International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Special Issue - NGEPT - 2019

Autonomous Robot For Bridge Inspection Using Raspberry Pi

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Abstract: Visual inspection is an important part of inspecting a bridge bearing. In fact, regular inspection is defined in the European and British standard for inspection and maintenance of structural bearings as: “close visual inspection without measurements, spaced at equal reasonably frequent, intervals”. Most of the main problems affecting bearings are reflected in changes to geometry, including: translation, rotation or deformation. Detection of cracks on bridge is a major role for maintaining the structure and reliability of bridges. Crack inspection is an important work in the maintenance of bridge and it is closely related to structure of the bridge. Presently it is done through a very manual procedure, an experienced human inspector monitors the whole bridge surface visually and try to detect cracks on the bridge and marks the location of crack. Proposed research focuses on implementing a system having a robot, equipped with a raspberry pi with pi-camera to inspect the bridge. The robot is travel from start point to end point. Cracks were identified with the help of Camera. Raspberry Pi is used as a processor for this robot, which is also best alternative used than the existing one, processing and intimating the manager is done with the help of Raspberry Pi.

Keywords: Raspberry Pi, IR Sensors, Pi Camera, Power Supply, Dc Motor Drivers, Rust And Crack Detection.

I. INTRODUCTION

The Regular inspection of bridge bearings often does not occur as frequently as required, in some cases due to difficult access or dangerous conditions. One way to increase frequency of inspection is to automate the inspection process. However, the wide range of bridge design and function means that there is not a one size fits all robots for bridge inspection, with technologies being developed for drones, underwater vehicles and climbing robots for steel structure bridges. Our contribution is a low cost solution to autonomously performing visual inspection, with technology that can be obtained and implemented in bridge bearing inspection in the near future. We focus on the implementation of autonomous navigation for autonomous inspection. Another motive for using robots for inspection is to increase the repeatability of inspections.

By employing the robots in bearing inspection of bridge with the help of image processing, the risk in bridge endurance and reliability is reduced in the proposed system Visual inspection is an important part of inspecting a bridge bearing. In fact, regular inspection is defined in the European and British standard for inspection and maintenance of structural bearings as: “close visual inspection without measurements, spaced at equal reasonably frequent, intervals”. Most of the main problems affecting bearings are reflected in changes to geometry, including: translation, rotation or deformation. Detection of cracks on bridge is a task for maintaining the structural health and reliability of concrete bridges. Crack inspection is an important task in the maintenance of bridge and it is closely related to structure of bridge. Currently it is done based on a manual procedure, an experienced human inspector monitors the whole bridge surface visually and try to detect cracks on the bridge and marks the location of crack. But this manual process have some limitations such limited accuracy. Proposed research focuses on implementing a system having a robot, equipped with a raspberry pi with pi-camera to inspect the bridge. The robot is travel from start point to end point. Cracks were identified with the help of Camera. Raspberry Pi is used as a processor for this robot, which is also best alternative used than the existing one, processing and intimating the manager is done with the help of Raspberry Pi.

II. RELATED WORK

It is mainly carried out in order to analyze the background of the current project which helps to find out flaws in the existing system & guides on which unsolved problems we can work out. So, the following topics not only illustrate the

 DOI : 10.18231/2454-9150.2019.0589

background of the project but also uncover the problems and flaws which motivated to propose solutions and work on this project. A different kinds of research has been done on power aware scheduling. Following division explores different references that discuss about several topics related to scheduling.

In [1], the authors discuss a machine vision system that is used to find pavement cracks for a robotic crack sealing machine. The robotic system includes a high-resolution digital camera which captures live or still images of the robot's 3.7 m by 4.3 m ~12 ft by 14 ft workspace. The live images are used for overall crack searching, whereas the higher resolution still images allow for accurate robot path planning in the system. The system interacts with the operator to select cracks to be sealed.

