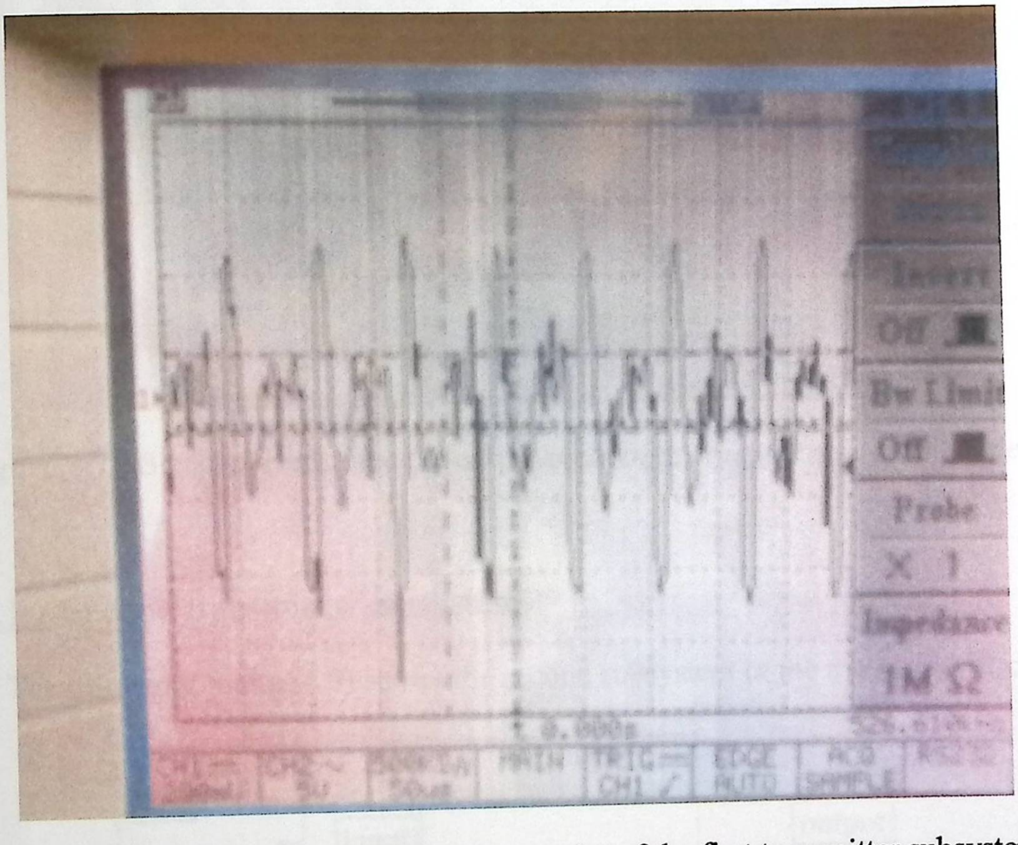


Figure (4.5): The first subsystem of the transmitter.

From the previous subsystem figure, the testing is done for the input signals from a camera on the transmitter circuit and on the output point of that subsystem. The frequency of the signal at the input point which is connected directly with a camera, was ranging between 10 KHz to 20 KHz depending on the changes of the images which taken by a camera, and the voltage at the input point was about 1.2 Vpp.

The signal waveform at the input point for the first subsystem is shown in the following figure:

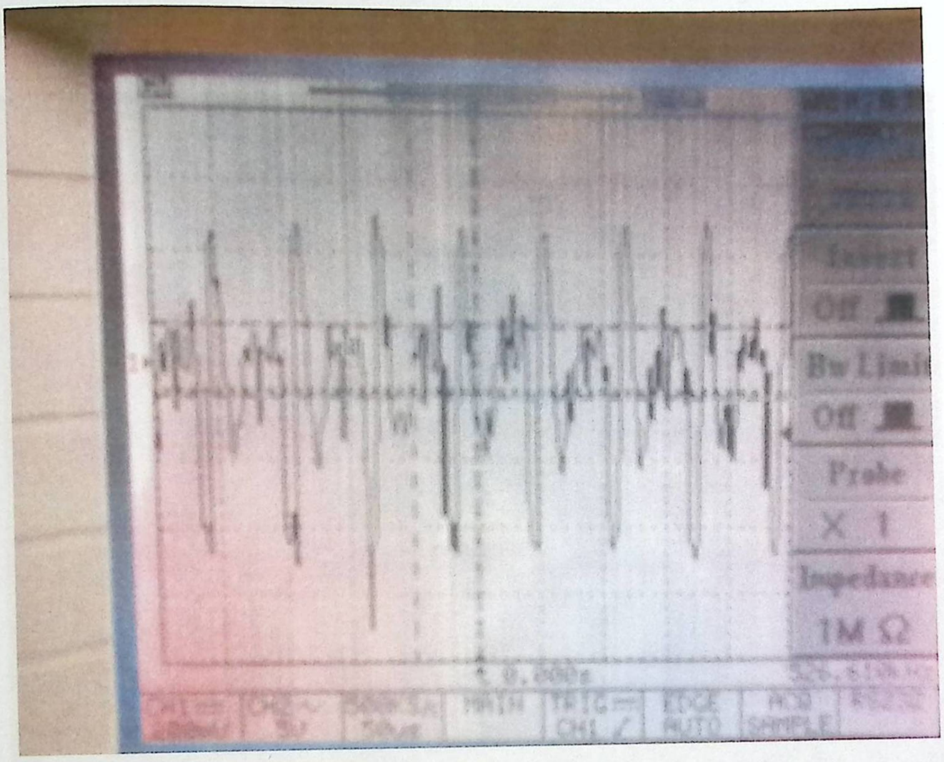


Figure(4.6): Signal waveform at the input point of the first transmitter subsystem .

The signal waveform at the output point of the first subsystem has the same signal waveform of the input point, because the capacitor C2; which appears in figure (4.5), is just for the purpose of making a coupling process on the original signal from the input point, it is also used to separate the various stages in a circuit, for example, to separates the dc and ac components and couples the output of the first stage to the input of the next stage.

So the frequency of the signal at the output point is almost the same as the frequency at the input point, which was ranging between 10 KHz to 20 KHz, and the voltage was about 1.2 Vpp.

The signal waveform at the output point for the first subsystem is shown in the following figure, which is the same as figure (4.6).



Figure(4.7): Signal waveform at the output point of the first transmitter subsystem.

4.3.1.2 Second transmitter subsystem.

The following figure (4.8) shows the second subsystem of the transmitter circuit:

