Solar Tracking & Charging System

A Project report submitted in partial fulfillment of the requirements for the degree of B. Tech in Electrical Engineering

by

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CERTIFICATE

To whom it may concern

This is to certify that the project work entitled **Solar Tracking & Charging System** is the bona fide work carried out by **SUBHRAJYOTI TALAPATRA (11701616019), ANUBHAV CHOWDHURY (11701616066), ABHIJIT KUMAR SINGH (11701616072),** the students of B.Tech in the Dept. of Electrical Engineering, RCC Institute of Information Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015, affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), West Bengal, India, during the academic year 2016-17, in partial fulfilment of the requirements for the degree of Bachelor of Technology in Electrical Engineering.

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We are also indebted to the The Department Electrical Engineering, RCC Institute of Information Technology for permitting us to pursue the project. We would like to take this opportunity to thank all the respected teachers of this department for being a perennial source of inspiration and showing the right path at the time of necessity

Thanks to the fellow members of our group for sincerely co-operating in this work-

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To
The Head of the Department
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Respected Sir,

In accordance with the requirements of the degree of Bachelor of Technology in the Department of Electrical Engineering, RCC Institute of Information Technology, We present the following thesis entitled "**Solar Tracking & Charging System**". This work was performed under the valuable guidance of **Prof. (Dr.) Shilpi Bhattacharya**

We declare that the thesis submitted is our own, expected as acknowledge in the test and reference and has not been previously submitted for a degree in any other Institution.

Yours Sincerely,

SUBHRAJYOTI TALAPATRA (11701616019),

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ABBREVIATIONS & ACRONYMS

CdTe	-	Cadmium Telluride
CIGS	-	Copper Indium Gallium (di)Selenide
CSP	-	Concentrated Solar Power
DC	-	Direct Current
EMF	-	Electromotive Force
I	-	Current
I/O	-	Input/Output
ICSP	-	In-Circuit Serial Programming
IDE	-	Integrated Development Environment
LCD	-	Liquid Crystal Display
LDR	-	Light Dependent Resistor
LUX	-	Luminous Flux
MCU	-	Microcontroller
MPPT	-	Maximum Power Point Tracking
PV	-	Photovoltaic
R	-	Resistor
RPM	-	Rotations per Minute
USB	-	Universal Serial Bus
V	-	Voltage

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ABSTRACT

With the impending scarcity of non-renewable resources, people are considering using alternate sources of energy. As the energy demand and the environmental problems increase, the natural energy sources have become very important as an alternative to the conventional energy sources. The renewable energy sector is fast gaining ground as a new growth area for numerous countries with the vast potential it presents environmentally and economically. From all other available resources sun energy is the most abundant and it's comparatively easy to convert it to electrical energy. Use of solar panel to convert sun's energy to electrical is very popular, but due to transition of the Sun from east to west the fixed solar panel may be able to generate optimum energy. The proposed system solves the problem by an arrangement for the solar panel to track the Sun.

The purpose of this project is to design and construct a solar tracker system that follows the sun direction for producing maximum out for solar powered applications. To get the maximum sunlight in a limited distance. LDRs are used to detect the sun direction. And the energy from the solar panels is stored in battery with the help of a charging arrangements. This tracking process is done by the microcontroller and LDR. The performance of the system has been tested and compared with static solar panel. This project describes the design of a low cost, solar tracking system. Duality ragged up with better compatibility as far as tracking of the sunlight from both the axis is concerned. Commercially single tracker is cheaper to use through booming of power is considerable and therefore a minuscule increase in the price is worthy and acceptable, provided maintenance cost should float around on an average level.

CHAPTER 1
(INTRODUCTION)

1. A. INTRODUCTION

Renewable energy is energy which originates from natural source such as sunlight, tides, wind rain, wave and etc. Solar Energy is the energy consequent from the sun through the form of solar radiation. Solar energy is a very large, inexhaustible source of energy. Today solar energy is the major eco-friendly & pollution less method of producing the electricity. The power from the sun incident on the Earth is approximately 1.8*1011MW, which is many thousands of times larger than the current consumption rate on the earth of all commercial energy sources. The main objective of this project is to improve solar tracker. Solar Tracker is a Device which follows the movement of the sun as it rotates from the east to the west each day. Using solar trackers upturns the amount of solar energy which is received by the solar energy collector and develops the energy output of the heat/electricity which is generated. The solar tracker can be used for more than a few applications such as solar day-lighting system, solar cells and solar thermal arrays. The commercial persistence of solar tracker is rise solar panel output, maximum efficiency of the panel, able to grab the energy throughout the day.

At the present time, clean renewable energy sources attract a great attention as an essential mean for solving the energy crisis around the globe Solar energy is in abundance and is free for all. Although it is not a continuous energy source. One of the most promising renewable energy sources characterized by a huge potential of conversion into electrical power is the solar energy. The green energy, also called renewable energy, has gained much attention now a day. Some renewable energy types are solar energy, hydro potential energy, terrestrial heat, wind energy, biomass energy, sea waves, temperature difference of sea, morning and evening tides, etc. Among these, solar energy is one of the most useful resources that can be used. However, so far the efficiency of generating electric energy from solar radiation is relatively low.

The main objective of this project is to improve solar tracker. The solar tracker can be used for several applications; these are solar cells, solar thermal arrays and solar day-lighting system. Nowadays, the highest efficiency of solar panel is 19%. So, the efficiency can be enhancing by using solar tracker. Tracker systems follow the sun throughout the day to maximize energy output. The Solar Tracker is a proven single-axis tracking technology that has been custom designed to integrate with solar modules and reduce system costs. The Solar Tracker generates up to 25% more energy than fixed mounting systems and provides a bankable energy production profile preferred by utilities.

1. B. PURPOSE

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Thus to get a constant output, an automated system is required which should be capable to constantly rotate the solar panel. The Sun Tracking System (STS) was made as a prototype to solve the problem, mentioned above. It is completely automatic and keeps the panel in front of sun until that is visible. The unique feature of this system is that instead of taking the earth as its reference, it takes the sun as a guiding source. Its active sensors constantly monitor the sunlight and rotate the panel towards the direction where the intensity of sunlight is maximum. With the rapid increase in population and economic development, the problems of the energy crisis and global warming effects are today a cause for increasing concern. The utilization of renewable energy resources is the key solution to these problems. Solar energy is one of the primary sources of clean, abundant and inexhaustible energy, which not only provides alternative energy resources, but also improves environmental pollution. The most immediate and technologically attractive use of solar energy is through photovoltaic conversion. The physics of the PV cell (also called solar cell) is very similar to the classical p-n junction diode. The PV cell converts the sunlight directly into direct current (DC) electricity by the photovoltaic effect . A PV panel or module is a packaged interconnected assembly of PV cells. In order to maximize the power output from the PV panels, one needs to keep the panels in an optimum position perpendicular to the solar radiation during the day. As such, it is necessary to have it equipped with a Sun tracker. Compared to a fixed panel, a mobile PV panel driven by a Sun tracker may boost consistently the energy gain of the PV panel.

CHAPTER 2

(LITERATURE OVERVIEW)

2. A. DEFINITION

A Solar tracker is an automated solar panel which actually follows the sun to get maximum power. The primary benefit of a tracking system is to collect solar energy for the longest period of the day, and with the most accurate alignment as the Sun’s position shifts with the seasons. Dual Axis Tracker have two different degrees through which they use as axis of rotation. The dual axis are usually at a normal of each rotate both east to west (zenithal) and north to south. Solar tracking is the most appropriate technology to enhance the electricity production of a PV system. To achieve a high degree of tracking accuracy, several approaches have been widely investigated. generally, they can be classified as either open-loop tracking types based on solar movement mathematical models or closed-loop tracking types using sensor-based feedback controllers. In the Open-loop tracking approach, a tracking formula or control algorithm is used. Referring to the literature, the azimuth and the elevation angles of the Sun were determined by solar movement models or algorithms at the given date, time and geographical information. The control algorithms were executed in a microprocessor controller . In the closed-loop tracking approach, various active sensor devices, such as charge couple devices (CCDs) or light dependent resistors (LDRs) were utilized to sense the Sun’s position and a feedback error signal as the generated to the control system to continuously receive the maximum solar radiation on the PV panel. This project proposes an empirical research approach on this issue. Solar tracking approaches can be implemented by using single-axis schemes and dual-axis structures for higher accuracy systems. In general, the single-axis tracker with one degree of freedom follows the Sun’s movement from the east to west during a day while a dual-axis tracker also follows the elevation angle of the Sun. In recent years, there has been a growing volume of research concerned with dual-axis solar tracking systems. However, in the existing research, most of them used two stepper motors or two DC motors to perform dual-axis solar tracking. With two tracking motors designs, two motors were mounted on perpendicular axes, and even aligned them in certain directions. In some cases, both motors could not move at the same time. Furthermore, such systems always involve complex tracking strategies using microprocessor chips as a control platform. In this work, employing a dual-axis with only single tracking motor, an attempt has been made to develop and implement a simple and efficient control scheme. The two axes of the Sun tracker were allowed to move simultaneously within their respective ranges. Utilizing conventional electronic circuits, no programming or computer interface was needed. Moreover, the proposed system used a stand-alone PV inverter to drive motor and provide power supply. The system was self-contained and autonomous. Experiment results have demonstrated the feasibility of the tracking PV system and verified the advantages of the proposed control implementation.

CHAPTER 3
(METHODOLOGY)

3. A. <u>OBJECTIVE</u>

In this projects include design and construction of an arduino based solar tracker. This solar tracker system uses the arduino board, a servomotor, 2 LDR and 2 resistors to rotate the solar panel towards the sun or a source of light. In this project LDR was selected since it has no polarity, and easy to interface with circuit, cheap, reliable and is described by high spectral sensitivity, so that difference in high intensity is represented immediately by change in its resistance value.

Features:-

1. Automatic controlling solar panel direction.

2. Storage of energy into rechargeable battery.

3. Stored energy is used for any electronic devices.

3. B. METHODOLOGY

This project consists of few sensors and a motorized mechanism for rotating the panel in the direction of sun. Moving the solar cell panel in the direction of sun can increase the solar energy generated from the solar cell. Microcontroller based control system takes care of sensing sunlight and controlling the motorized mechanism. This system works continuously without any interruption. The device features sun-tracking capabilities for maximum energy gathering and darkness recognition to establish optimal operation times.

Contemplating the idea of building the said project, the idea that has been conceived primarily is to make the best use of solar energy. The next path that unravels is firstly the method to be adopted in storing the solar energy at its maximum level which further ends up with hatching of the project called "SOLAR TRACKING AND CHARGING SYSTEM''. Culminating towards making the said project caviar in its utilization several components have been unleashed, some of which are mentioned so-

1. Solar Panel,

2. DC Motor,

3. Arduino Nano V3 (Microcontroller)

4. LDR sensor module

5.L317

6. Rechargeable Battery,

All in consolidation of the said components the concerned project is orchestrated, ought to seek for imbibing the sun rays at its maximum level through the LDR sensor module etched on the edges of the solar panel in accordance with the length of it, revolves in aid with the DC motor by maintaining the proportionality of the Sun's movement. Therefore, the genesis lies upon the fact of making solar energy a profitable source in the production of various other aspects which are in rest with the acute need of the society. In addition to which it would be further worthier to state that when the world is being maligned and sick through the pollution ruckus this project could unveil to be a robust endeavor.

CHAPTER 4
(THEORY)

THEORITICAL BACKGROUND OF SOLAR TRACKER

4.A._. The Earth: Rotation and Revolution

The position of the sun changes continuously throughout the day. It is due to the motion of earth that we experience sun at different angles in the sky. Earth exhibit two types of motion. One is the motion of earth along its own axis, and the other is the earth revolving around the sun. the motion of the earth along its own axis, known as **rotation**, results in the phenomenon of days and nights. One rotation of the earth takes 23 hours and 56 minutes. On its own axis, the motion of the earth is west to east.