In the research paper [2], they presented an image processing algorithm customized for high-speed, real-time inspection of pavement cracking. A pavement image captured is divided into grid cells of 8 x 8 pixels, and each cell is classified as a non-crack or crack cell using the grayscale information of the border pixels. Whether a crack cell can be regarded as a basic element (or seed) depends on its contrast to the neighbouring cells. A number of crack seeds can be called a crack cluster, if they fall in the linear string. This algorithm permits the detection of cracks in one image to be done in less than 25 msec, which is the maximum time needed for the frame grabber to accumulate line images from the line-scan camera to form a new frame image.

In [3], they deliberated about a semi-automatic measuring system that can extract images of cracks in the surface of concrete from multitemporal images. The proposed system can deal with multitemporal images needing only a few manually measured seed points to indicate cracks on the first image and new cracks on the others. The system improves the degree of automatic extraction and recording of the length and width of the cracks. Most of the existing systems are left void on the concept of self alignment, less expensive, less complex hardware etc. with more accuracy and reliability. Moreover, most of the image processing algorithms used in the existing systems are more time consuming as they need separate pc for image processing technique.

III. PROBLEM IDENTIFICATION

In general, the present inspection of bridge structure is performed manually. However, 1) It is almost impossible to inspect inaccessible sections. 2) large-scaled inspection vehicles may interfere with traffic flows and a number of personnel are required to inspect a wide area in a short time, 3) poor working conditions for visual inspection can cause harm to the safety of inspectors, 4) frequent replacement of persons in charge and subjectivity in inspection reduce the reliability of data collection and management 5) maintenance expenses may be wasted since it is hard to determine precisely the point of time at which repair and reinforcement shall be executed. So in order to solve this problem we have developed a new bridge inspection system. The name of the system is Bridge Inspection Robot using raspberry pi with Open CV (BIRRCV). In the proposed system of an intelligent bridge inspection system by using a Robot and IT technology which enables acquiring images of the bridge condition for managing the safety is classified. The purpose of this study is divided into two major parts: 1) the image acquisition of a bridge structure with the application of a vision-based robot which is autonomous. 2) Development of image processing algorithm using Open CV for assessing condition of the bridge, and detecting any crack captured in the images.

B. Existing System

In the Existing System they have implemented only the rust detection system.

- Most of the research works done on the bridge inspection are more concentrated on the reliable movement.
- In some existing research works, the image processing tools are employed to find the rust over the bridge bearings.
- And in most of the recent research works, action related to robotics is left void without any proper solution.

B. Issues

- Regular inspection of bridge bearings often does not occur as frequently as required, in some cases due to difficult access or dangerous conditions.
- One solution to increase the frequency of inspection is to automate the inspection process.
- Our contribution is a low cost solution to autonomously performing visual inspection, with technology that can be obtained and implemented in bridge bearing inspection .
- We focus on the implementation of autonomous navigation for autonomous inspection.
- Another motive for using robots for inspection is to increase the repeatability of inspections.

C. Proposed System

In the proposed autonomous robot for bridge inspection system, the autonomous actions are attained by employing microcontroller. The Raspberry microcontroller is used in the proposed system which makes the reliability and endurance in the concerned application oriented

 DOI : 10.18231/2454-9150.2019.0589

ISSN : 2454-9150 Special Issue - NGEPT - 2019

environment to be more precise compared to existing systems based on image processing unit. Raspberry pi is a tiny sized computer. It is still a Linux computer and can provide all the expected abilities that implies, at a low power consumption level.

In the proposed system, for bridge inspection image processing embedded with python is utilized. The camera interfaced to the central raspberry controller unit will record the live video of the bridge terrain area. The live video will be processed and interpreted in the raspberry computer itself. Upon detection of any problems in bearings of bridge, then the control asks the help of central computer system. It is nothing more than a core controller. If any faulting in found on bearings of the bridge, the controller will automatically initiate the buzzer buzzing the fault findings. By employing the robots in bearing inspection of bridge with the help of image processing, the risk in bridge endurance and reliability is reduced in the proposed system.