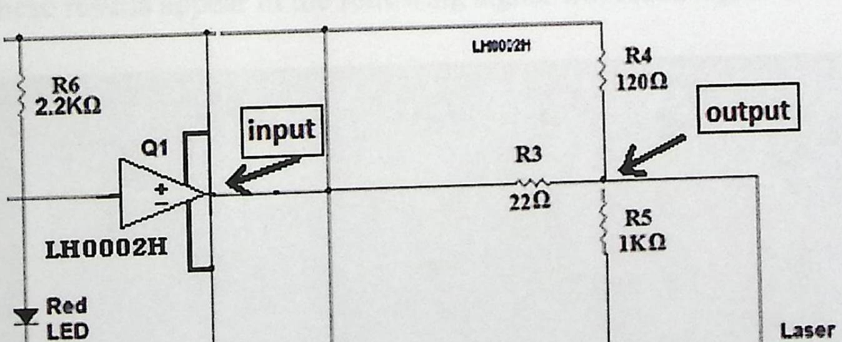
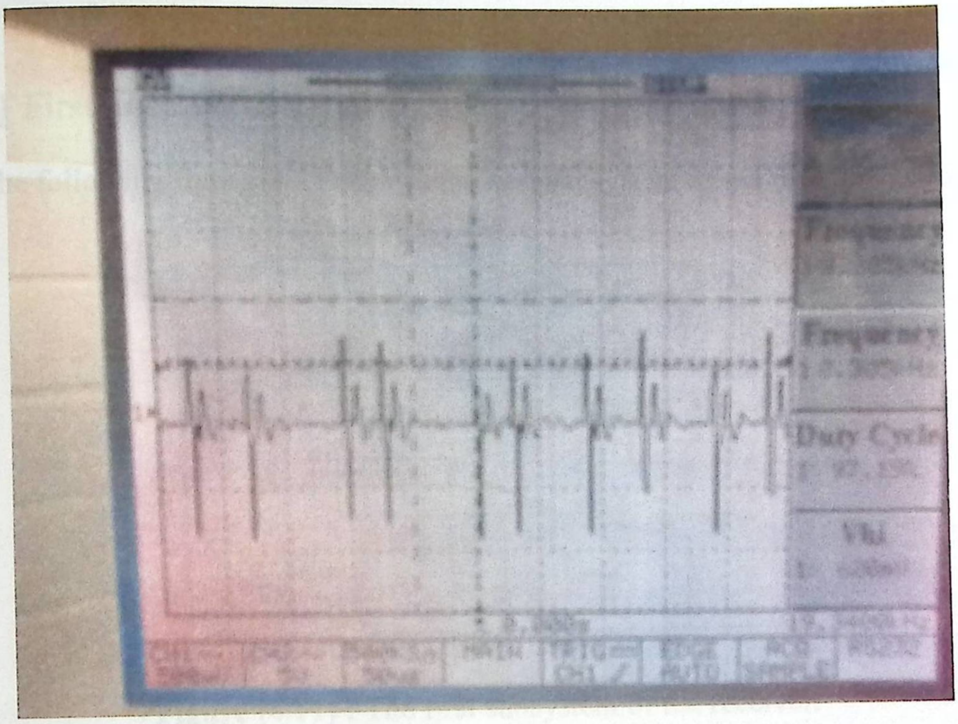


Figure (4.8): The second subsystem of the transmitter.

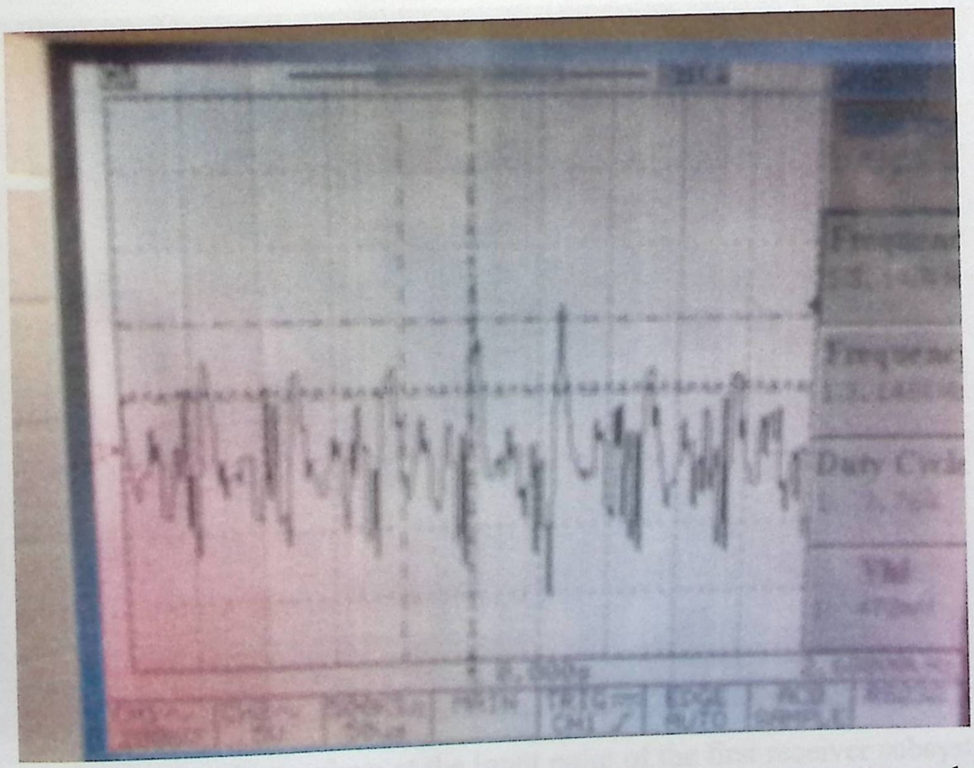
The input point of the previous figure, is the point at which the result of the modulation process is done. The frequency of the signal at the input point was ranging between 10 KHz to 20 KHz, and the voltage at that point was about 1.6 Vpp.

The signal waveform at the input point for the second subsystem is shown in the following figure:



Figure(4.9): Signal waveform at the input point of the second transmitter subsystem.

The frequency of the signal at the output point of the second subsystem; which is connected to the 650 nm red laser diode, is about 13 KHz, and the voltage was about 1.8 Vpp. These results appear in the following signal waveform figure :



Figure(4.10): Signal waveform at the output point of the second transmitter subsystem

4.3.2 Receiver Subsystem.

For the testing process, the receiver circuit has in general two subsystems as shown in the following sections.

4.3.2.1 First receiver subsystem.

The following figure (4.11) shows the first subsystem of the receiver circuit:

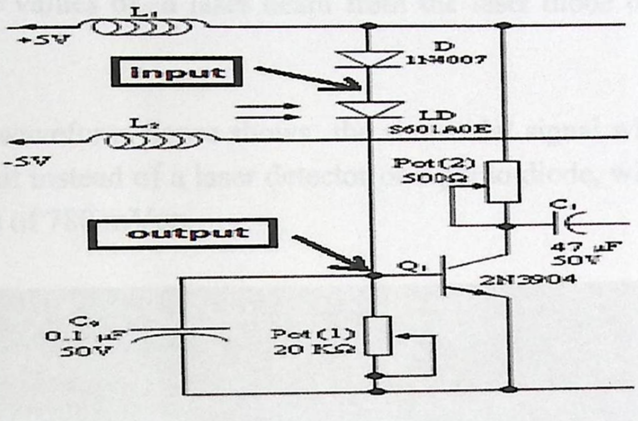
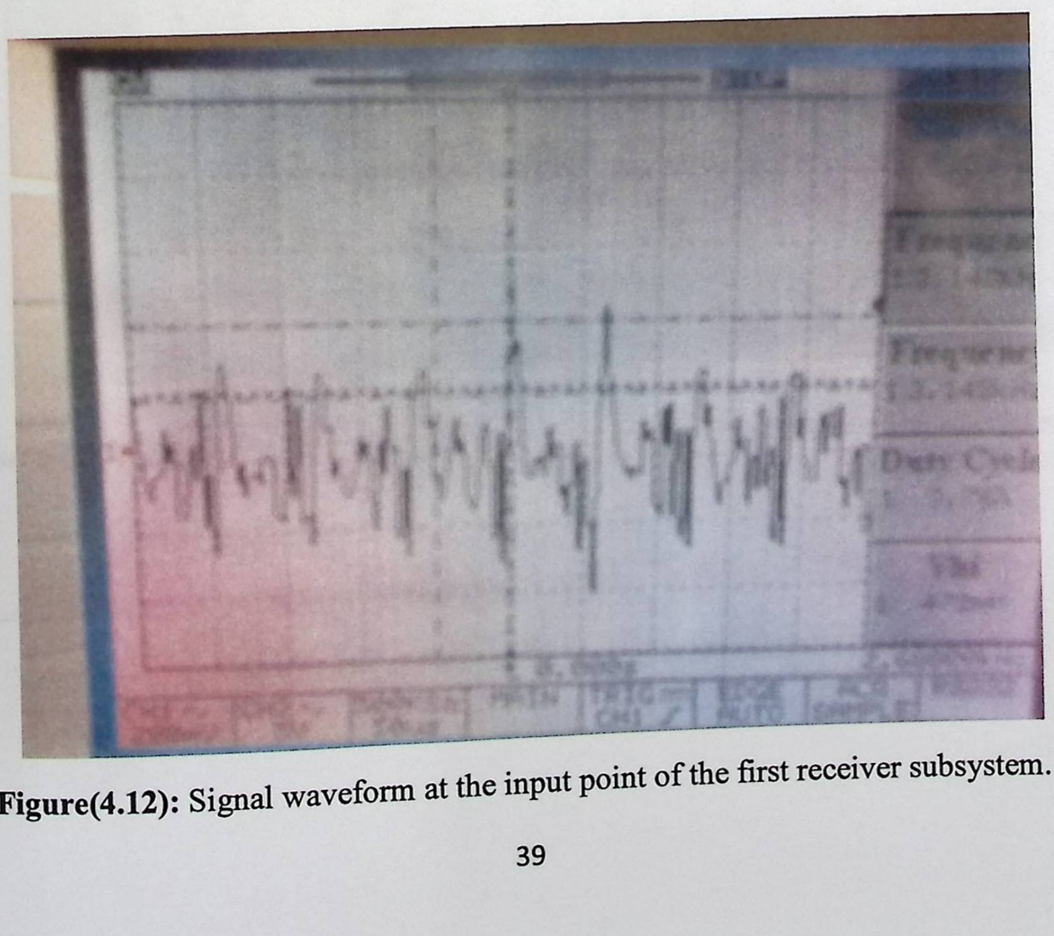


Figure (4.11) : The first subsystem of the receiver.