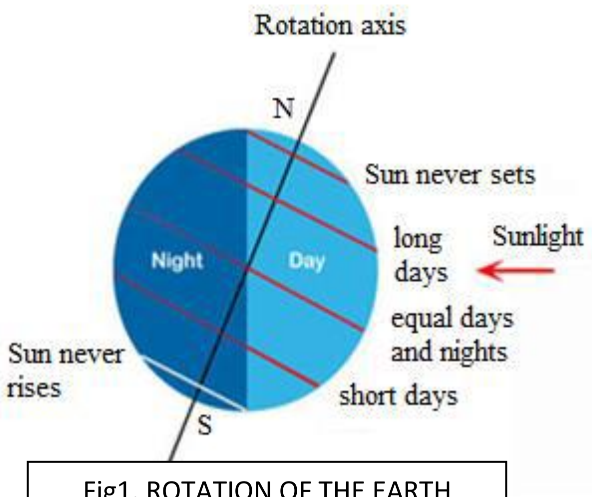


Fig1. ROTATION OF THE EARTH

Revolution, that is the motion of the earth around the sun is responsible for the different seasons in the year. The earth takes 365 days to revolve around the sun. Earth revolves around the sun in an

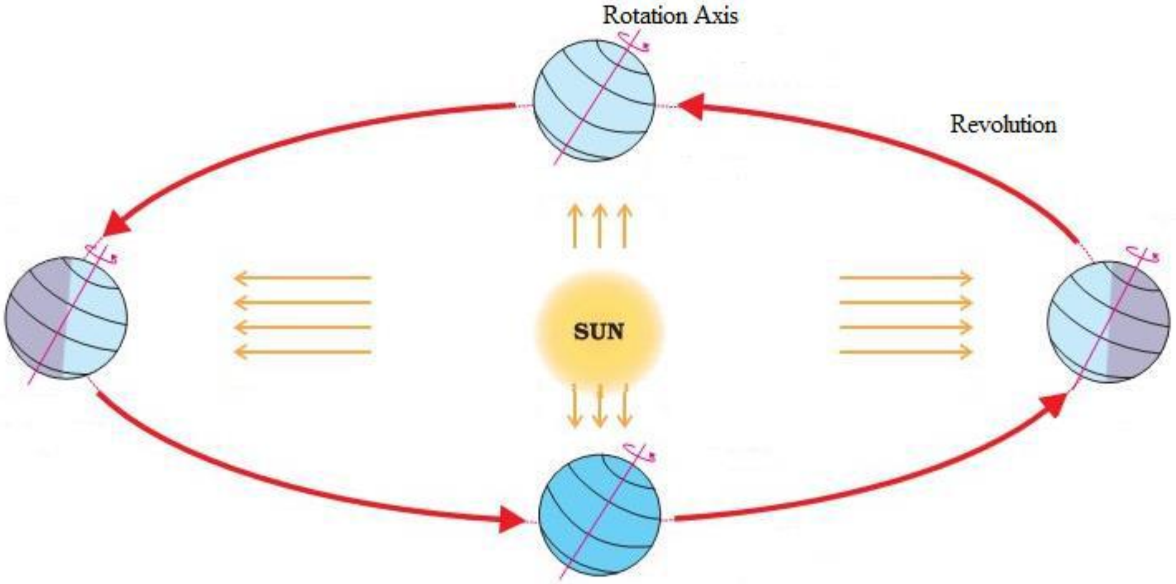


Fig2. ROTATION AND REVOLUTION OF THE EARTH

elliptical orbit and the plane covered by the earth during the revolution is known as an ellipsis. The axis of rotation and ellipsis makes an angle of 66.5 degrees between themselves. This is the explanation behind the summer/winter solaces and spring autumn equinoxes. Due to these motions of the earth, the amount of sunlight received throughout the year varies.

Sunlight is the electromagnetic radiation from the sun expropriated by the earth. The total power given off by the sun into space is much more than that intercepted by the earth.

Within a given period of time, the emission of solar radiation is somewhat constant and the intensity this radiation hitting a unit area of the earth's crust is also constant, known as solar constant. The value of this solar constant can be expressed as: -

$$G_{SC} = \sigma . T^4 . \left(\frac{4\pi R}{4\pi D}\right)^2 = 1367\,W/m^2$$

In the above expression, σ is termed as Stefan Boltzmann Constant with a value of 5.67×10^{-8} $W/m^2 . K^4$, R is known as the radius of the Sun, 696·106 m and D is 150 ·109 m, the average distance between the Sun and the earth.

The absorption of solar radiation on the surface of the earth also varies with different parameters. Latitude and longitude are one of the prescribed parameters. Latitude the horizontal imaginary line, parallel to the equator, is the angle suspended by the arc linearly join a person's position and the equator, at the center of the earth. On the contrary longitudes are the vertical imaginary lines, where longitude is the angle suspended by the arc joining the north-pole and south-pole as well as passing through the given location, linearly with the Greenwich meridian, at the center of the earth. The latitude and longitude express north-south and east-west directions respectively on the earth.

The sunlight is observed at different angles depending on the place on the earth and the angles of the sun. The sun's angle can be classified into the following: -

• Elevation Angle

• Zenith Angle

• Azimuth Angle

The elevation angle is the angle made by the sun with the horizon. The elevation angle is 0 degree at sunrise and 90 degrees around noontime, at the equator. The elevation angle is different at a different time of the day and different for different latitudes. The depicted formula can be used to determine the elevation angle.

$$\alpha = 90 + \varphi - \delta$$

When the equation above gives a number greater than 90° then subtract the result from 180°. It means the sun at solar noon is coming from the south as is typical the northern hemisphere.
φ is the latitude of the location of interest (+ve for the northern hemisphere and −ve for the southern hemisphere). δ is the declination angle, which depends on the day of the year.

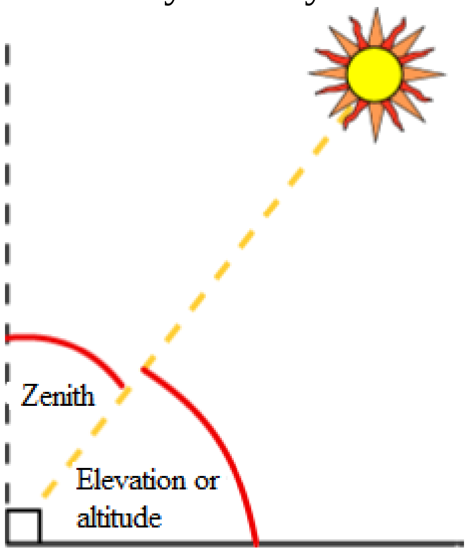


Fig 3.

Zenith angle is akin with elevation angle. The only difference being it is measured along the vertical. Therefore, it's the angle between the sun and the vertical

i.e.

Zenith Angle = 90° – elevation angle.

$\zeta = 90° - \alpha$

Azimuthal Angle, this is the compass direction from which the sunlight is coming. At solar noon, the sun is directly south in the northern hemisphere and directly north in the southern hemisphere. The azimuth angle varies throughout the day. At the equinoxes, the sun rises directly east and sets directly west regardless of the latitude. Therefore, the azimuth angles are 90 degrees at sunrise and 270 degrees at sunset.

Sunrise and Sunset time can be formulated by the following formulas-

Sunrise= $12 - \frac{1}{15°}\cos^{-1}(-\tan\varphi\tan\delta) - \frac{TC}{60}$

Sunset= $12 + \frac{1}{15°}\cos^{-1}(-\tan\varphi\tan\delta) - \frac{TC}{60}$

Where φ being the latitude of the place, δ being the declination angle and TC is the Time Correction.

4.B. Types of Solar Tracker

Types	**Specification**
Active Solar Tracker	• It uses motors and gear trains or direct drive actuators, to follow the movement of the sun. • Directed by a controller. • Deactivates during darkness based on the design of the system. • It uses a light sensor to locate the angle at which maximum sunlight can be absorbed. • The MCU directs the solar panel to change the angle.
Passive Solar Tracker	• It uses a liquid, easily compressible and boiled. • It is driven by the solar heat. • The fluid moves
Chronological Solar Tracker	• Works with the rotation of the earth. • Have no sensors. • Depends on the geographical location. • Uses a controller to calculate the moment and position of the earth with respect to the sun at a given time and location.
Single Axis Tracker	• Tracks in a single cardinal direction. • It has a single row tracking configuration. • More reliable. • It has a longer lifespan. The common categories in which single axis

Single Axis Tracker	trackers can be classified holds: • Horizontal single axis trackers (HSAT). • Horizontal single axis tracker with tilted modules (HTSAT). • Vertical single axis tracker (VSAT). • Tilted single axis tracker (TSAT). • Polar aligned single axis tracker (PSAT).
Dual Axis Tracker	• It moves along two cardinal directions (Horizontal & Vertical). • The axes are traditionally orthogonal. • Its efficiency is much more than any single Axis Tracker. • It conventionally follows the movement of the sun and hence captivates maximum solar radiations.

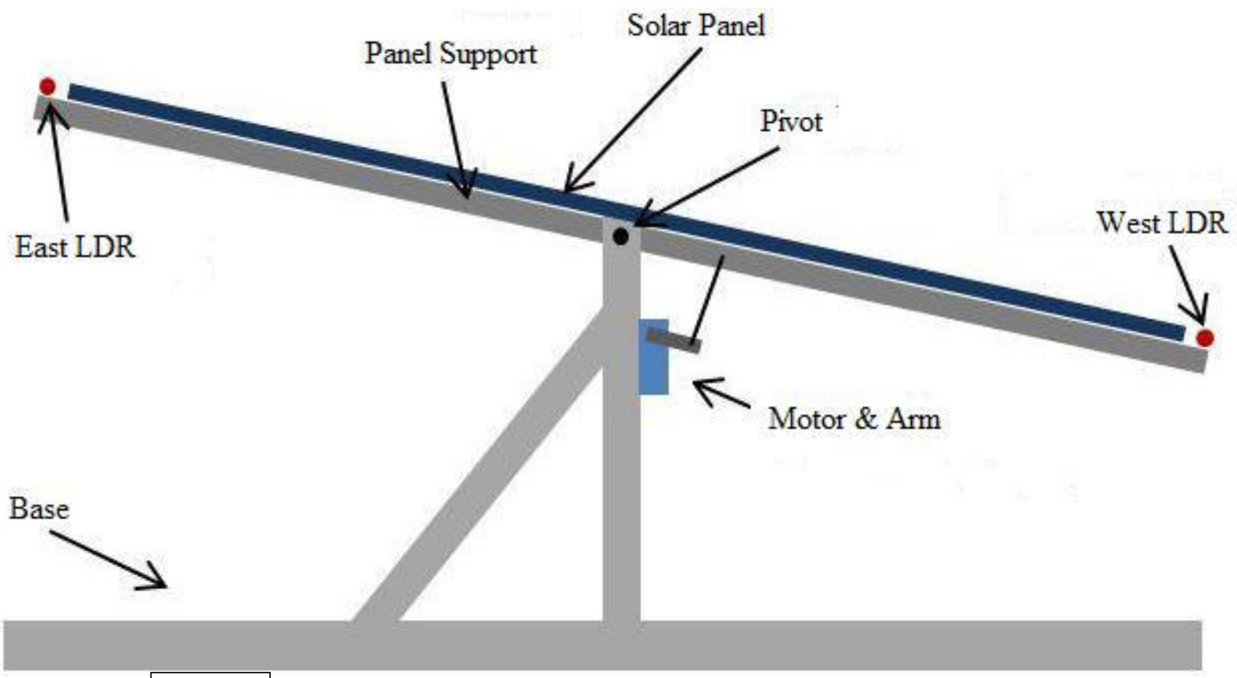
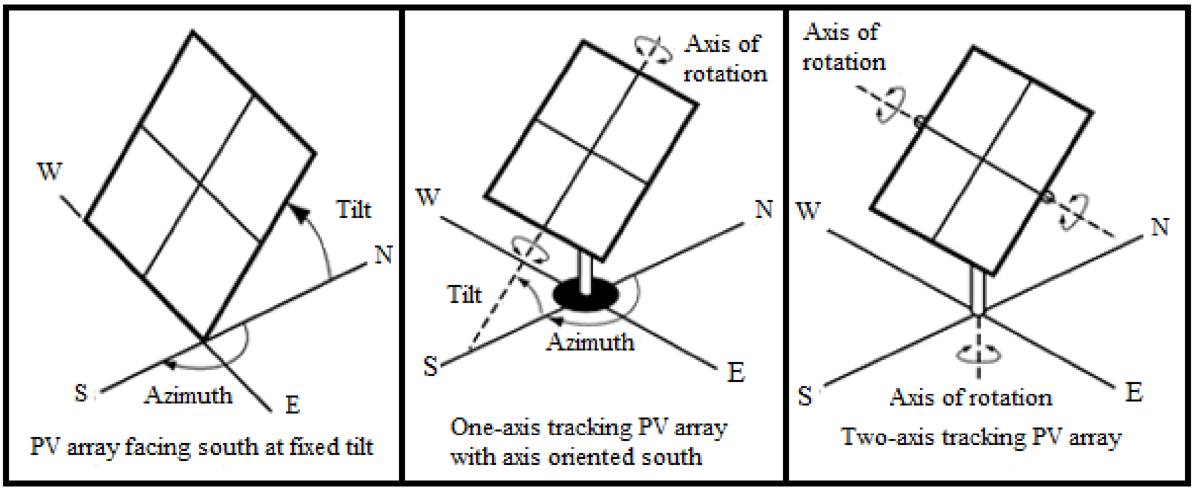


Fig 4. ***Single Axis Solar Tracker Design***



Dual Axis Solar Tracker

4.C. Fixed Plate Collectors

The fixed collectors are secured at a place where the gross solar energy obtained is comparatively higher than most of the predefined places and is the inclination is kept in accordance with the defined