D. Advantages:

- Assurance of public safety
- Real time monitoring of bridge's condition
- Human error can be avoided

IV. ARCHITECTURE

The proposed intelligent bridge inspection system consists of robot transporting unit, which have the ability to move autonomously robot. The robot transporting vehicle is equipped with the IR sensors on all direction. The IR sensors connected over every corner of the robot helps in self alignment of the robot as well as the bearing hole detection. Upon The transportation has three axes of tilt, rotate and move, and is driven by the hydraulic valve control. It can move the robot to any desired location on the lower part of bridge. The robot unit is nothing more than a computer unit and the computer used here is Raspberry pi 3 Model B+. The robot is equipped with pi camera for the image acquisition for steel bearing crack or rust detection. Fig.1 5 shows the inspection machine vision robot for acquisition of bridge deck images. The robot unit itself is the image processing unit. The Raspberry pi is hardcoded in such a way to acquire images using pi camera by controls the camera's zoo magnification by the measured distance and image acquisition resolution that worker has to set up. Since the measuring distance will not be fixed, a commercial pi camera, which can provide auto focusing function and zoom magnification, was used instead of the industrial CCD camera which requires changing lenses and manual focusing function according to the numerical formula whenever user captures images. The acquired images are taken into processing by the raspberry pi where OpenCV library is used as the image processing platform (API library) for the rust detection. The movement of the robot is controlled by the motor connected to the unit via the L293D motor driver.

A. Objectives:

- ❖ Automation in bridge inspection
- ❖ Self Alignment in robot movement
- ❖ Automatic bridge bearing hole detection
- ❖ High speed image processing algorithm
- ❖ Compact system unit
- ❖ Incorporation of robot and Image processing in Single Unit etc.

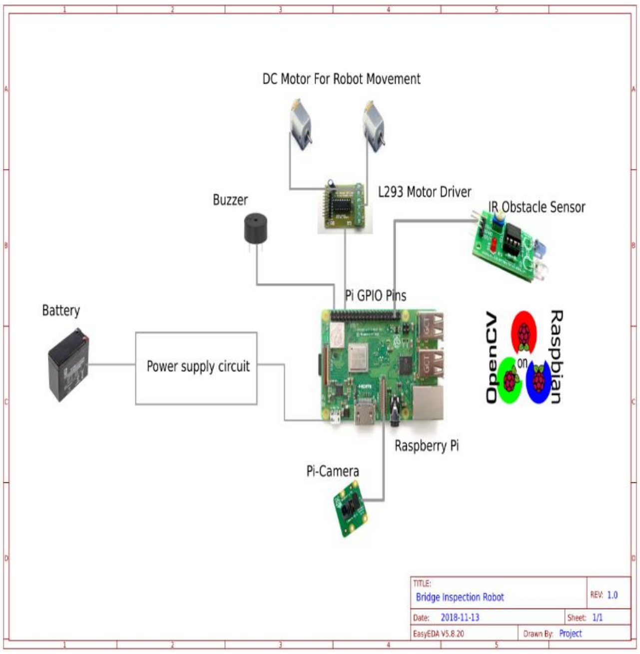


Fig.1 Functional Block diagram

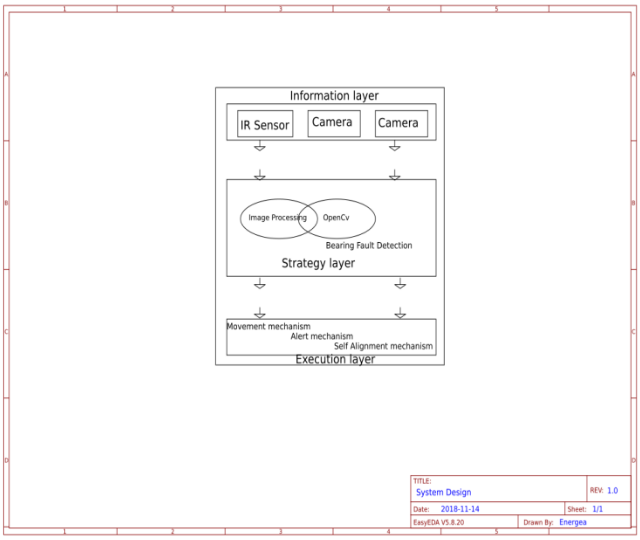


Fig.2 System Design

A hierarchical architecture with three independent layers: (a) an information layer, (b) strategy layer, and (c) execution layer, as shown in Figure, is proposed to design a flexible and robust vision-based autonomous robot system. Each layer is responsible for specific functions. The environmental changes is collected in the information layer. The information data includes the image data captured from