From the previous subsystem figure, the testing is done first at the input point; which is the point that receives the laser beam on the receiver side. At this point, the frequency of the received signal is almost the same as the frequency of the transmitted signal from laser diode, which was about 13 KHz, and the voltage was about 1.8 Vpp. The signal waveform of these results appear in the following figure:

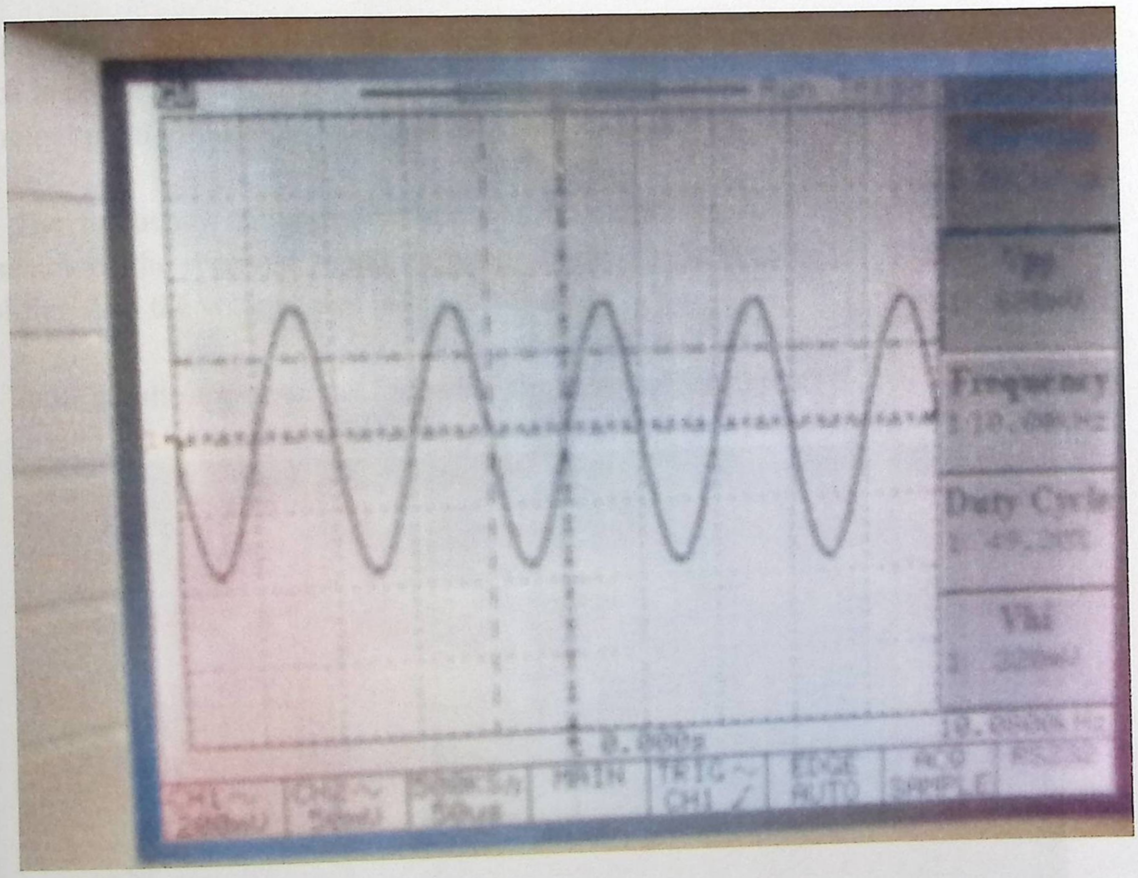


Figure(4.12): Signal waveform at the input point of the first receiver subsystem.

The output point of this subsystem, is the output of the detector or a photo diode, which has a weak signal; therefore the photo diode circuitry is followed by one or more amplification stages. This is to amplify the signal to yield an electrical signal representing the original input.

For the testing process of the receiver circuit parts, the photo diode is removed and a sinusoidal signal is produced from a function generator, which connected directly to the receiver circuit. This sinusoidal signal has a value of frequency and voltage same as the values of a laser beam from the laser diode on the transmitter side.

The following waveform figure shows the sinusoidal signal which was inserted to the receiver circuit instead of a laser detector or a photo diode, with a frequency of 10 KHz and voltage of 780 mVpp.



Figure(4.13): Sinusoidal waveform at the output point of the first receiver subsystem.

4.3.2.2 second receiver subsystem.

The following figure (4.14) shows the second subsystem of the receiver circuit:

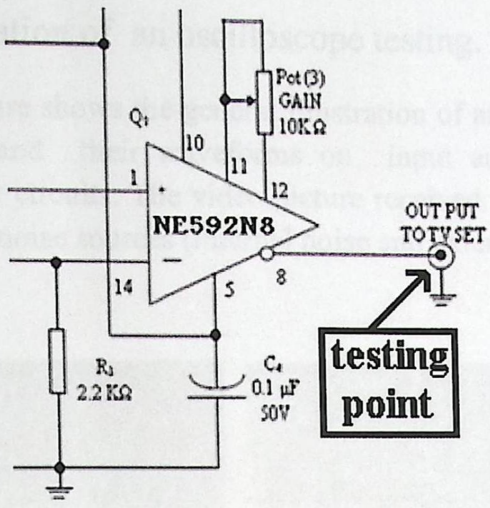


Figure (4.14) : The first subsystem of the receiver.

For this subsystem, the testing is done at the endpoint of the receiver circuit, which is connected directly to the TV screen. The endpoint of the receiver circuit is the output point of NE592N8 differential video amplifier.