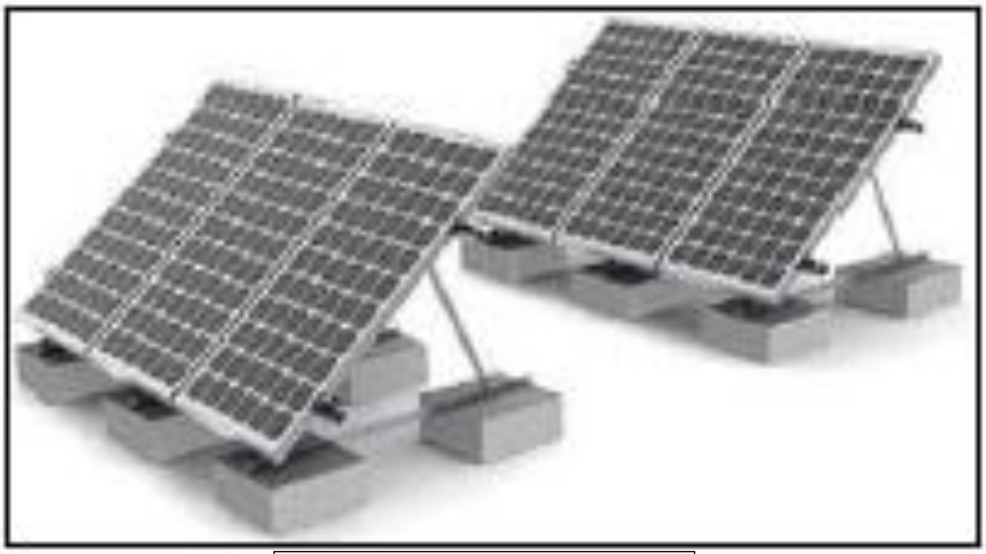
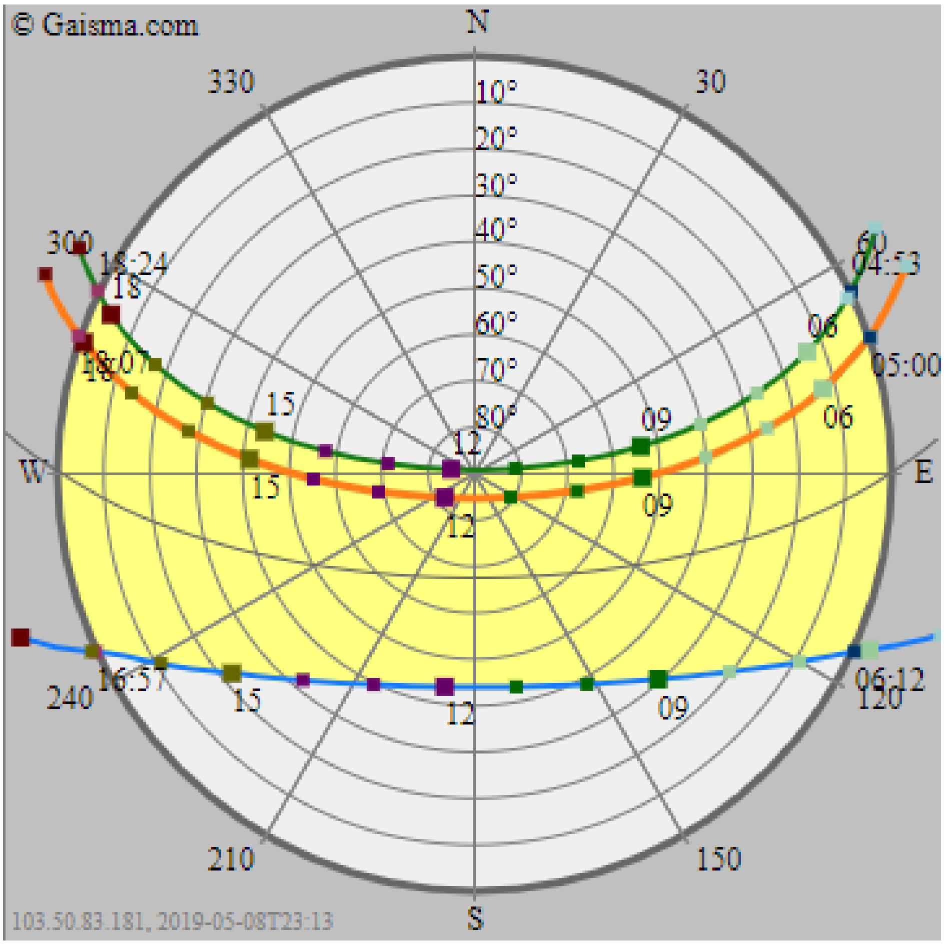


Fig 5.

context. The motive is to install collected places which are subjected to receive the maximum amount of sunlight and collect solar energy over a long period of time hence the demand for tracking devices can be overcome. This creates a substantial diminution in the expenses and the preservation of the collectors. The knowledge of the movement of the sun throughout a season and different hours of the year is essential to enable maximum captivation of solar energy.

The Sun chart for Calcutta is shown below—



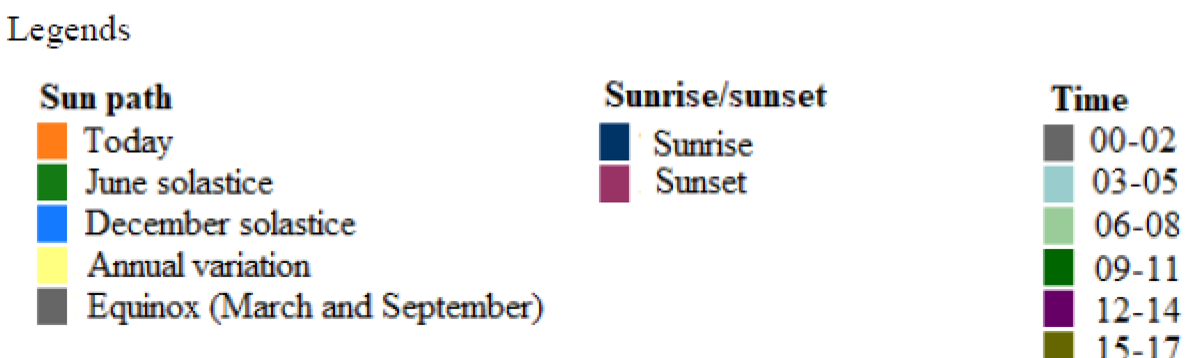


Fig 6.

Through the use of the chart, it is possible to ascertain the position of the sun at different times and seasons so that the panel can be fixed for maximum output. Fixed trackers are cheaper in tropical countries like Kenya. For countries beyond +10 degrees North and -10 degrees South of the equator, there is need for serious tracking. This is because the position of the midday sun varies significantly.

The chart shows that the position of the sun is highest between 1200h and 1400h. For the periods outside this range, the collectors are obliquely oriented to the sun and therefore only a fraction reaches the surface of absorption.

CHAPTER 5

(HARDWARE OVERVIEW)

The following is a brief description of the major components that are being used for completion of the project.

5.A. SOLAR PANEL

Solar panels generate free power from the sun by converting sunlight to electricity with no moving parts, zero emissions, and no maintenance. The solar panel, the first component of an electric solar energy system, is a collection of individual silicon cells that generate electricity from sunlight. The photons (light particles) produce an electrical current as they strike the surface of the thin silicon wafers. A single solar cell produces only about 1/2 (.5) of a volt. However, a typical 12 volt panel about 25 inches by 54 inches will contain 36 cells wired in series to produce about 17 volts peak output. If the solar panel can be configured for 24 volt output, there will be 72 cells so the two 12 volt groups of 36 each can be wired in series, usually with a jumper, allowing the solar panel to output 24 volts. When under load (charging batteries for example), this voltage drops to 12 to 14 volts (for a 12 volt configuration) resulting in 75 to 100 watts for a panel of this size.

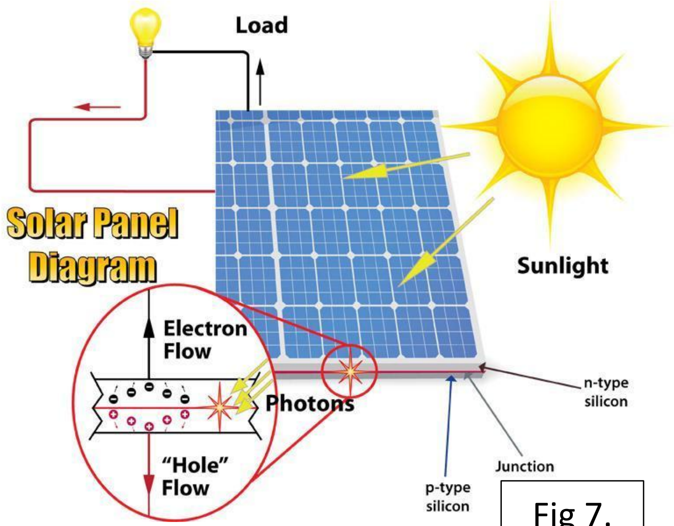


Fig 7.

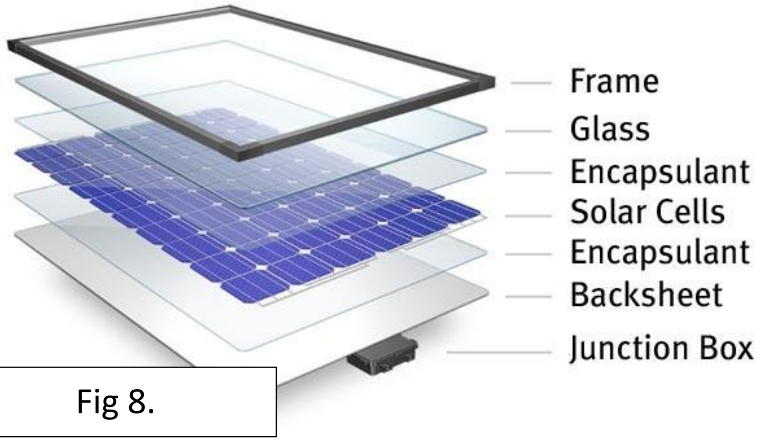


Fig 8.

Multiple solar panels can be wired in parallel to increase current capacity (more power) and wired in series to increase voltage for 24, 48, or even higher voltage systems.

The 3 basic types of Solar Panels:

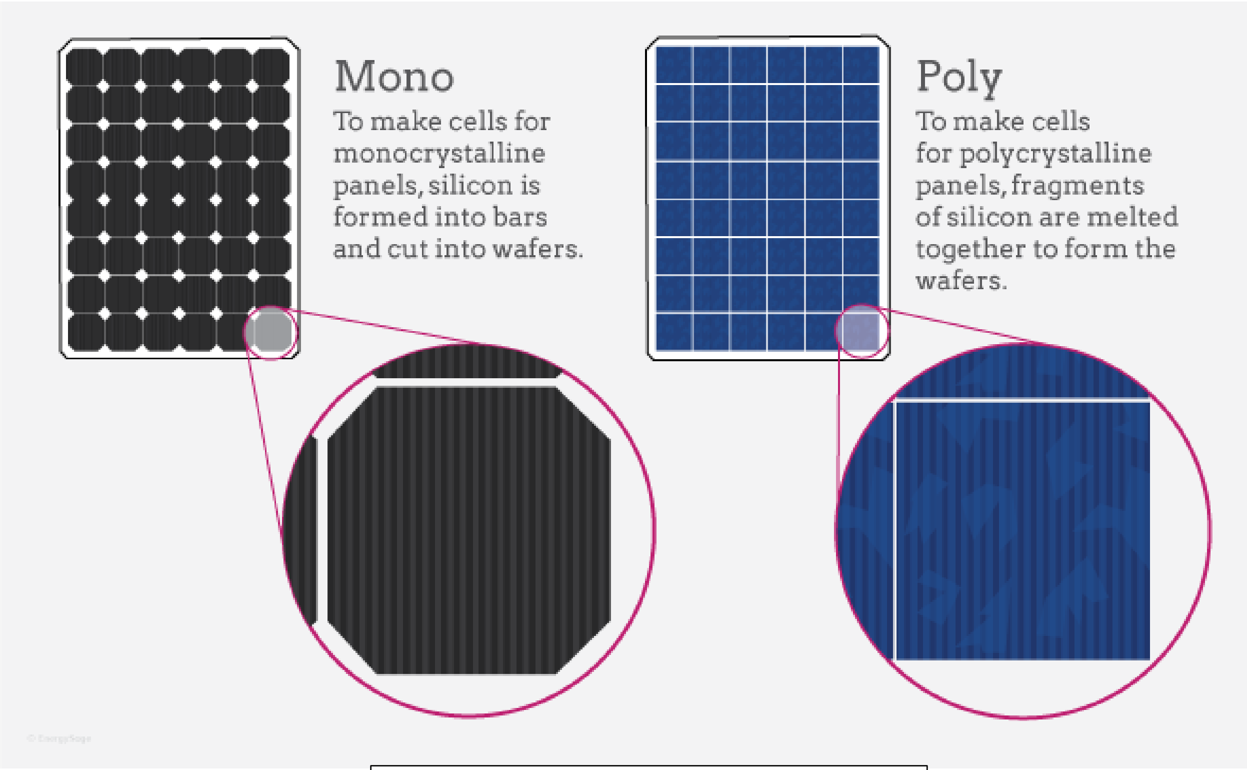


Fig 9.

Monocrystalline solar panels: The most efficient and expensive solar panels are made with Monocrystalline cells. These solar cells use very pure silicon and involve a complicated crystal growth process. Long silicon rods are produced which are cut into slices of .2 to .4 mm thick discs or wafers which are then processed into individual cells that are wired together in the solar panel.