DOI : 10.18231/2454-9150.2019.0589

the camera, the distance data from infrared sensors etc. All of these data are collected once every 50ms. The robot can use the wireless connection to communicate with the other robots, so the environmental data includes some useful data obtained from the other robots. Since our system itself is the robot no needs of wireless connection for information transfer. The role assigned and strategy determination of each robot are performed in the strategy layer according to the environmental data obtained from the information layer. In our case, from the input image the bearing rust detection mechanism is performed in strategy layer. The robot's behaviour is executed in the execution layer, which is the lowest layer and the main hardware layer of the robot. Some mechanisms and circuits for the robot individual skills are implemented in this layer. The alert mechanism and movement motor circuit are developed for the tactics in this layer.

V. FEATURE ENHANCEMENT AND APPLICATIONS

The idea of the implementation is from the machine vision system that is used to detect the cracks of bridge lower surface automatically from the captured images. There are many kinds of damages according to the types of bridge, for example, cracks, corrosions, subsidence, fatigue. Among these damages, the crack information becomes one of the most important factors in deciding the bridge repairs. The utilized machine vision system is composed of camera, a processing unit board and a vision processing program on the computer.

A. Application to real World:

A new inspection methodology that uses multiple small mobile robots to create a virtual sensor network that can be used on existing bridge. Multiple robots could provide readings from multiple points (in order to measure the vibration of the dynamics). In addition, unlike imbedded sensors, the robots would be able to change their locations on the bridge in order to provide a comprehensive map of the structure. While there will be locations on the bridges that are inaccessible to the robots, there currently exists substantial research in estimating the presence of bridge damage from measurements of the frequency response and mode shapes of the structure. These estimation methods could provide an early indication of potential damage that could be followed by more thorough inspections. The image processing is also addressed as a major issue in the proposed project.

VI. FIGURES/TESTING RESULT

A. Raspberry Pi 3 Model B

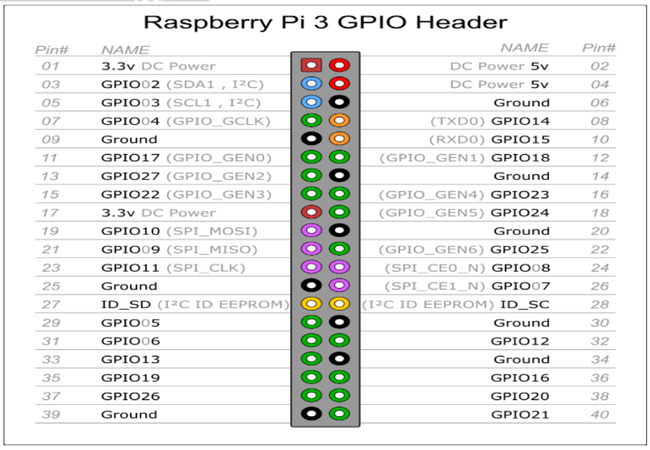
The Raspberry Pi 3 model is a small single board computers developed by United Kingdom by Raspberry Pi Foundation. Several generations of Raspberry Pi have been released. The models which are featured by a Broadcom system on a chip (SoC)by using an integrated ARM compatible central processing unit (CPU) and on-chip graphics processing unit (GPU).The first generation (Raspberry Pi 1 Model B) was developed in February 2012, followed by the simpler and cheaper Model A. In 2014, the Foundation released a board with an improved version, Raspberry Pi 1 Model B+. The Raspberry Pi 3 Model B includes 802.11n WiFi, Bluetooth 4.0, and a quad-core 64-bit ARM Cortex A53 running at 1.2 GHz. It's a usable desktop computer.

B. SoC

It built specifically for the new Pi 3, the Broadcom BCM2837 system-on-chip (SoC) It includes four high-performance ARM Cortex-A53 processing cores running at 1.2GHz with 32kB Level 1 and 512kB Level 2 cache memory, a VideoCore IV graphics processor, and it is linked to a 1GB LPDDR2 memory module of the board.