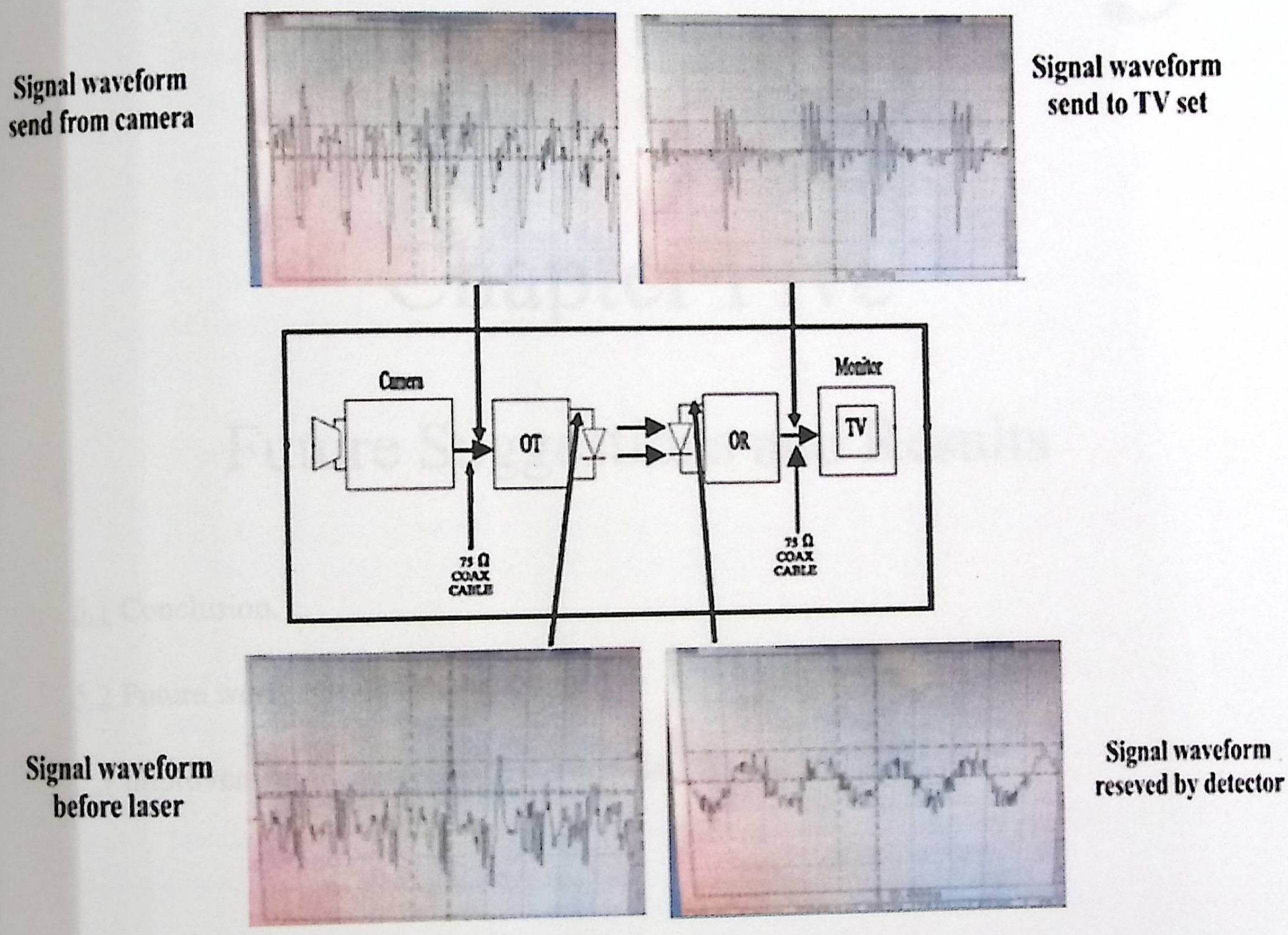
The frequency at this point is about 100 KHz whish is about ten times the frequency of the received signal on photo diode, this is because the presence of an amplifier. And the voltage here is about 912 mVpp.

These results appear in the following signal waveform figure :

Figure(4.15): Signal waveform at the output point of the second receiver subsystem.

4.3.3 General Illustration of an oscilloscope testing.

The following figure shows the general illustration of an oscilloscope testing for the signals strength and their waveforms on input and output points of the transmitter and receiver circuits. The video picture received by the TV screen wasn't obvious because of the noise sources (internal noise and external noise).



Figure(4.16): General illustration of an oscilloscope testing processes.

5

Chapter Five

Future Suggestions and Results

5.1 Conclusion.

5.2 Future work.

5.3 Improvement by changing of the modulation type.

5.1 conclusion.

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

- The possibility of transmitting video life picture is presented in this work rather simple, cheap and available elements.

- The produced picture wasn't obvious because of the noise sources.

- as the distance between the transmitter and the receiver Increase, the efficiency of the system decrease , so intensity laser beam must used.
- The designed system using (AM) modulation technique in simplex mode Indoor was achieved , it is possible to use duplex mode by employing the same design .
- To increase the range of communication system, it is possible to use beam expander , more powerful laser and/or more sensitive detector .

- The free-space optical communication distance (range) indoor between a working transmitter and receiver is just about five meters, thus the designed system acts as a demonstration system which uses the benefits of the wireless laser communication.

After concluding this project, other future implementations of the system could be suggested.

5.2 Future work.

For implementing this system more and more, the type of the modulation could be change, also the type of the laser and its color or detector could be change too, as it will be shown in the following sections.

5.3 Improvement by changing the modulation.

In this project the type of modulation that was used is the AM modulation, because the video 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, it is possible to change this type of modulation and use the frequency modulation FM.

The main advantages of FM over AM are :

- Improved signal to noise ratio.
- Waves at higher frequencies can carry more data than the waves at low frequency.
- Smaller geographical interference between neighboring stations.
- Less radiated power.
- Well defined service areas for given transmitter power.

A general description of the laser transmission system using the FM is as follow :

The video signal enters the transmitter circuit, and passes through a LPF then to an amplifier, Then it goes to a section followed by the FM modulation circuits, and finally the laser diode.

At the receiver side, a laser detector is located to get modulated beam then the signal enters to a BPF which followed by an FM demodulator, then to a selection circuits that lead to a video amplifier, and finally to the TV screen

The disadvantages of FM transmission system are :

- FM suffers more attenuation than AM signal.
- Much more Bandwidth (as much as 20 times as much).
- More complicated receiver and transmitter.

Another types of modulation could be used, but also the circuit of them would be more complicated than the AM or FM modulation. So, sending digit data using the laser beam also could be done.

Changing of the modulation including a change in the bandwidth, so changing the bandwidth needs a change in the type of the laser also to change the wave length and the power.

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Appendix

2N3904

SMALL SIGNAL NPN TRANSISTOR

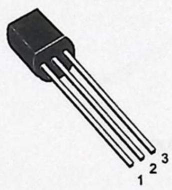
PRELIMINARY DATA

Ordering Code	Marking	Package / Shipment
2N3904	2N3904	TO-92 / Bulk
2N3904-AP	2N3904	TO-92 / Ammopack

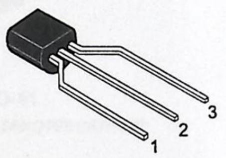
- SILICON EPITAXIAL PLANAR NPN TRANSISTOR
- TO-92 PACKAGE SUITABLE FOR THROUGH-HOLE PCB ASSEMBLY
- THE PNP COMPLEMENTARY TYPE IS 2N3906

APPLICATIONS

- WELL SUITABLE FOR TV AND HOME APPLIANCE EQUIPMENT
- SMALL LOAD SWITCH TRANSISTOR WITH HIGH GAIN AND LOW SATURATION VOLTAGE

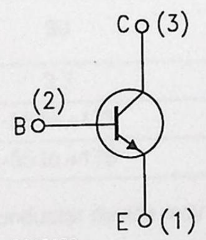


TO-92
Bulk



TO-92
Ammopack

INTERNAL SCHEMATIC DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_{CBO}	Collector-Base Voltage ($I_E = 0$)	60	V
V_{CEO}	Collector-Emitter Voltage ($I_B = 0$)	40	V
V_{EBO}	Emitter-Base Voltage ($I_C = 0$)	6	V
I_C	Collector Current	200	mA
P_{tot}	Total Dissipation at $T_C = 25\ ^oC$	625	mW
T_{stg}	Storage Temperature	-65 to 150	^oC
T_j	Max. Operating Junction Temperature	150	^oC

February 2003

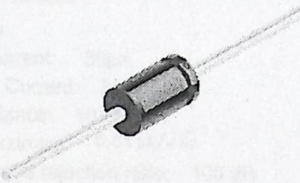
FAIRCHILD SEMICONDUCTOR®

May 2009

1N4001 - 1N4007
General Purpose Rectifiers

Features

- Low forward voltage drop.
- High surge current capability.



DO-41
COLOR BAND DENOTES CATHODE

Absolute Maximum Ratings * $T_A = 25°C$ unless otherwise noted

Symbol	Parameter	Value							Units
		4001	4002	4003	4004	4005	4006	4007	
V_{RRM}	Peak Repetitive Reverse Voltage	50	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current .375 " lead length @ $T_A = 75°C$	1.0							A
I_{FSM}	Non-Repetitive Peak Forward Surge Current 8.3ms Single Half-Sine-Wave	30							A
I^2t	Rating for Fusing (t<8.3ms)	3.7							A^2sec
T_{STG}	Storage Temperature Range	-55 to +175							°C
T_J	Operating Junction Temperature	-55 to +175							°C

* These ratings are limiting values above which the serviceability of any semiconductor device may by impaired.