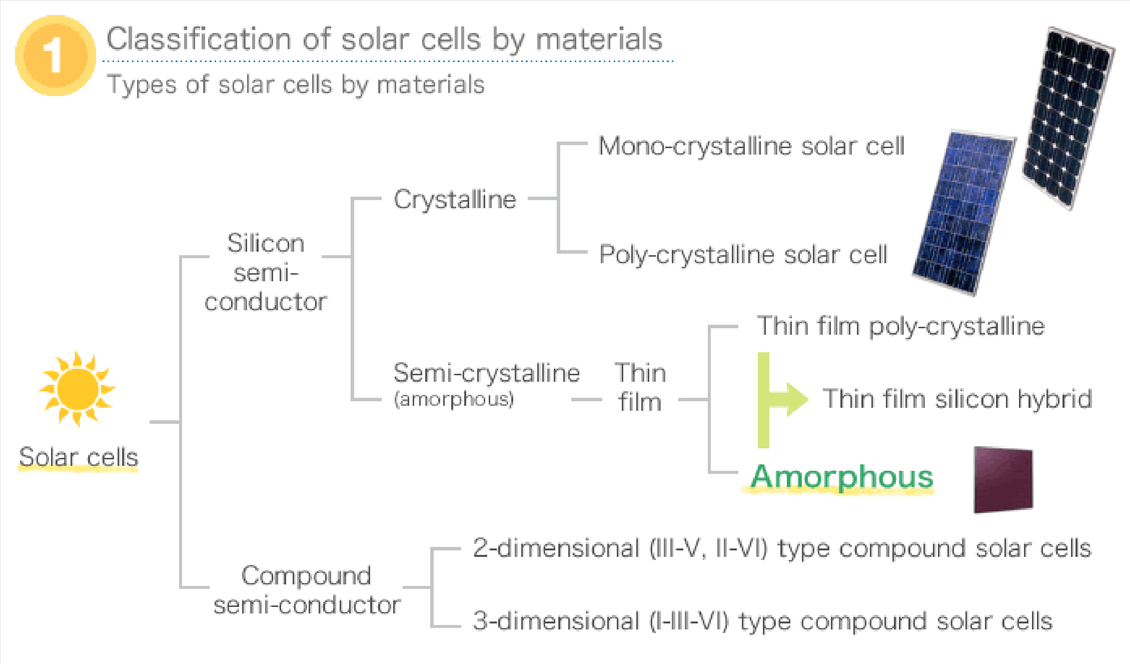


Fig 10.

Polycrystalline solar panels: Often called Multi-crystalline, solar panels made with Polycrystalline cells are a little less expensive & slightly less efficient than Monocrystalline cells because the cells are not grown in single crystals but in a large block of many crystals. This is what gives them that striking shattered glass appearance. Like Monocrystalline cells, they are also then sliced into wafers to produce the individual cells that make up the solar panel.

Amorphous solar panels: These are not really crystals, but a thin layer of silicon deposited on a base material such as metal or glass to create the solar panel. These Amorphous solar panels are much cheaper, but their energy efficiency is also much less so more square footage is required to produce the same amount of power as the Monocrystalline or Polycrystalline type of solar panel. Amorphous solar panels can even be made into long sheets of roofing material to cover large areas of a south facing roof surface.

Cell Technology	Crystalline Silicon	Thin Film Silicon
Types	• Mono-crystalline silicon (c-Si) • Poly-crystalline silicon (pc-Si/ mc-Si)	• Amorphous Silicon (a-Si) • Cadmium telluride (CdTe) • Copper indium gallium (di)selenide (CIG/CIGS)
Temperature resistivity	Lower	Higher
Module Efficiency	13-19%	4-12%

There are several other factors on which the efficiency of a solar cell depends.

- • Cell temperature
- • Energy Conversion Efficiency
- • Maximum power point tracking .

Solar panels are a cumulative orientation of photovoltaic cells. The PV cells are arranged in a solar panel or a PV array such that is serves the purpose of exciting the electron of the material consisting inside the solar cells using photons. The average amount of sunlight received by solar panels particular depends on the position of the sun.

5.B. SERVO MOTOR

Fig 11

A **servo motor** is an electrical device which can push or rotate an object with great precision. If we want to rotate and object at some specific angles or distance, then we use servo motor. It is just made up of simple motor which run through **servo mechanism**. If motor is used is DC powered then it is called DC servo motor, and if it is AC powered motor then it is called AC servo motor. We can get a very high torque servo motor in a small and light weight packages. Due to these features they are being used in many applications like toy car, RC helicopters and planes, Robotics, Machine etc. The position of a servo motor is decided by electrical pulse and its circuitry is placed beside the motor.

Wire Configuration

Wire Number	**Wire Colour**	**Description**
1	Brown	Ground wire connected to the ground of system
2	Red	Powers the motor typically +5V is used
3	Orange	PWM signal is given in through this wire to drive the motor

TowerPro SG-90 Features

Operating Voltage is +5V typically

Torque: 2.5kg/cm

Operating speed is 0.1s/60°

Gear Type: Plastic

Rotation : 0°-180°

Weight of motor : 9gm

Package includes gear horns and screws

Selecting the Servo Motor

There are lots of servo motors available in the market and each one has its own specialty and applications. The following two paragraphs will help us identify the right type of servo motor for our project/system.

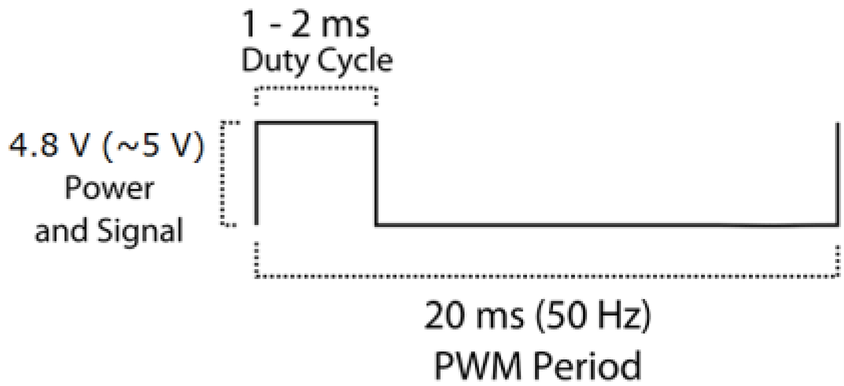
Most of the hobby Servo motors operates from 4.8V to 6.5V, the higher the voltage higher the torque we can achieve, but most commonly they are operated at +5V. Almost all hobby servo motors can rotate only from 0° to 180° due to their gear arrangement so make sure project can live with the half circle if no, you can prefer for a 0° to 360° motor or modify the motor to make a full circle. The gears in the motors are easily subjected to wear and tear, so if your application requires stronger and long running motors you can go with metal gears or just stick with normal plastic gear.

Next comes the most important parameter, which is the **torque** at which the motor operates. Again there are many choices here but the commonly available one is the 2.5kg/cm torque which comes with the Tower pro SG90 Motor. This 2.5kg/cm torque means that the motor can pull a weight of 2.5kg when it is suspended at a distance of 1cm. So if you suspend the load at 0.5cm then the motor can pull a load of 5kg similarly if you suspend the load at 2cm then can pull only 1.25. Based on the load which you use in the project you can select the motor with proper torque. The below picture will illustrate the same.

Fig. 12

Using a Servo Motor

After selecting the right Servo motor for the project, comes the question how to use it. As we know there are three wires coming out of this motor. The description of the same is given on top of this page. To make this motor rotate, we have to power the motor with +5V using the Red and Brown wire and send PWM signals to the Orange colour wire. Hence we need something that could generate PWM signals to make this motor work, this something could be anything like a 555 Timer or other Microcontroller platforms like Arduino, PIC, ARM or even a microprocessor like Raspberry Pie. Now, how to control the direction of the motor? To understand that let us a look at the picture given in the datasheet.



From the picture we can understand that the PWM signal produced should have a frequency of 50Hz that is the PWM period should be 20ms. Out of which the On-Time can vary from 1ms to 2ms. So when the on-time is 1ms the motor will be in 0° and when 1.5ms the motor will be 90°, similarly when it is 2ms it will be 180°. So, by varying the on-time from 1ms to 2ms the motor can be controlled from 0° to 180°

Servo Mechanism

It consists of three parts:

Controlled device

Output sensor

Feedback system

It is a closed loop system where it uses positive feedback system to control motion and final position of the shaft. Here the device is controlled by a feedback signal generated by comparing output signal and reference input signal.

Here reference input signal is compared to reference output signal and the third signal is produces by feedback system. And this third signal acts as input signal to control device. This signal is present as long as feedback signal is generated or there is difference between reference input signal and reference output signal. So the main task of servomechanism is to maintain output of a system at desired value at presence of noises.

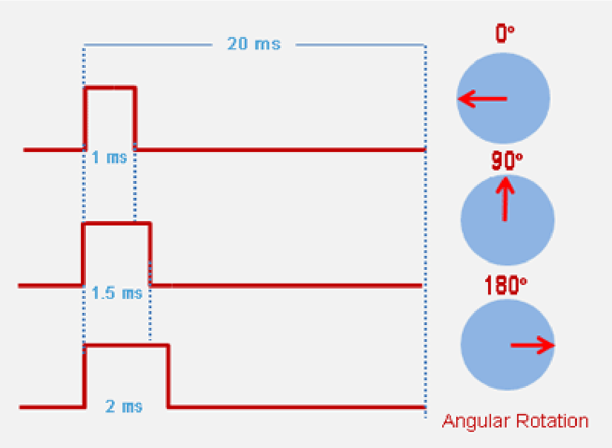
Working principle of Servo Motors

A servo consists of a Motor (DC or AC), a potentiometer, gear assembly and a controlling circuit. First of all we use gear assembly to reduce RPM and to increase torque of motor. Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to another input terminal of the error detector amplifier. Now difference between these two signals, one comes from potentiometer and another comes from other source, will be processed in feedback mechanism and output will be provided in term of error signal. This error signal acts as the input for motor and motor starts rotating. Now motor shaft is connected with potentiometer and as motor rotates so the potentiometer and it will generate a signal. So as the potentiometer's angular position changes, its output feedback signal changes. After sometime the position of potentiometer reaches at a position that the output of potentiometer is same as external signal provided. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer, and in this situation motor stops rotating.

Controlling Servo Motor:

Servo motor is controlled by PWM (Pulse with Modulation) which is provided by the control wires. There is a minimum pulse, a maximum pulse and a repetition rate. Servo motor can turn 90 degree from either direction form its neutral position. The servo motor expects to see a pulse every 20 milliseconds and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90° position, such as if pulse is shorter than 1.5ms shaft moves to 0° and if it is longer than 1.5ms than it will turn the servo to 180°.

Servo motor works on **PWM (Pulse width modulation)** principle means its angle of rotation is controlled by the duration of applied pulse to its Control PIN. Basically servo motor is made up of **DC motor which is controlled by a variable resistor (potentiometer) and some gears**. High speed force of DC motor is converted into torque by Gears. We know that WORK= FORCE X DISTANCE, in DC motor Force is less and distance (speed) is high and in Servo, force is High and distance is less. Potentiometer is connected to the output shaft of the Servo, to calculate the angle and stop the DC motor on required angle.



Servo motor can be rotated from 0 to 180 degree, but it can go up to 210 degree, depending on the manufacturing. This degree of rotation can be controlled by applying the **Electrical Pulse** of proper width, to its Control pin. Servo checks the pulse in every 20 milliseconds. Pulse of 1 ms (1 millisecond) width can rotate servo to 0 degree, 1.5ms can rotate to 90 degree (neutral position) and 2 ms pulse can rotate it to 180 degree.

5.C. ARDUINO NANO

Arduino is an Integrated Development Environment based upon Processing. It has made very easy several things namely these are embedded system, physical computing, robotics, automation and other electronics based things.

Every Arduino has the same functionality (more or less) and the same features except the number of pins and size. Arduino Nano is a small chip board based on ATmega 328p.

Pin Description:

No.	Pin Number	Pin Description
1	D0 – D13	Digital Input / Output Pins.
2	A0 – A7	Analog Input / Output Pins.
3	Pin # 3, 5, 6, 9, 11	Pulse Width Modulation (PWM) Pins.
4	Pin # 0 (RX) , Pin # 1 (TX)	Serial Communication Pins.
5	Pin # 10, 11, 12, 13	SPI Communication Pins.
6	Pin # A4, A5	I2C Communication Pins.
7	Pin # 13	Built-In LED for Testing.
8	D2 & D3	External Interrupt Pins.

Arduino Nano is a small, compatible, flexible and breadboard friendly Microcontroller board, developed by Arduino.cc in Italy, based on ATmega328p (Arduino Nano V3.x) / Atmega168 (Arduino Nano V3.x).

It comes with exactly the same functionality as in Arduino UNO but quite in small size.

It comes with an operating voltage of 5V; however, the input voltage can vary from 7 to 12V.

Arduino Nano Pinout contains 14 digital pins, 8 analog Pins, 2 Reset Pins & 6 Power Pins.

Each of these Digital & Analog Pins is assigned with multiple functions but their main function is to be configured as input or output.

They are acted as input pins when they are interfaced with sensors, but if you are driving some load then use them as output.

Functions like pinMode() and digitalWrite() are used to control the operations of digital pins while analogRead() is used to control analog pins.

The analog pins come with a total resolution of 10bits which measure the value from zero to 5V.

Arduino Nano comes with a crystal oscillator of frequency 16 MHz. It is used to produce a clock of precise frequency using constant voltage.

There is one limitation using Arduino Nano i.e. it doesn't come with DC power jack, means you cannot supply external power source through a battery.