C. GPIO

The Raspberry Pi 3 features the some of the 40-pin general-purpose input-output (GPIO) header as all the Pi 's going back to the Model B+ and Model A+. One of the existing GPIO pins will work without any modification; the change was switch to which UART is exposed on the GPIO's pins, but that's handled internally by the operating system.

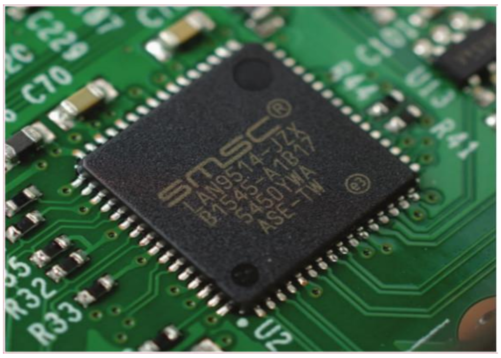


D. USB chip

The Raspberry Pi 3 shares the some of the SMSC LAN9514 chip as its predecessor, for the Raspberry Pi 2, adding 10/100 Ethernet connectivity and four USB channels to the board. The SMSC chip connects to the SoC through a single USB channel, acting as a USB-to-Ethernet adaptor and USB hub.

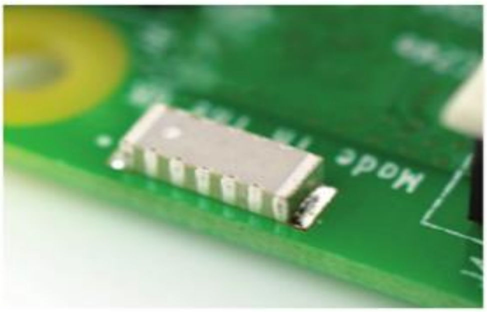
 DOI : 10.18231/2454-9150.2019.0589

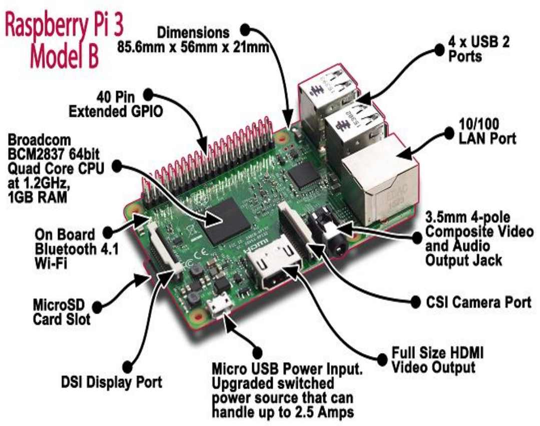
ISSN : 2454-9150 Special Issue - NGEPT - 2019



E. Antenna

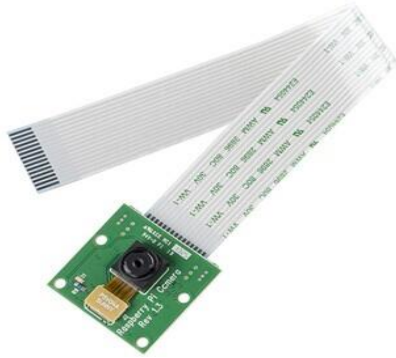
There is no need to connect an external antenna to the Raspberry Pi 3. Its radios are connected to the chip antenna soldered directly to the board, in order to keep the size of the device to a minimum. Despite its diminutive stature, it should be more than capable of picking up wireless LAN and Bluetooth signals – even through walls.





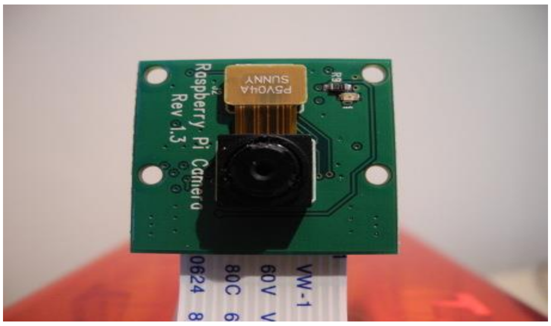
F. Pi Camera

The Raspberry Pi Camera Module is an 5MP CMOS camera with a fixed focus lens that is capable of capturing all images as well as high quality video. Stills are captured at a resolution of 2592 x 1944, while video is supported at 1080p at 30 FPS, 720p at 60 FPS and 640x480 at 60 or 90 FPS.The camera is supported in the latest version of Raspbian, Raspberry Pi's preferred operating system.