Thermal Characteristics

Symbol	Parameter	Value	Units
P_D	Power Dissipation	3.0	W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	50	°C/W

Electrical Characteristics $T_A = 25°C$ unless otherwise noted

Symbol	Parameter	Value	Units
V_F	Forward Voltage @ 1.0A	1.1	V
I_{rr}	Maximum Full Load Reverse Current, Full Cycle $T_A = 75°C$	30	µA
I_R	Reverse Current @ Rated V_R $T_A = 25°C$	5.0	µA
	$T_A = 100°C$	50	µA
C_T	Total Capacitance $V_R = 4.0V$, f = 1.0MHz	15	pF

National Semiconductor

December 2001

LF155/LF156/LF256/LF257/LF355/LF356/LF357 JFET Input Operational Amplifiers

General Description

These are the first monolithic JFET input operational amplifiers to incorporate well matched, high voltage JFETs on the same chip with standard bipolar transistors (BI-FET™ Technology). These amplifiers feature low input bias and offset currents/low offset voltage and offset voltage drift, coupled with offset adjust which does not degrade drift or common-mode rejection. The devices are also designed for high slew rate, wide bandwidth, extremely fast settling time, low voltage and current noise and a low 1/f noise corner.

Features

Advantages

- Replace expensive hybrid and module FET op amps
- Rugged JFETs allow blow-out free handling compared with MOSFET input devices
- Excellent for low noise applications using either high or low source impedance—very low 1/f corner
- Offset adjust does not degrade drift or common-mode rejection as in most monolithic amplifiers
- New output stage allows use of large capacitive loads (5,000 pF) without stability problems
- Internal compensation and large differential input voltage capability

Applications

- Precision high speed integrators
- Fast D/A and A/D converters
- High impedance buffers
- Wideband, low noise, low drift amplifiers
- Logarithmic amplifiers
- Photocell amplifiers
- Sample and Hold circuits

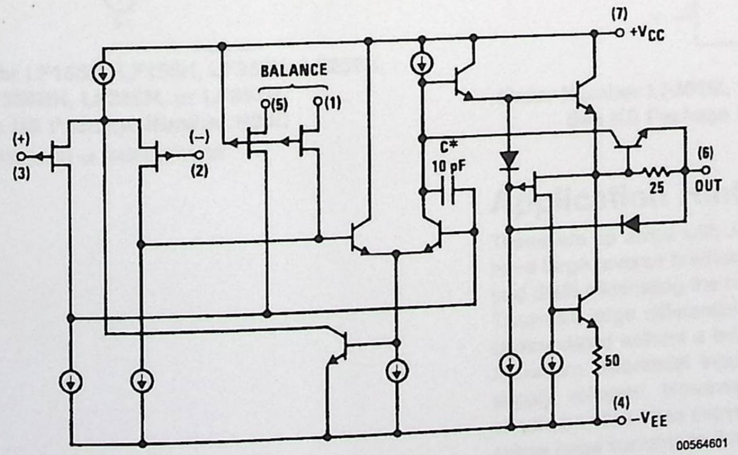
Common Features

- Low input bias current: 30pA
- Low Input Offset Current: 3pA
- High input impedance: $10^{12}\Omega$
- Low input noise current: $0.01\ \mathrm{pA}/\sqrt{\mathrm{Hz}}$
- High common-mode rejection ratio: 100 dB
- Large dc voltage gain: 106 dB

Uncommon Features

	LF155/ LF355	LF156/ LF256/ LF356	LF257/ LF357 (A_V=5)	Units
Extremely fast settling time to 0.01%	4	1.5	1.5	µs
Fast slew rate	5	12	50	V/µs
Wide gain bandwidth	2.5	5	20	MHz
Low input noise voltage	20	12	12	$\mathrm{nV}/\sqrt{\mathrm{Hz}}$

Simplified Schematic



*3pF in LF357 series.

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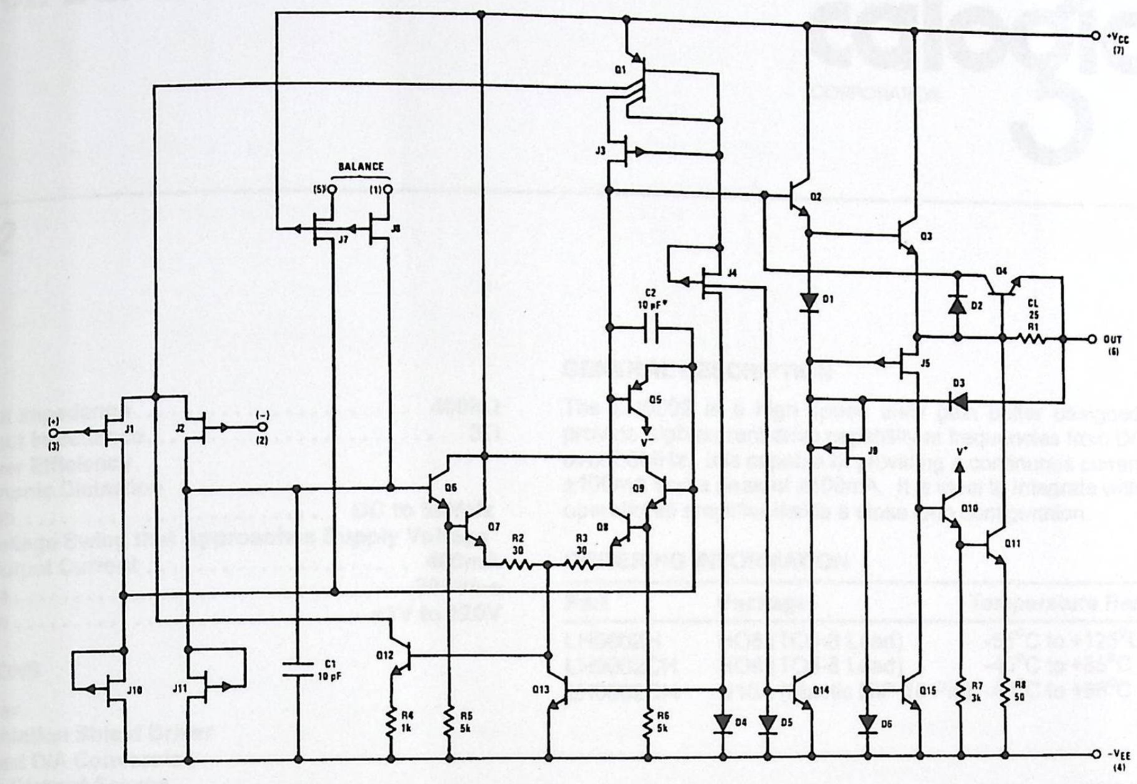
Detailed Schematic

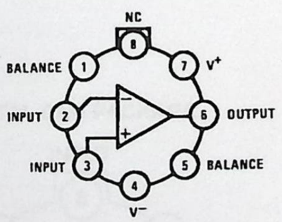


00564613

*C = 3pF in LF357 series.

Connection Diagrams (Top Views)

Metal Can Package (H)

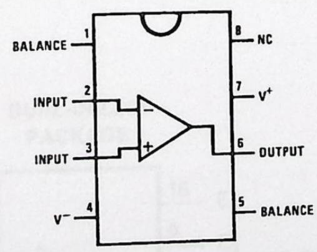


00564614

Order Number LF155H, LF156H, LF256H, LF257H, LF356BH, LF356H, or LF357H
See NS Package Number H08C

*Available per JM38510/11401 or JM38510/11402

Dual-In-Line Package (M and N)



00564629

Order Number LF356M, LF356MX, LF355N, or LF356N
See NS Package Number M08A or N08E

Application Hints

These are op amps with JFET input devices. These JFETs have large reverse breakdown voltages from gate to source and drain eliminating the need for clamps across the inputs. Therefore large differential input voltages can easily be accommodated without a large increase in input current. The maximum differential input voltage is independent of the supply voltages. However, neither of the input voltages should be allowed to exceed the negative supply as this will cause large currents to flow which can result in a destroyed unit.