This board doesn't use standard USB for connection with a computer; instead, it comes with Mini USB support.

Tiny size and breadboard friendly nature make this device an ideal choice for most of the applications where sizes of the electronic components are of great concern.

Flash memory is 16KB or 32KB that all depends on the Atmega board i.e Atmega168 comes with 16KB of flash memory while

Atmega328 comes with a flash memory of 32KB. Flash memory is used for storing code. The 2KB of memory out of total flash memory is used for a bootloader.

The SRAM can vary from 1KB or 2KB and EEPROM is 512 bytes or 1KB for Atmega168 and Atmega328 respectively.

This board is quite similar to other Arduino boards available in the market, but the small size makes this board stand out from others.

the specifications of Arduino

Following figure shows Nano Board.

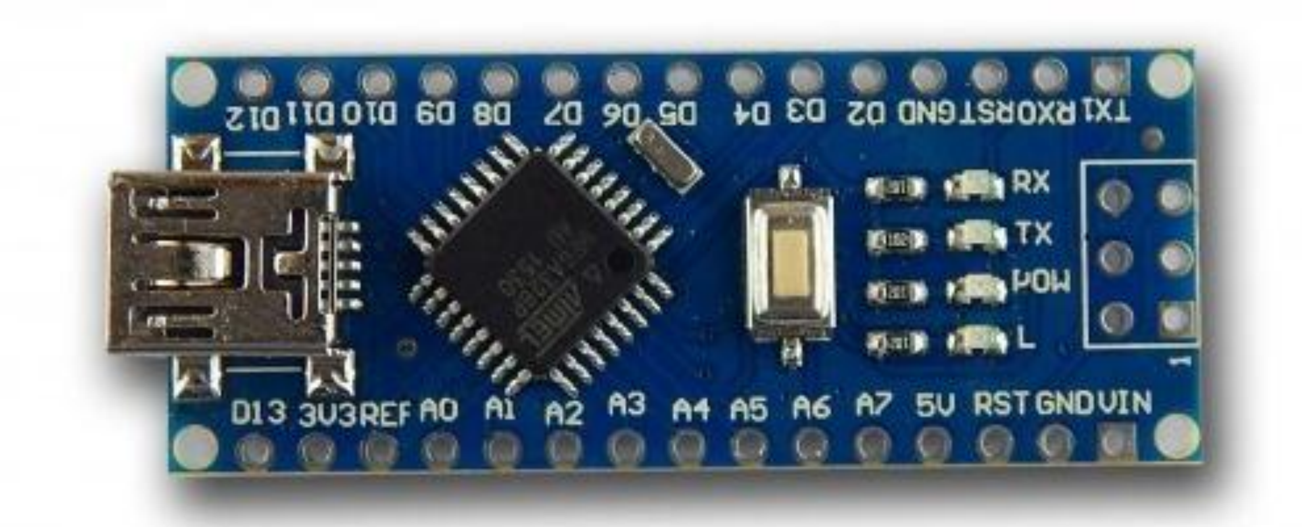


Fig 13

Microcontroller	Atmega328p/Atmega 168
Operating Voltage	5V
Input Voltage	7 – 12 V
Digital I/O Pins	14
PWM	6 out of 14 digital pins
Max. Current Rating	40mA
USB	Mini
Analog Pins	8
Flash Memory	16KB or 32KB
SRAM	1KB or 2KB
Crystal Oscillator	16 MHz
EEPROM	512bytes or 1KB
USART	Yes

It is programmed using Arduino IDE which is an Integrated Development Environment that runs both offline and online.

No prior arrangements are required to run the board. All you need is board, mini USB cable and Arduino IDE software installed on the computer. USB cable is used to transfer the program from computer to the board.

No separate burner is required to compile and burn the program as this board comes with a built-in boot-loader.

Following figure shows the pinout of Arduino Nano Board.

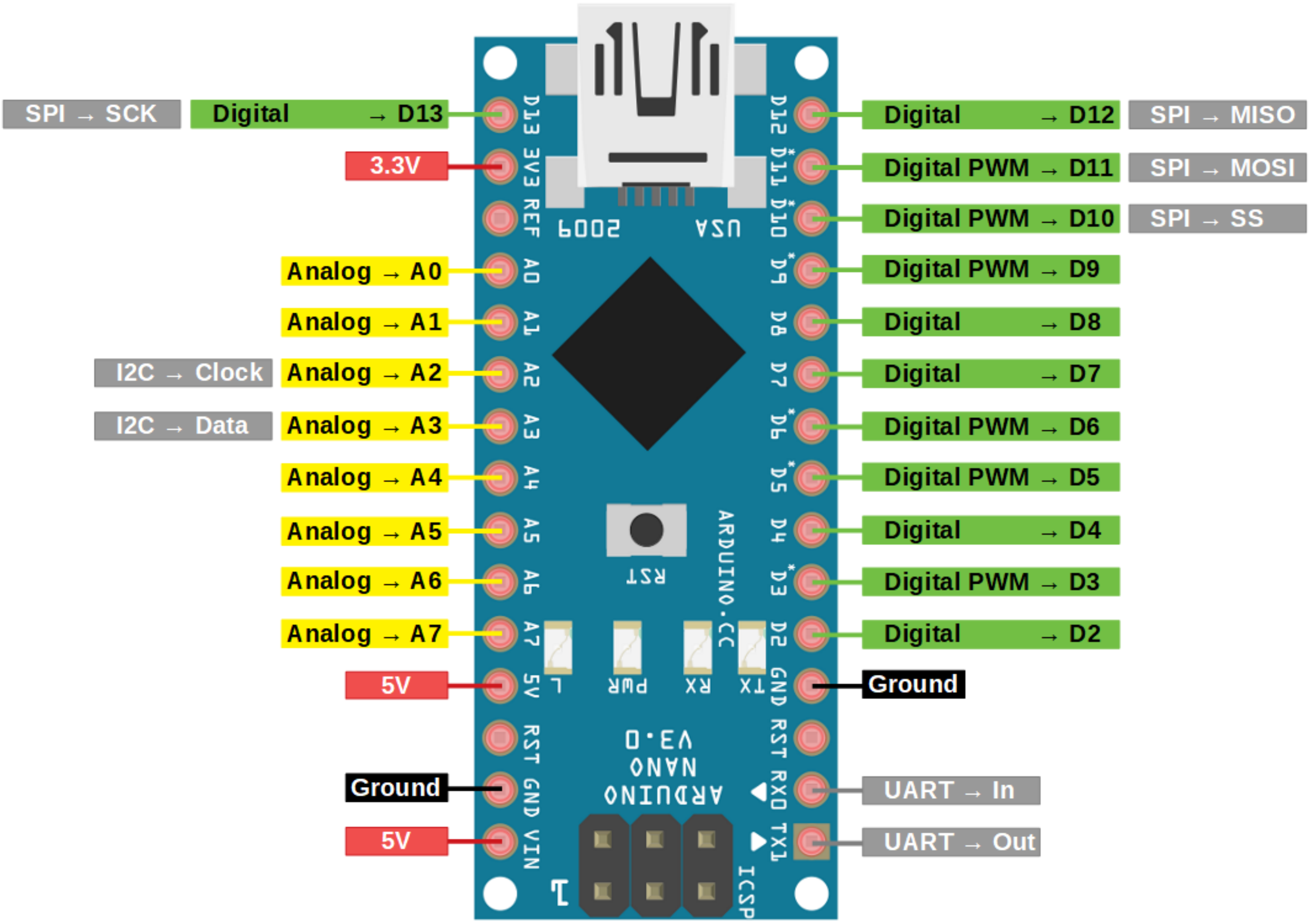


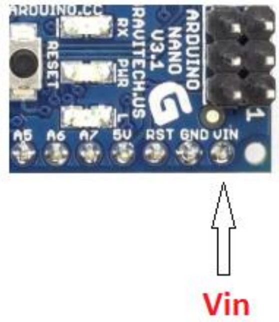
Fig 15

Each pin on the Nano board comes with a specific function associated with it.

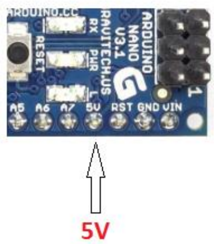
We can see the analog pins that can be used as an analog to digital converter where A4 and A5 pins can also be used for I2C communication. Similarly, there are 14 digital pins, out of which 6 pins are used for generating PWM.

PIN Description

Vin. It is input power supply voltage to the board when using an external power source of 7 to 12 V.



5V. it is a regulated power supply voltage of the board that is used to power the controller and other components placed on the board.

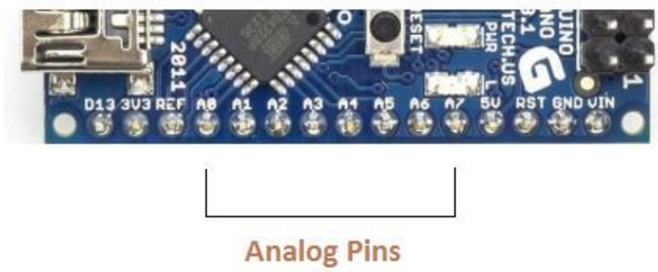


3.3V. this is a minimum voltage generated by the voltage regulator on the board.

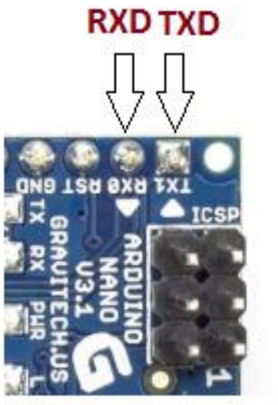
GND. These are the ground pins on the board. There are multiple ground pins on the board that can be interfaced accordingly when more than one ground pin is required.

Reset. Reset pin is added on the board that resets the board. It is very helpful when running program goes too complex and hangs up the board. LOW value to the reset pin will reset the controller.

Analog Pins. There are 8 analog pins on the board marked as A0 – A7. These pins are used to measure the analog voltage ranging between 0 to 5V.



Rx, Tx. These pins are used for serial communication where Tx represents the transmission of data while Rx represents the data receiver.



13. This pin is used to turn on the built-in LED.

AREF. This pin is used as a reference voltage for the input voltage.

PWM. Six pins 3,5,6,9,10, 11 can be used for providing 8-pit PWM (Pulse Width Modulation) output. It is a method used for getting analog results with digital sources.

SPI. Four pins 10(SS),11(MOSI),12(MISO),13(SCK) are used for SPI (Serial Peripheral Interface). SPI is an interface bus and mainly used to transfer data between microcontrollers and other peripherals like sensors, registers, and SD card.

External Interrupts. Pin 2 and 3 are used as external interrupts which are used in case of emergency when we need to stop the main program and call important instructions at that point. The main program resumes once interrupt instruction is called and executed.

I2C. I2C communication is developed using A4 and A5 pins where A4 represents the serial data line (SDA) which carries the data and A5 represents the serial clock line (SCL) which is a clock signal, generated by the master device, used for data synchronization between the devices on an I2C bus.

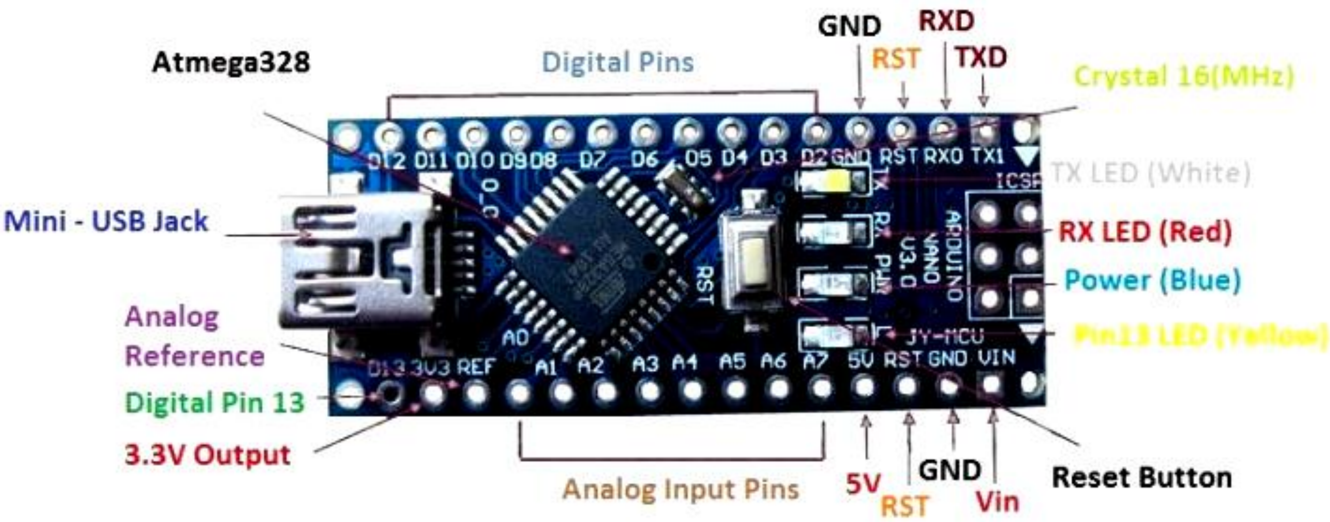


Fig 16

Communication and Programming

The Nano device comes with an ability to set up a communication with other controllers and computers. The serial communication is carried out by the digital pins like pin 0 (Rx) and pin 1 (Tx) where Rx is used for receiving data and Tx is used for the transmission of data. The serial monitor is added on the Arduino Software which is used to transmit textual data to or from the board. FTDI drivers are also included in the software which behaves as a virtual com port to the software.