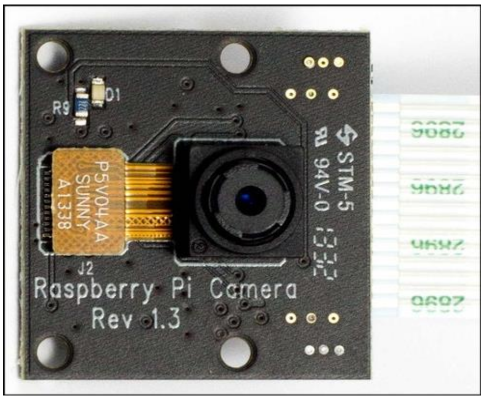


G. Camera Detail

The Raspberry Pi camera board v.1 has a 5 MPixel sensor, and it connects through ribbon cable to Raspberry Pi's Camera Serial Interface (CSI) bus. The cameras image sensor has a resolution of five megapixels and has a fixed focus lens. The software for the camera supports to the full resolution still images up to 2592x1944 and video resolutions of 1080p30, 720p60 and 640x480p60/90.

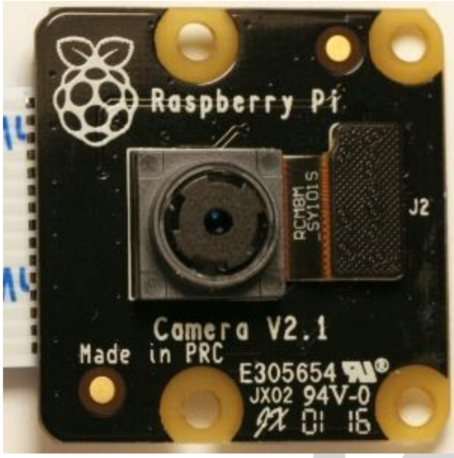


The "Pi NoIR" version of the v.1 camera is released on 28 October 2013. It has the same sensor with the IR filter and a black PCB. With no IR filter, it can use near-IR wavelengths (700 - 1000 nm) like a security camera, with the tradeoff of color rendition.



DOI : 10.18231/2454-9150.2019.0589

The "Pi Camera v2.1" is released 25 April 2016, in both normal and NoIR versions. It uses the Sony IMX219 8-megapixel sensor with a slightly wider (62 degrees H) and faster (f/2.0) lens. The board is the same 25 x 24 mm size, and is intended as a drop-in replacement for the previous camera. Initial production of v2.1 camera boards have lens focus set closer than v.1 (infinity). This can be modified. Later production was set at infinity.



H. *POWER SUPPLY UNIT*

The circuit needs 2 different voltages, +5V & +12V, to work. The dual voltages are supplied by this specially designed power supply. The main object of the ‘power supply’ is, as the name itself implies, to deliver the required amount of stabilized and pure power to the circuit. Every typical power supply contains the following sections:

1. Step-down Transformer: The conventional supply, that is generally available to the user, is 230V AC. It is necessary to step down the mains supply to the desired level.The reason for this is, for proper working of the regulator IC (say KIA 7805) it needs at least 2.5V more than the expected output voltage

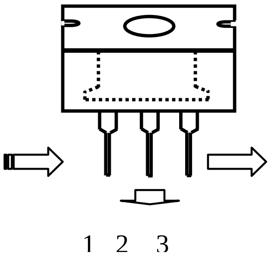
2. Rectifier stage*:* The step-downed Alternating Current is converted into Direct Current. The rectification is achieved by using passive components such as diodes. If the power supply is designed for low voltage drawing circuits (say +5V).