Exceeding the negative common-mode limit on either input will force the output to a high state, potentially causing a

LH0002 Buffer

calogic
CORPORATION

H0002

EATURES

- High Input Impedance 400kΩ
- Low Output Impedance 3Ω
- High Power Efficiency
- Low Harmonic Distortion
- Bandwidth . . . . DC to 50MHz
- Output Voltage Swing that Approaches Supply Voltage
- Pulsed Output Current 400mA
- Slew Rate 200V/µs
- Operation . . . . ±5V to ±20V

PPLICATIONS

- Line Driver
- Instrumentation Shield Driver
- High Speed D/A Conversion
- Precision Current Source
- Video Driver

GENERAL DESCRIPTION

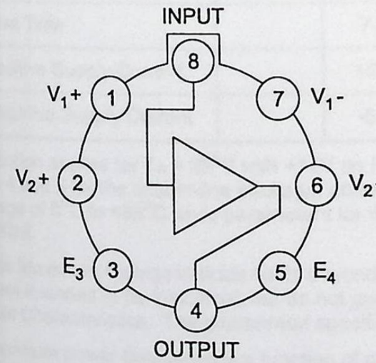
The LH0002 is a high speed unity gain buffer designed to provide high current drive capability at frequencies from DC to over 50MHz. It is capable of providing a continuous current of ±100mA and a peak of ±400mA. It is ideal to integrate with an operational amplifier inside a close loop configuration.

ORDERING INFORMATION

Part	Package	Temperature Range
LH0002H	HO8 (TO5-8 Lead)	-55°C to +125°C
LH0002CH	HO8 (TO5-8 Lead)	-40°C to +85°C
LH0002CN	N10A (Plastic DIP-10 Pin)	-40°C to +85°C

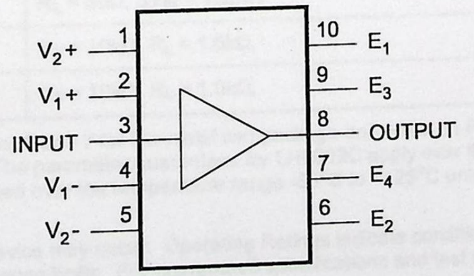
CONNECTION DIAGRAMS

METAL CAN PACKAGE



HO8A

DUAL-IN-LINE PACKAGE



N10A

CALOGIC CORPORATION, 237 Whitney Place, Fremont, California 94539, Telephone: 510-656-2900, FAX: 510-651-1076

UTE MAXIMUM RATINGS (Note 2)

/Aerospace specified devices are required, please
he Calogic Sales Office for availability and
tions.

oltage. . . . . ±22V
Dissipation (Note 3) 600mW
ltage . . . . (Equal to Power Supply Voltage)
Temperature Range . . . . -65°C to +150°C
n Temperature
ckage . . . . +150°C
ckage . . . . +175°C
State Output Current . . . . ±100mA
Output Current (50ms On/1 sec. Off) . . . . . . ±400mA
emperature Soldering (10 seconds)
l Can. . . . . 300°C
ic. . . . . 300°C
ating (Note 5) 2kV

OPERATING RATINGS (Note 3)

Temperature Range
LH0002H . . . . -55°C to +125°C
LH0002C . . . . -40°C to +85°C

Thermal Resistance (Note 4)
θ_{JA}, H Package. . . . . 125°C/W
θ_{JC}, H Package . . . . 15°C/W
θ_{JA}, N Package. . . . . 120°C/W

TRICAL CHARACTERISTICS (Note 1)

BOL	PARAMETER	MIN	TYP	MAX	UNITS	CONDITIONS
	Voltage Gain	0.95	0.97			R_S = 10kΩ, R_L = 1.0KΩ, V_{IN} = ±10V
	Input Impedance	180	400		kΩ	R_S = 200kΩ, V_{IN} = ±1.0V, R_L = 1.0kΩ,
	Output Impedance		6.0	10	Ω	V_{IN} = ±1.0V, R_L = 50Ω, R_S = 10kΩ
	Output Voltage Swing	±10	±11		V	R_L = 1.0kΩ, V_{IN} = ±12V
	Output Voltage Swing	±10	±11		V	V_S = ±15V, V_{IN} = ±12V, R_S = 50Ω, R_L = 100Ω, T_A = 25°C
	DC Output Offset Voltage		±10	±30	mV	R_S = 300Ω, R_L = 1.0kΩ,
	DC Input Bias Current		±6.0	±10	μA	R_S = 10kΩ, R_L = 1.0kΩ,
	Harmonic Distortion		0.1		%	V_{IN} = 5.0Vrms, f = 1.0kHz
	Rise Time		7.0	12	ns	R_L = 50Ω, ΔV_{IN} = 100mV
	Positive Supply Current		+6.0	+10	mA	R_S = 10kΩ, R_L = 1.0kΩ,
	Negative Supply Current		-6.0	-10	mA	R_S = 10kΩ, R_L = 1.0kΩ,

1. Specification applies for T_A = 25°C with +12V on Pins 1 and 2; -12V on Pins 6 and 7 for the metal can package and +12V on Pins 1 and 2V on Pins 4 and 5 for the dual-in-line package, unless otherwise specified. The parameter guarantees for LH0002C apply over the perature range of 0°C to +85°C while parameters for the LH0002 are guaranteed over the temperature range -55°C to +125°C unless rwise specified.

e 2. Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for h the devices intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed.

e 3. The maximum power dissipation is a function of maximum junction temperature (T_JMax), total thermal resistance (θ_{JA}), and ambient perature (T_A) maximum allowed power dissipation at any ambient is $P_D = (T_JMax - T_A)/\theta_{JA}$.

e 4. For operating at elevated temperatures, the device must be derated based on the thermal resistance θ_{JA} and T_JMax. $T_J = T_A + P_D\theta_{JA}$.

e 5. Human body model, 1.5kΩ in series with 100pF.

o amplifier NE592

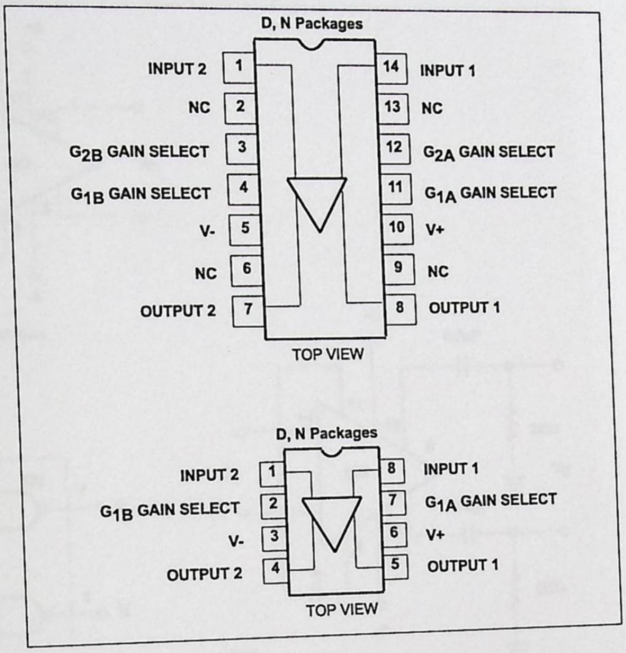
PTION

is a monolithic, two-stage, differential output, wideband
fier. It offers fixed gains of 100 and 400 without external
s and adjustable gains from 400 to 0 with one external
e input stage has been designed so that with the addition
ternal reactive elements between the gain select
he circuit can function as a high-pass, low-pass, or
filter. This feature makes the circuit ideal for use as a
lse amplifier in communications, magnetic memories,
leo recorder systems, and floppy disk head amplifiers.
able in an 8-pin version with fixed gain of 400 without
omponents and adjustable gain from 400 to 0 with one
sistor.