The Tx and Rx pins come with an LED which blinks as the data is transmitted between FTDI and USB connection to the computer.

Arduino Software Serial Library is used for carrying out a serial communication between the board and the computer.

Apart from serial communication the Nano boards also support I2C and SPI communication. The Wire Library inside the Arduino Software is accessed to use the I2C bus.

The Arduino Nano is programmed by Arduino Software called IDE which is a common software used for almost all types of board available. Simply download the software and select the board you are using. There are two options to program the controller i.e either by the bootloader that is added in the software which sets you free from the use of external burner to compile and burn the program into the controller and another option is by using ICSP (In-circuit serial programming header).

Arduino board software is equally compatible with Windows, Linux or MAC, however, Windows are preferred to use.

5.D. LDR (LIGHT DEPENDENT RESISTOR)

A Light Dependent Resistor (LDR) is also called a photo resistor or a cadmium sulfide (CdS) cell. LDR is a device whose sensitivity depends upon the intensity of light falling on it. It is also called a photoconductor. It is basically a photocell that works on the principle of photoconductivity. The passive component is basically a resistor whose resistance value decreases when the intensity of light decreases. When the strength of the light falling on LDR increases the LDR resistance decreases, while if the strength of the light falls on LDR is decreased resistance increased. In the time of darkness or when there is no light, the resistance of LDR is in the range of mega ohms, while in the presence of light or in brightness in decrease by few hundred ohms.

Testing of LDR- Before mounting any component in the circuit it is a good practice to check whether a component works properly or not so that you can avoid consumption of time in troubleshooting. For testing LDR set the range of millimeter in resistance measurement. After that put the lids on the legs of LDR (as LDR have no polarity so you can connect any lid with leg). Measure the resistance of LDR in the light or brightness, resistance must be low. Now cover LDR properly so that no light beam fall in it, again measure the resistance it must be high. If you got the same result means that LDR is good.

This optoelectronic device is mostly used in light varying sensor circuit, and light and dark activated switching circuits. Some of its applications include camera light meters, street lights.

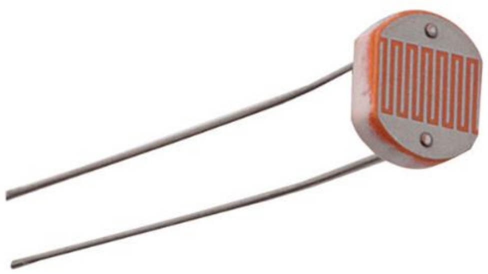


Fig 17

LDR Structure and Working:

The basic structure of an LDR is shown below.

The snake like track shown below is the Cadmium Sulphide (CdS) film which also passes through the sides. On the top and bottom are metal

Fig 18

films which are connected to the terminal leads. It is designed in such a way as to provide maximum possible contact area with the two metal films. The structure is housed in a clear plastic or resin case, to provide free access to external light. As explained above, the main component for the construction of LDR is cadmium sulphide (CdS), which is used as the photoconductor and contains no or very few electrons when not illuminated. In the absence of light it is designed to have a high resistance inthe range of megaohms. As soon as light falls on the sensor, the electrons are liberated and the conductivity of the material increases. When the light intensity exceeds a certain frequency, the photons absorbed by the semiconductor give band electrons the energy required to jump into the conduction band. This causes the free electrons or holes to conduct electricity and thus dropping the resistance dramatically (< 1 Kiloohm).

5.E. LM317 (Positive-Voltage Regulator)

The LM317 device is an adjustable three-terminal positive-voltage regulator capable of supplying more than 1.5 A over an output-voltage range of 1.25 V to 37 V. It requires only two external resistors to set the output voltage. The device features a typical line regulation of 0.01% and typical load regulation of 0.1%. It includes current limiting, thermal overload protection, and safe operating area protection. Overload protection remains functional even if the ADJUST terminal is disconnected.

Features

- Output Voltage Range Adjustable
- From 1.25 V to 37 V
- Output Current Greater Than 1.5 A
- Internal Short-Circuit Current Limiting
- Thermal Overload Protection
- Output Safe-Area Compensation

Pin Configuration and Functions

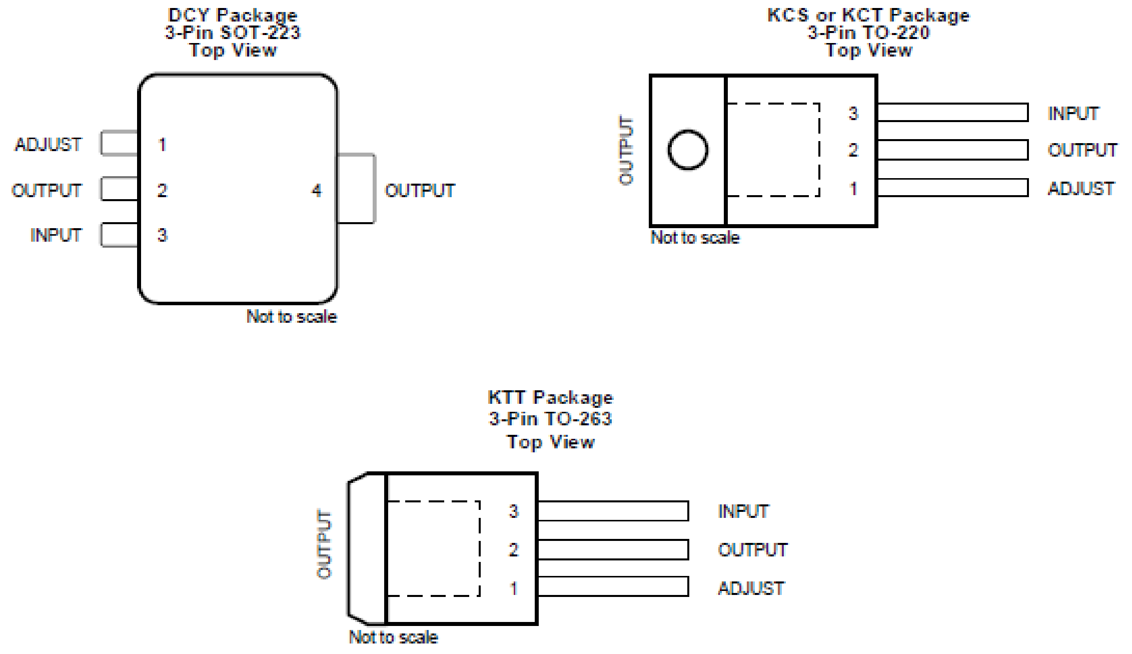


Fig 19

Pin Functions

PIN			I/O	DESCRIPTION
NAME	TO-263, TO-220	SOT-223		
ADJUST	1	1	I	Output voltage adjustment pin. Connect to a resistor divider to set V_O
INPUT	3	3	I	Supply input pin
OUTPUT	2	2, 4	O	Voltage output pin

The flexibility of the LM317 allows it to be configured to take on many different functions in DC power applications.

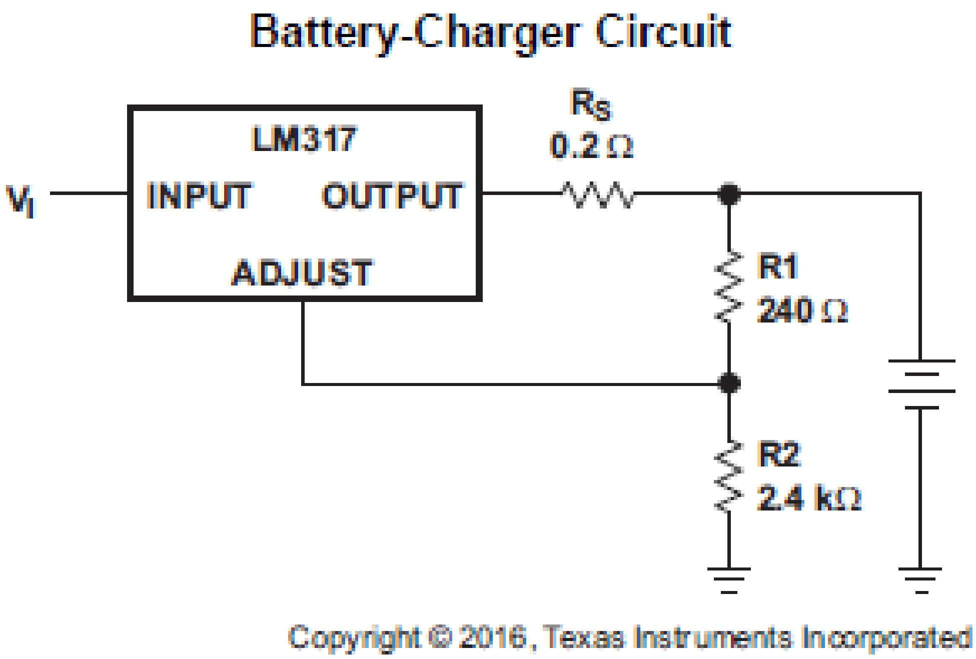


Fig 20

CHAPTER 6

(PROTOTYPE MODELLING)

6. A. TWO LDR THEORY

The figure depicts the notion for the instalment of the light dependent resistors (LDR). A secure state is attained when the light intensities of the two LDR become the same. The principal source of light energy, the Sun, moves from east to west. This movement of the Sun causes the variation in the level of light intensities falling on the two LDRs. The designed algorithm compares the variation in the light intensities inside the microcontroller and the motor then is operated to rotate the solar panel, so it moves aligned with the trail of the light source.

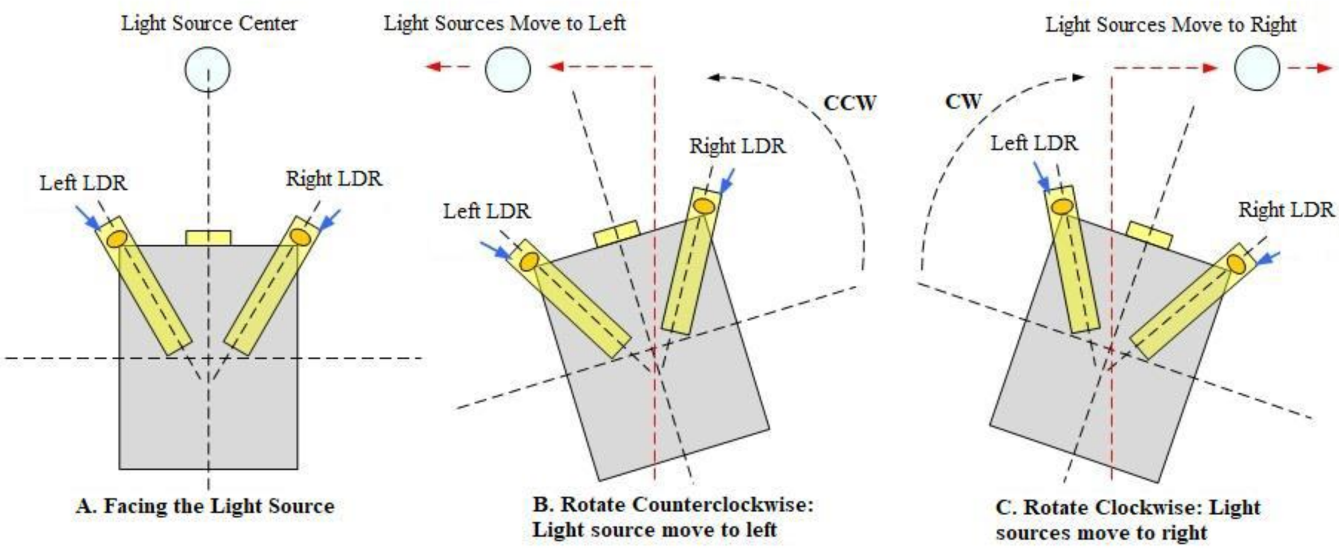


Fig 21

6.B. SOLAR TRACKER:

6.B. i. Circuit Diagram

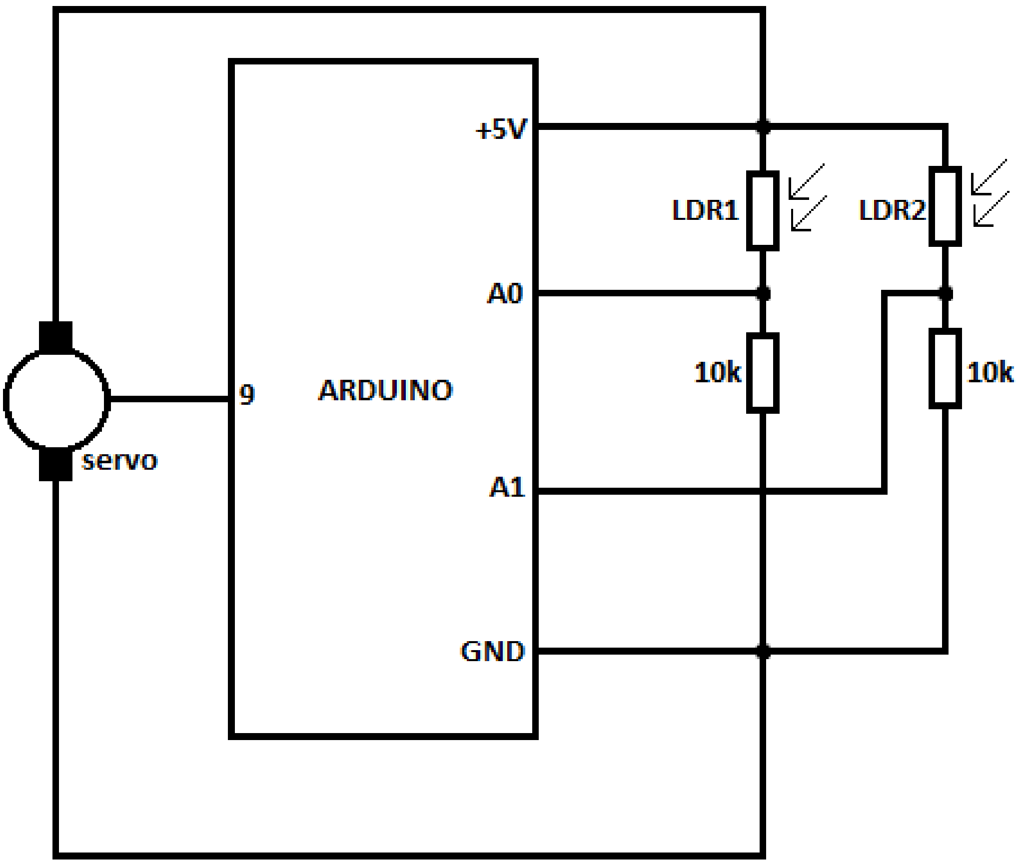


Fig 22 . Solar Tracker Cicuit Diagram

6.B. ii. **Circuit Description**

The two LDR’s are placed at the two sides of solar panel and the Servo is used to rotate the solar panel. The servo will move the solar panel towards the LDR whose resistance will be low, mean towards the LDR on which light is falling, that way it will keep following the light. And if there is same amount of light falling on both the LDR, then servo will not rotate. The servo will try to move the solar panel in the position where both LDR’s will have the same resistance means where same amount of light will fall on both the resistors and if resistance of one of the LDR will change then it rotates towards lower resistance LDR.

The main impulsion is to design a high quality solar tracker. This project is divided into two parts; hardware and software. It consists of three main constituent which are the inputs, controller and the output as shown in Fig B photo resistor or Light-dependent resistor (LDR) or photocell is a light-controlled variable resistor. LDRs or Light Dependent Resistors are very useful especially in light/dark sensor circuits. Normally the resistance of an LDR is very high, sometimes as high as 1000 000 ohms, but when they are illuminated with light resistance drops dramatically. LDR’s have low cost and simple structure. The Servo motor can turn either clockwise or anticlockwise direction depending upon the sequence of the logic signals. The sequence of the logic signals depends on the difference of light intensity of the LDR sensors. The principle of the solar tracking system is done by Light Dependant Resistor (LDR). Two LDR’s are connected to Arduino analog pin AO to A1 that acts as the input for the system. The built-in Analog-to-Digital Converter will convert the analog value of LDR and convert it into digital. The inputs are from analog value of LDR, Arduino as the controller and the Servo motor will be the output. LDR1 and LDR2 are taken as pair .If one of the LDR gets more light intensity than the other, a difference will occur on node voltages sent to the respective Arduino channel to take necessary action. The Servo motor will move the solar panel to the position of the high intensity LDR that was in the programming.

6.B. iii. Block Diagram

In this projects include design and construction of an arduino based solar tracker. This solar tracker system uses the arduino board, a servomotor, 2 LDR and 2 resistors to rotate the solar panel towards the sun or a source of light. In this project LDR was selected since it has no polarity, and easy to interface with circuit, cheap, reliable and is described by high spectral sensitivity, so that difference in high intensity is represented immediately by change in its resistance value. The block diagram of proposed system as shown in figure.

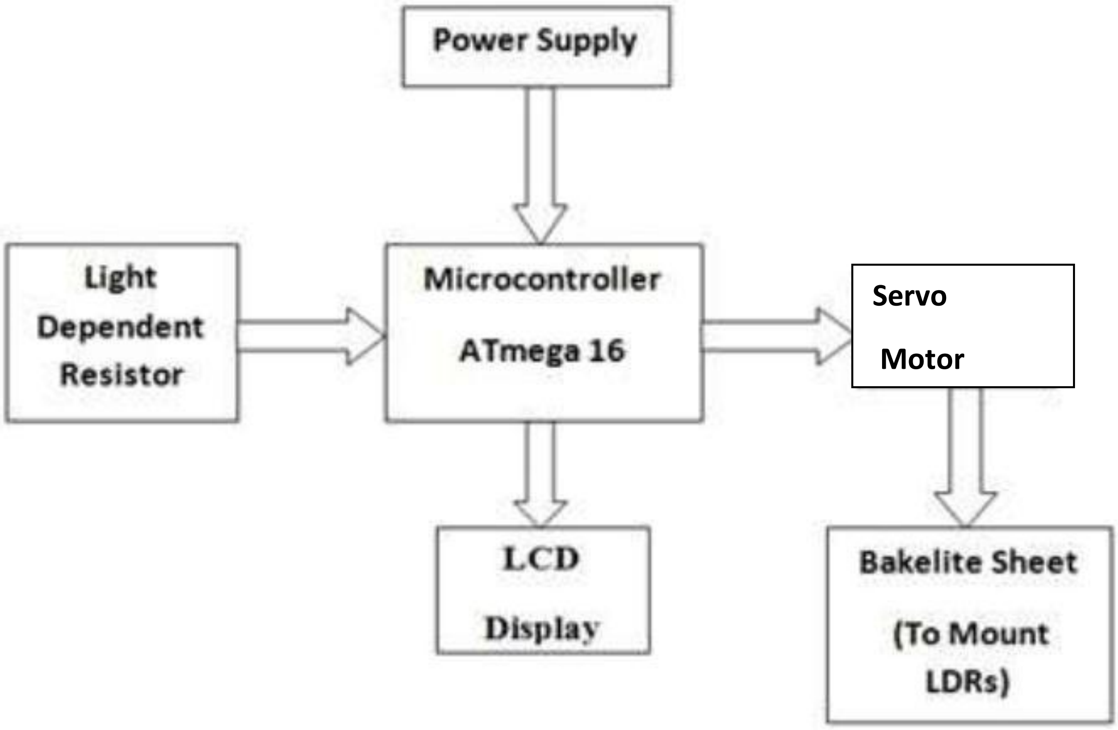


Fig 23 a

Operation

- LDRs are used as the main light sensors. The servo motor is fixed to the structure that holds the solar panel. The program for Arduino is uploaded to the microcontroller. The working of the project is as follows.
- LDRs sense the amount of sunlight falling on them. 2 LDRs are divided into top, bottom..
- For east – west tracking, the analog values from two top LDRs and two bottom LDRs are compared and if the top set of LDRs receive more light, the vertical servo will move in that direction.
- If the bottom LDRs receive more light, the servo moves in that direction.
- If the right set of LDRs receive more light, the servo moves in that direction.

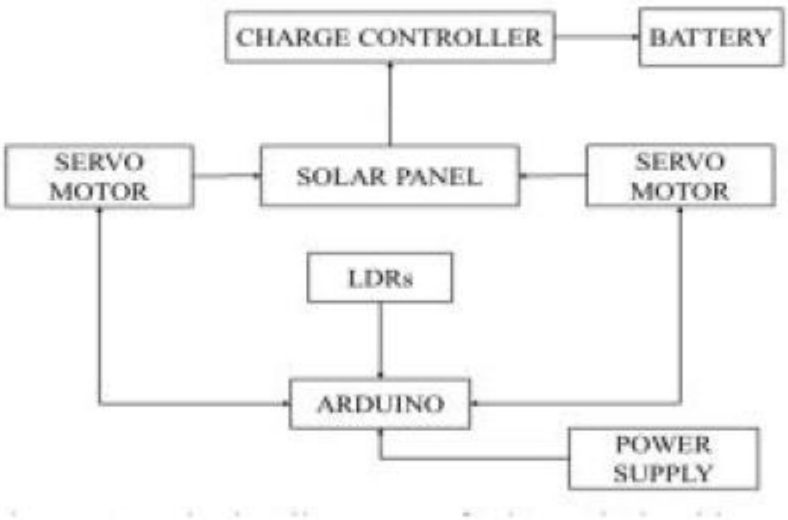


Fig 23 b

6.B. iv. Mechanical Structure

Ideally the stand should be made from aluminum angle as it is strong, durable and suitable for outdoor use but it can also be made from wood, plywood or PVC piping.

The stand is essentially made in two parts, the base and the panel support. They are joined around a pivot point on which the panel support rotates. The servo is mounted onto the base and the arm actuates the panel support.

The panel should protrude from the panel support as little as possible to keep the out of balance load on the servos to a minimum. Ideally, the pivot point should be placed at the Centre of gravity of the panel and panel support together so that the servo has an equal load placed on it no matter which direction the panel is facing although this is not always practically possible.

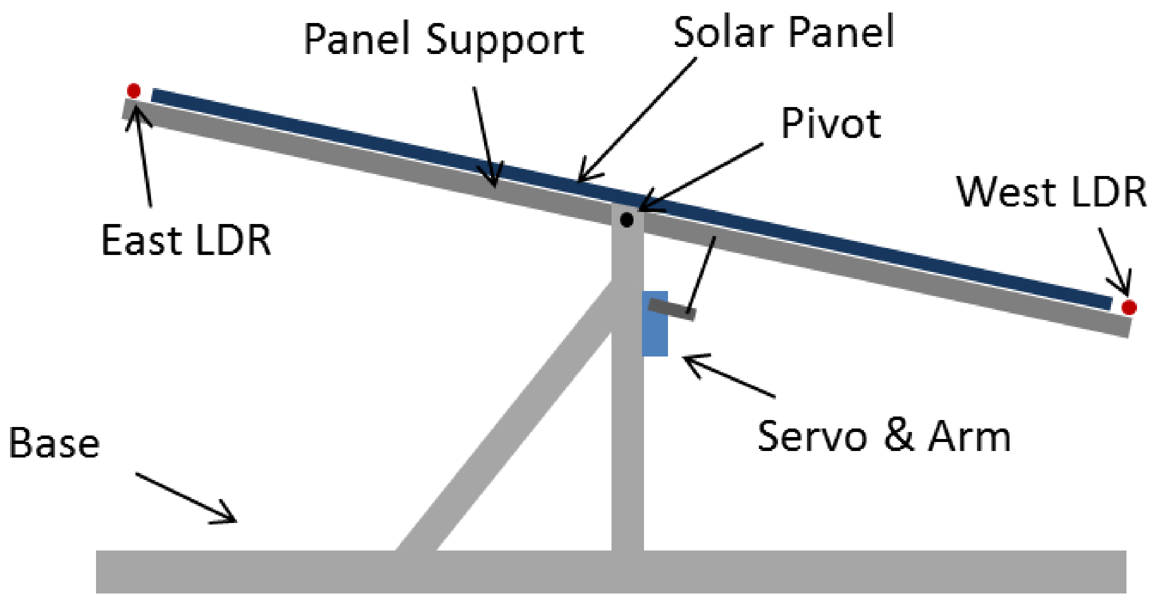


Fig 24

6.C. BATTERY CHARGING CIRCUIT:

6.C.i. Circuit Diagram

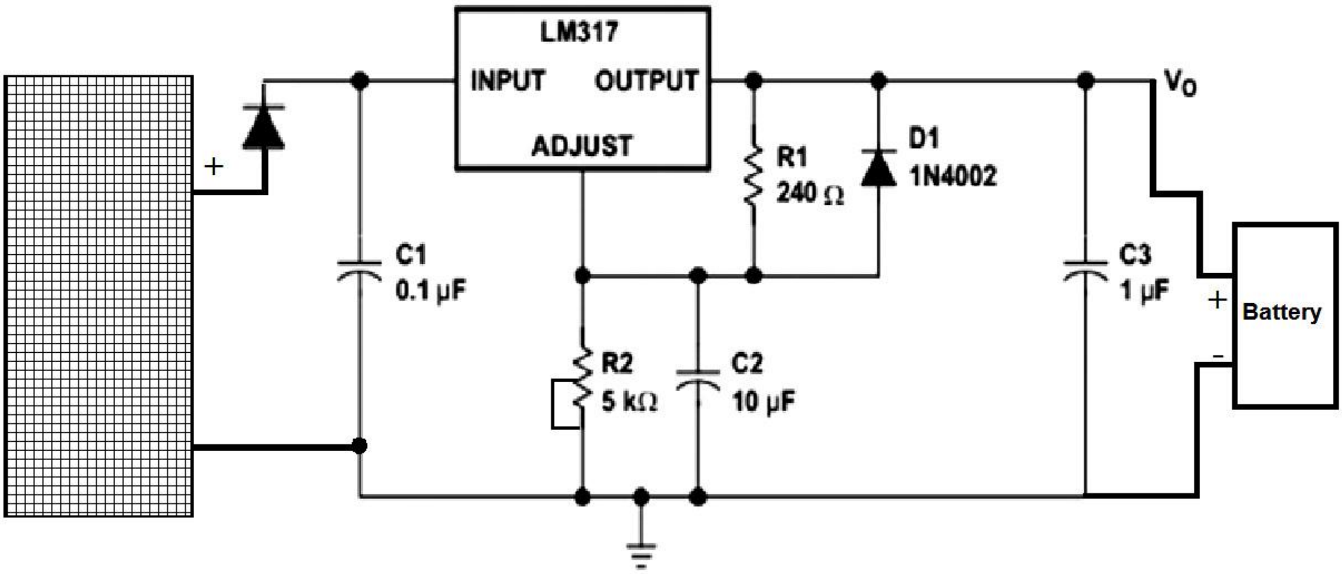


Fig25.Circuit Diagram of the Battery Charging circuit using LM317

6.C.ii. Circuit Description

- This an Automatic Battery Charger Circuit for sealed lead acid batteries. LM317 acts as voltage regulator and current controlling device. Charging current is controlled by R1, and R2 is used to set the charging current.
- As the battery gets charged, the current flowing through the R1 increases. This result in increase in the current and voltage from the LM317.
- When the battery becomes fully charged, charger reduces the charging current to the battery, and the battery is charged in trickle charging mode.
- The input at LM317 should be around 2 volts higher than the output voltage from the LM317.