3. Filter stage*:* This rectified output contains some percentage of superimposed AC ripples. So to filter these AC components filter stage is built around the rectifier stage. This electrolytic capacitor has polarities, take care while connecting the circuit.

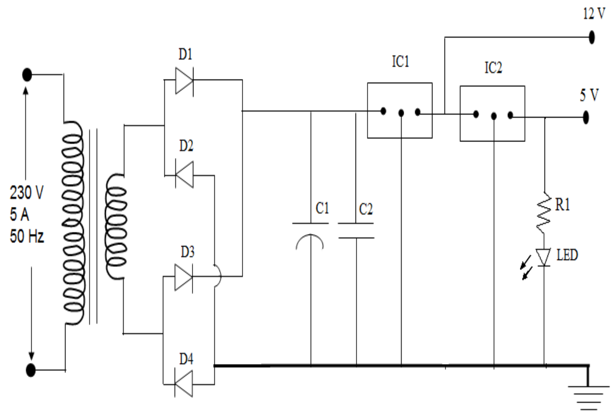
4. Voltage Regulation*:* The filtered DC output is not stable. It varies in accordance with the fluctuations in mains supplies varying load current. The variation of load current is observed due to voltage drop in transformer windings, rectifier and filter circuit.

Circuit Description: A DC power supply which maintains the output voltage constant irrespective of AC mains fluctuations is known as **regulated DC power supply.** This laboratory power supply offers excellent line and load regulation and output voltages of +5V & +12 V at output currents are up to one amp.

KIA 78xx



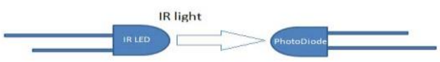
I. CIRCUITDIAGRAM OF +5V & +12V BRIDGE RECTIFIER REGULATED POWER



IR Transmitter and Receiver

Infrared sensor circuits is one of the basic and most popular sensor module in an electronic device. This sensor is analogous to human’s visionary senses, which is used in many applications in electronics, like it is used in Remote control system, motion detector, Product counter, Line follower Robots, Alarms etc.

The placing of IR LED and Photodiode can be done in two ways they are Direct and Indirect. In Direct incidence, IR LED and photodiode are kept in front of one another, so that IR radiation can directly falls on photodiode. If we place any object between them, then it stops the falling of IR light on photodiode.



In Indirect Incidence, both the IR LED and Photo diode are placed in parallel (side by side), facing both in same direction. In that fashion, when a object is kept in front of IR pair, the IR light gets reflected by the object and gets absorbed by photodiode. Note that object shouldn’t be black as it will absorb all the IR light, instead of reflect.

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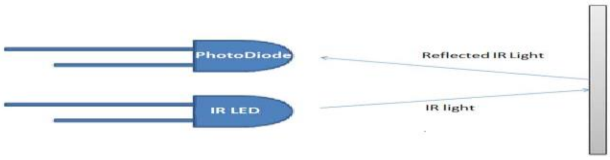
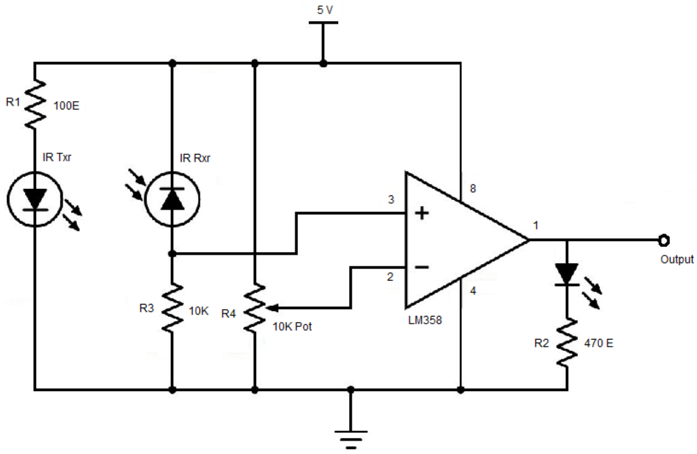
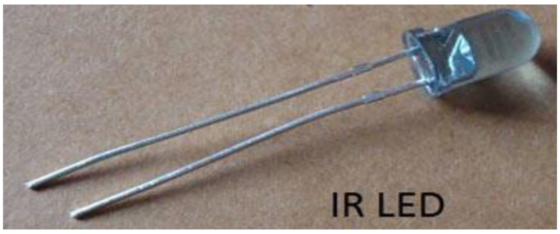