RES

z unity gain bandwidth
ble gains from 0 to 400
ble pass band
quency compensation required
shaping with minimal external components
TD processing available

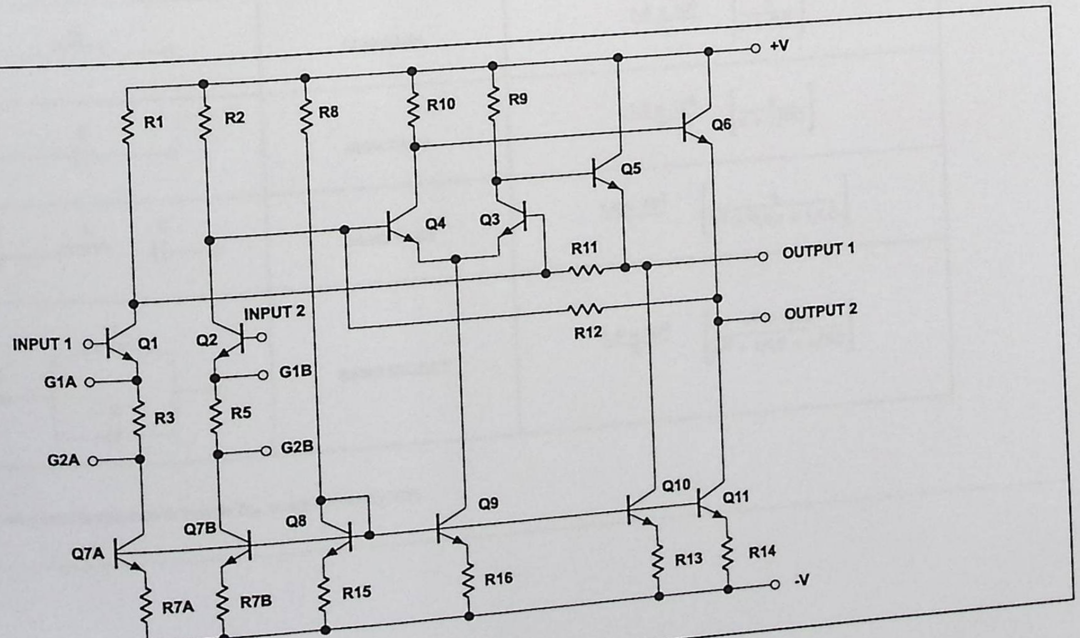
PIN CONFIGURATIONS



APPLICATIONS

- Floppy disk head amplifier
- Video amplifier
- Pulse amplifier in communications
- Magnetic memory
- Video recorder systems

CK DIAGRAM



853-0911 06456

o amplifier

NE592

PTION

is a monolithic, two-stage, differential output, wideband
fier. It offers fixed gains of 100 and 400 without external
s and adjustable gains from 400 to 0 with one external
e input stage has been designed so that with the addition
ternal reactive elements between the gain select
he circuit can function as a high-pass, low-pass, or
filter. This feature makes the circuit ideal for use as a
lse amplifier in communications, magnetic memories,
leo recorder systems, and floppy disk head amplifiers.
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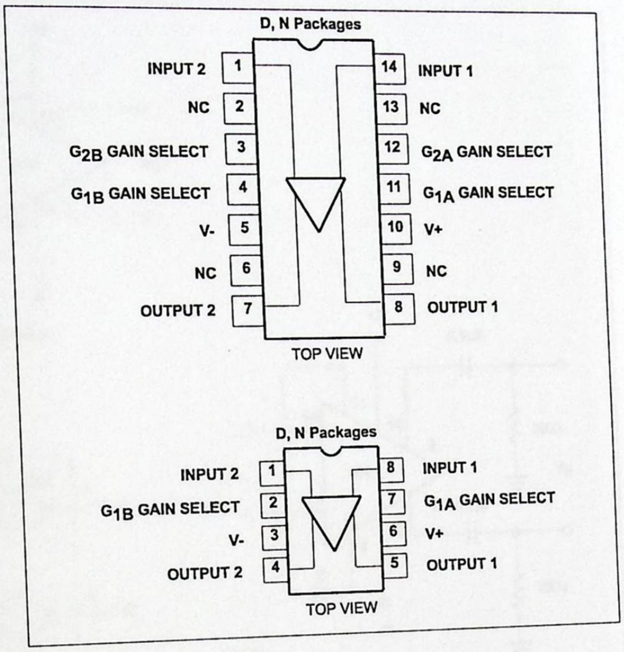
omponents and adjustable gain from 400 to 0 with one
esistor.

RES

- z unity gain bandwidth
- able gains from 0 to 400
- able pass band
- quency compensation required
- shaping with minimal external components
- TD processing available

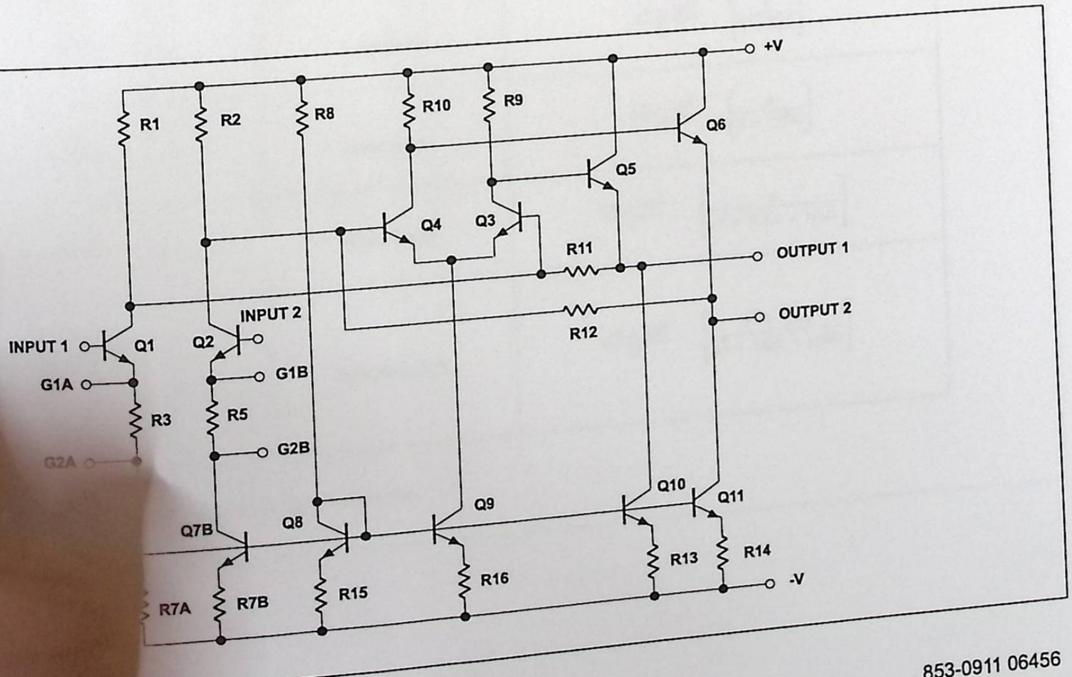
PIN CONFIGURATIONS



APPLICATIONS

- Floppy disk head amplifier
- Video amplifier
- Pulse amplifier in communications
- Magnetic memory
- Video recorder systems

CK DIAGRAM



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Video amplifier

NE592

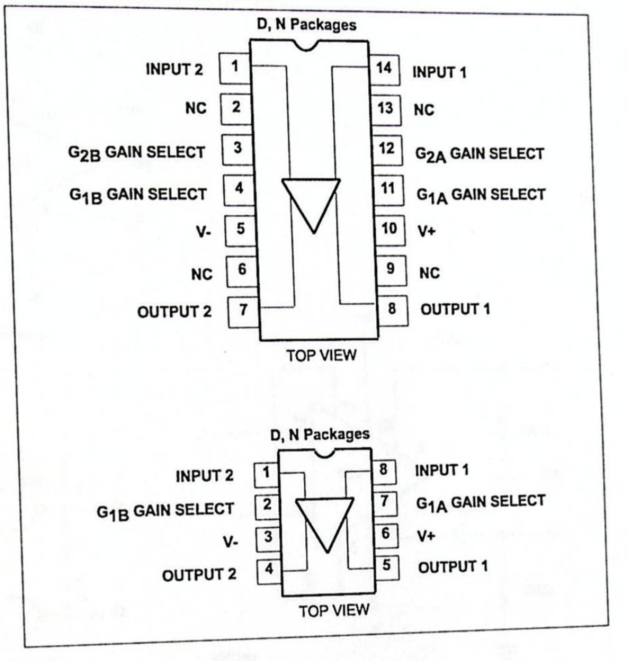
DESCRIPTION

The NE592 is a monolithic, two-stage, differential output, wideband video amplifier. It offers fixed gains of 100 and 400 without external components and adjustable gains from 400 to 0 with one external resistor. The input stage has been designed so that with the addition of a few external reactive elements between the gain select terminals, the circuit can function as a high-pass, low-pass, or band-pass filter. This feature makes the circuit ideal for use as a video or pulse amplifier in communications, magnetic memories, display, video recorder systems, and floppy disk head amplifiers. Now available in an 8-pin version with fixed gain of 400 without external components and adjustable gain from 400 to 0 with one external resistor.