IR Sensor Circuit Diagram:



I. IR LED

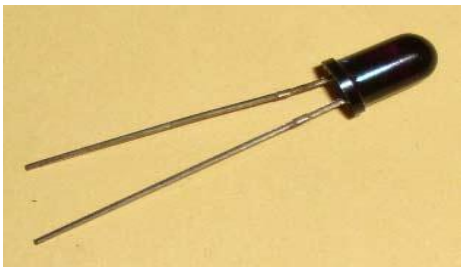
IR LED emits the light, in the range of Infrared frequency. IR light is invisibleas its wavelength (700nm – 1mm) is much higher than the visible light range.Infrared have the same properties as visible light, but it can be focused, reflected and polarised like visible light.



J. Photo Diode

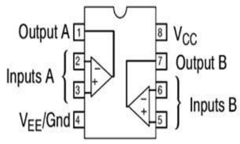
Photodiode is considered as a Light dependent Resistor (LDR), it has very High resistance in absence of light and become low when light falls on it. Photodiode is a semiconductor it has a P-N junction, operated in Reverse Bias, means it start conducting the current in reverse direction when Light falls on it,the amount of current flow is proportional to the amount of Light.

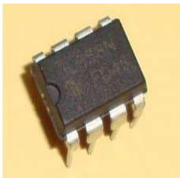
Photodiode looks like a LED, with a Black colour coating on its outer side. It is used in reversed biased, showed in circuit diagram.



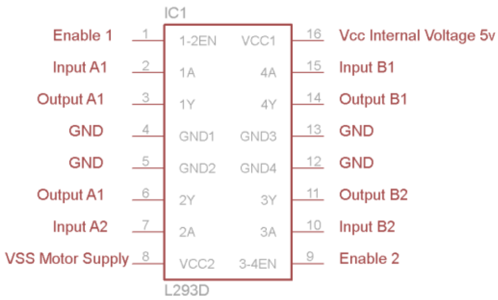
K. LM358

LM358 is an operational amplifier (Op-Amp) and this circuit we are using it as a voltage comparator. The LM358 has two independent voltage comparators inside ,It can be powered by single PIN, and we can use the single IC to build two IR sensor modules also. We used only one comparator here, which have inputs at PIN 2 & 3 and output at PIN 1. The voltage comparator has two inputs, one is inverting input and second is non-inverting input (PIN 2 and 3 in LM358). When voltage as non-inverting input (+) is higher than the voltage as inverting input (-), then the output of comparator (PIN 1) is High. And if the voltage of inverting input (-) is Higher than non-inverting end (+), then output is LOW.





L293D Pin Diagram



Working of L293D

There are 4 input pins l293d, pin 2,7 on the left and pin 15 ,10 on the right as shown on the pin diagram. Left input pins will regulate the rotation of motor connected across left side and the right input for motor on the right hand side. The motors are rotated on the basis of the inputs provided through the input pins as LOGIC 0 or LOGIC 1. The simple way is to provide Logic 0 or 1 across the input pins for rotating the motor.

DC Geared Motor

VII. CONCLUSION

The work has been described the design, analysis, and control of a new type of robot for the inspection of steel

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surfaces such as bridge members. We outlined a novel tilting foot design that allows us to modulate the force of permanent magnetic feet by introducing an air gap. We used this tilting foot to create a robotic device capable of three unique modes of locomotion; the Moonwalk can be used for moving quickly along flat surfaces, the Shuffle can be used for walking along surfaces with small inclines, and the swing can be used to traverse small obstacles. The robot performs these actions by using only a single actuator in tandem with simple locking mechanisms. Finally, we designed and constructed an initial prototype. Experimental studies were used to verify the validity of the design as well as the efficacy of the moonwalk and shuffle gait modes. There exist limitations to the current design and implementation.

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