FEATURES

- 120MHz unity gain bandwidth
- Adjustable gains from 0 to 400
- Adjustable pass band
- No frequency compensation required
- Wave shaping with minimal external components
- MIL-STD processing available

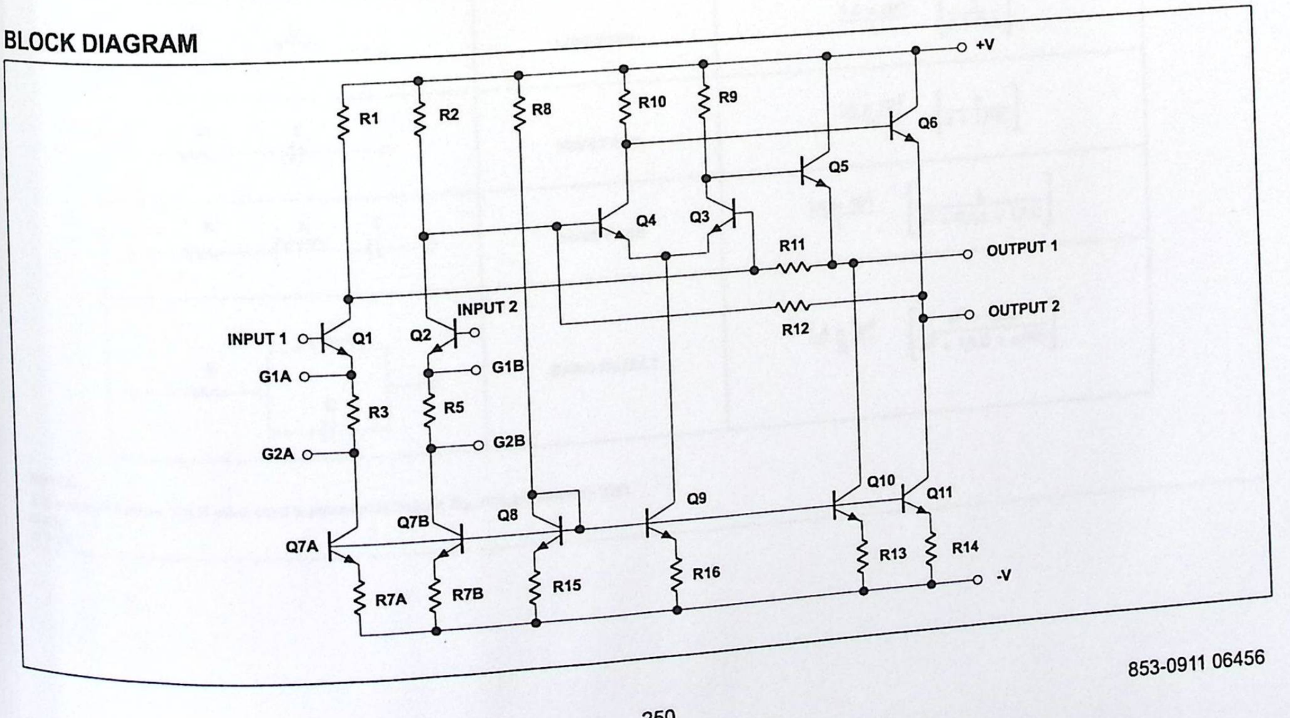
PIN CONFIGURATIONS



APPLICATIONS

- Floppy disk head amplifier
- Video amplifier
- Pulse amplifier in communications
- Magnetic memory
- Video recorder systems

BLOCK DIAGRAM



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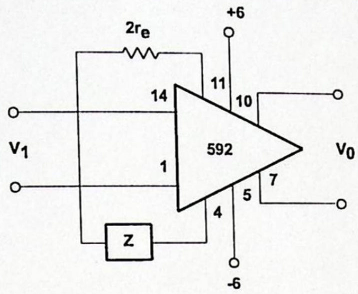
TYPICAL APPLICATIONS

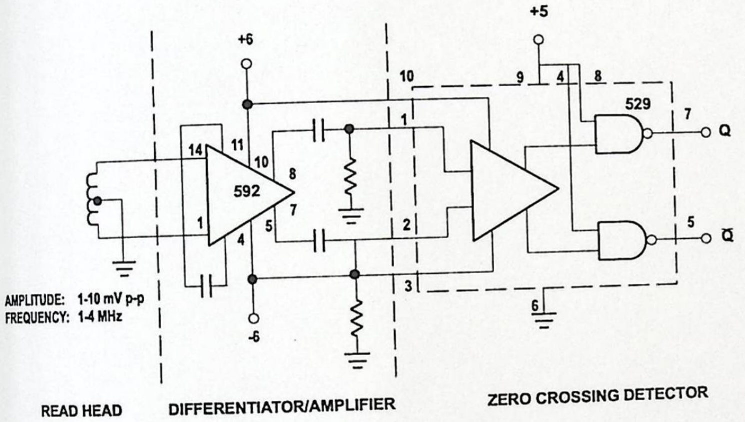


NOTE:

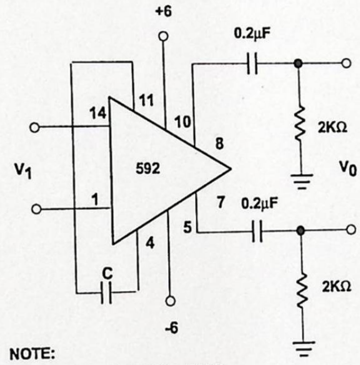
$$\frac{V_0(s)}{V_1(s)} \approx \frac{1.4 \cdot 10^4}{Z(S) + 2r_e}$$

$$\approx \frac{1.4 \cdot 10^4}{Z(S) + 32}$$

Basic Configuration



Disc/Tape Phase-Modulated Readback Systems



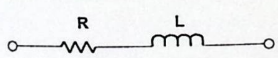
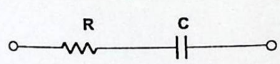
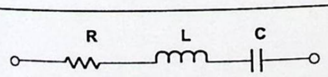
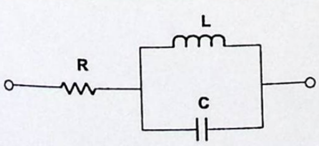
NOTE:

For frequency $F_1 << 1/2\,\pi\,(32)\,C$

$$V_O \approx 1.4 \times 10^4 C \frac{dVi}{dT}$$

Differentiation with High Common-Mode Noise Rejection

FILTER NETWORKS

Z NETWORK	FILTER TYPE	$\frac{V_0(s)}{V_1(s)}$ TRANSFER FUNCTION
	LOW PASS	$\frac{1.4 \times 10^4}{L}\left[\frac{1}{s + R/L}\right]$
	HIGH PASS	$\frac{1.4 \times 10^4}{R}\left[\frac{s}{s + 1/RC}\right]$
	BAND PASS	$\frac{1.4 \times 10^4}{L}\left[\frac{s}{s^2 + R/Ls + 1/LC}\right]$
	BAND REJECT	$\frac{1.4 \times 10^4}{R}\left[\frac{s^2 + 1/LC}{s^2 + 1/LC + s/RC}\right]$

NOTES:

In the networks above, the R value used is assumed to include $2r_e$, or approximately 32Ω.

$S = j\omega$

$\omega = 2\pi f$