Components Used in this Project:

- Arduino NANO -1
- Solar panel (6V, 500mA) -1
- Servo Motor (sg90) -1
- LDR X 3 (Light Dependent Resistor)
- 10K resistors - 2
- LM317 - 1
- R3 (1K) – 1
- VR1 (10K) – 1
- LED
- 4V, 1Ah Battery
- Aluminum Plate
- Chasis

CHAPTER 7

(CONCLUSION & FUTURE SCOPE)

7.A. RESULT

Result of this project is, when light falls on the LDR, its resistance varies and a potential divider circuit is used to obtain corresponding voltage value (5v) from the resistance of LDR. The voltage signal is send to the Arduino microcontroller. Established on the voltage signal, a corresponding PWM signal is send to the servo motor which causes it to rotate and to end with attains a position where intensity of light falls on the solar panel is maximum.

7. B. CONCLUSION

An arduino solar tracker was designed and constructed in the current work. LDR light sensors were used to sense the intensity of the solar light occurrence on the photo-voltaic cells panel. Conclusions of this project is summarized as ,The existing tracking system successfully sketched the light source even it is a small torch light, in a dark room, or it is the sun light rays. The Arduino solar tracker with servo motor is employed by means of Ardiuno ATmega328p microcontroller. The essential software is developed via Arduino nano. The cost and reliability of this solar tracker creates it suitable for the rural usage. The purpose of renewable energy from this project offered new and advanced idea to help the people.

Today in the world of rampant productivity, energy is the fundamental source upon which the whole civilization is based upon. As it is said that energy can neither be created nor be destroyed and, in that response, it can be signified that it can somehow be stored. The attempt towards making such goal substantiated, this project has been endeavoured towards unravelling the path of such objectivity. It is quite natural that constant utilisation of energies somehow opens the door of scarcity as per as earthly sources are concerned. Sun, in the stand of which, the tallest source, spiked over for age’s right from the origin of the whole universe, through which life has been conceived, is the basic and the mother source of all the energies. Considering the very fundamental from the viewpoint of storing such energy, the project has been unravelled. Energies other than from the Sun, are the process from which such are been produced through the burning of various materials, involving emission of a large amount of pollution, causing the environment and the atmosphere sick day by day. Fastness and smartness of the world’s current behavioural visibility, where easy access of every sphere of life is in need of the acute comfortability, every day is a new challenge of hatching something new and unique which makes an energy to be the ultimatum source behind all the hard work exists. In that regards it would be worthier to reveal that commercialisation has boomed its wings to such an extent in the need of money and power that we are somehow present in the pool of acute ignorance of the world's resources scarcity, in consequence of which the whole world is wounded. Healing the world is the basis cultivation with which the hour clock is calling and this project presents the eye, therefore, to open the corridors of reducing the amount of pollution in storing of energy culled out from the Sun and also to make the pace of advancement revved around.

Solar trackers generate more electricity than their stationary counterparts due to an increased direct exposure to solar rays.There are many different kinds of solar tracker, such as single-axis and dual-axis trackers, which can help us find the perfect fit for our unique jobsite. Installation size, local weather, degree of latitude, and electrical requirements are all important considerations that can influence the type of solar tracker that's best for us.Solar trackers generate more electricity in roughly the same amount of space needed for fixed tilt systems, making them ideal optimizing land usage.Solar trackers are slightly more expensive than their stationary counterparts, due to the more complex technology and moving parts necessary for their operation.

Some ongoing maintenance is generally required, though the quality of the solar tracker can play a role in how much and how often this maintenance is needed.

7.C. FUTURE SCOPE

The very embodiment through which the futuristic conundrum be set aside, is the project called “Single Axis Solar Tracking and Charging System”. A trailblazer by its spirit, this system works in its utmost efficiency, whether that be in terms of its pecuniary ability or in terms of its accessibility. In the smoke of the darkness where pollution engulfing every spheres of advancement as an outcome of producibility, this device in its very efficiency work towards only advancement and development by flushing out the pollution at large.

CHAPTER 8
(References)

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[3] M. A. Panait, T. Tudorache: A Simple Neural Network Solar Tracker for Optimizing Conversion Efficiency in Off-Grid Solar Generators, ICREPQ 2008, Spain

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[5] A. M. Morega, A. Bejan: A Constructal Approach to the Optimal Design of Photovoltaic Cells, Int. Journal of Green Energy, pp. 233-242, 2005

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[8] P. A. Basore: Manufacturing a New Polycrystalline Silicon PV Technology, Conference Record of the 2006 IEEE 4th World Conference on Photovoltaic Energy Conversion, pp. 2089-2093, 2006

[9] P. Turmezei: Chalcogenide Materials for Solar Energy Conversion, Acta Polytechnica Hungarica, Vol. 1, No. 2, pp. 13-16, 2004

[10] Technosoft: IBL2403 Intelligent Drive User Manual

APPENDIX A

(SOFTWARE CODING)

Arduino Code

```
#include <Servo.h>

Servo myservo;

int pos = 0;  // Variable to store the servo
position.

int inputPhotoLeft = 1; // Easier to read, instead of
just 1 or 0.

int inputPhotoRight = 0;

int Left = 0; // Store readings from the
photoresistors.

int Right = 0; // Store readings from the
photoresistors.

void setup()

{

myservo.attach(9); // Attach servo to pin 9.

}

void loop()

{

// Reads the values from the photoresistors to the
Left and Right variables.

Left = analogRead(inputPhotoLeft);

Right = analogRead(inputPhotoRight);

// Checks if right is greater than left, if so move
to right.

if (Left > (Right +20))

// +20 is the deadzone, so it wont jiggle back and
forth.

{

if (pos < 179)
```

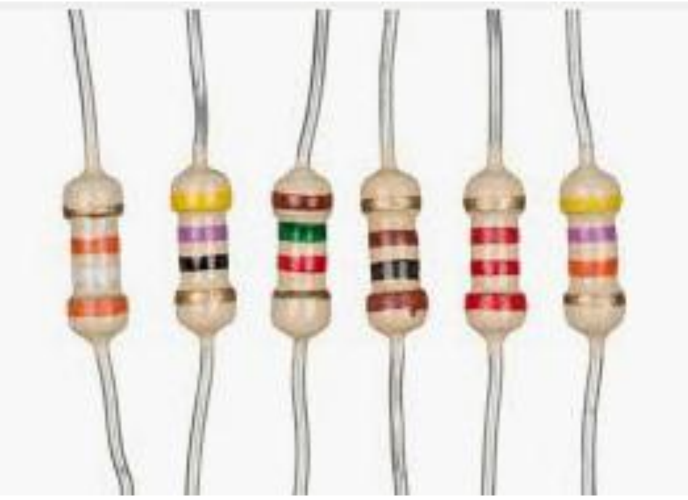
```
pos++;

myservo.write(pos);

}

// Checks if left is greater than rigt, if so move to
left.

if (Right > (Left +20))

// +20 is the deadzone, so it wont jiggle back and
forth.

{

if (pos > 1)

pos -= 1;

myservo.write(pos);

}

// Added some delay, increase or decrease if you want
less or more speed.

delay(10);

}
```

APPENDIX B

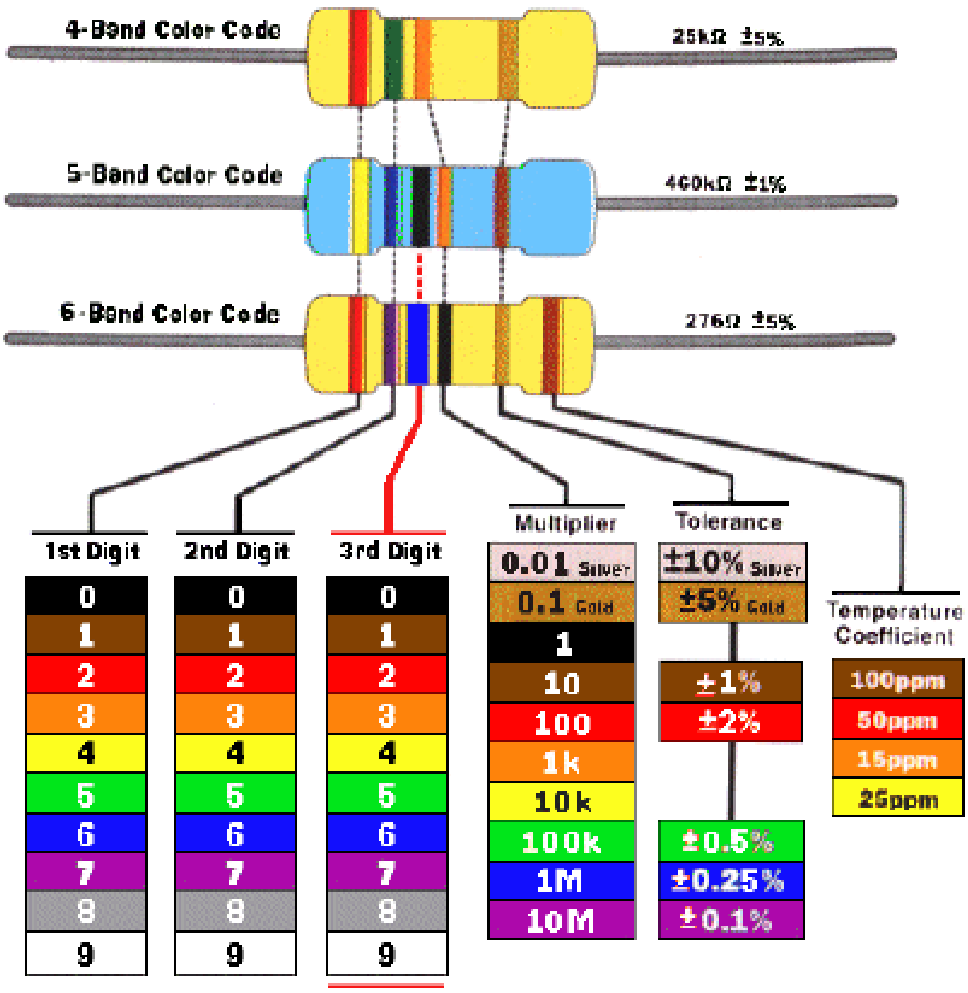
(HARDWARE DESCRIPTION)

1. **RESISTOR**

Resistance is the opposition of a material to the current. It is measured in Ohms Ω. All conductors represent a certain amount of resistance, since no conductor is 100% efficient. To control the electron flow (current) in a predictable manner, we use resistors. Electronic circuits use calibrated lumped resistance to control the flow of current. Broadly speaking, resistor can be divided into two groups viz. fixed & adjustable (variable) resistors. In fixed resistors, the value is fixed & cannot be varied. In variable resistors, the resistance value can be varied by an adjuster knob. It can be divided into (a) Carbon composition (b) Wire wound (c) Special type. The most common type of resistors used in our projects is carbon type. The resistance value is normally indicated by color bands. Each resistance has four colors, one of the band on either side will be gold or silver, this is called fourth band and indicates the tolerance, others three band will give the value of resistance (see table). For example if a resistor has the following marking on it say red, violet, gold. Comparing these colored rings with the color code, its value is 27000 ohms or 27 kilo ohms and its tolerance is ±5%. Resistor comes in various sizes (Power rating).The bigger the size, the more power rating of 1/4 watts. The four color rings on its body tells us the value of resistor value.



Color Code of the resistor



2. 4V,1Ah, RECHARGEABLE BATTERY

- **Lead Acid Battery**

- **Technical Specifications:**
  Strong ABS body – *NOT TO BE DROPPED.*
-
  DC 4.0 Volts,
- Lead Acid Sealed
- Maintenance Free Battery.

- Dimensions: 30(L) x 22(W) x 64.5(H)mm, +3mm terminal.

  Used in Toys, Games, Electronic Devices, Emergency Lights, Solar Lanterns, Camping, Trekking, Picnics and others.

- Batteries can be stored for more than 6 months at 25′ C (Charge before storing),

- Self discharge rate is less than 5% per month at 25′ C.

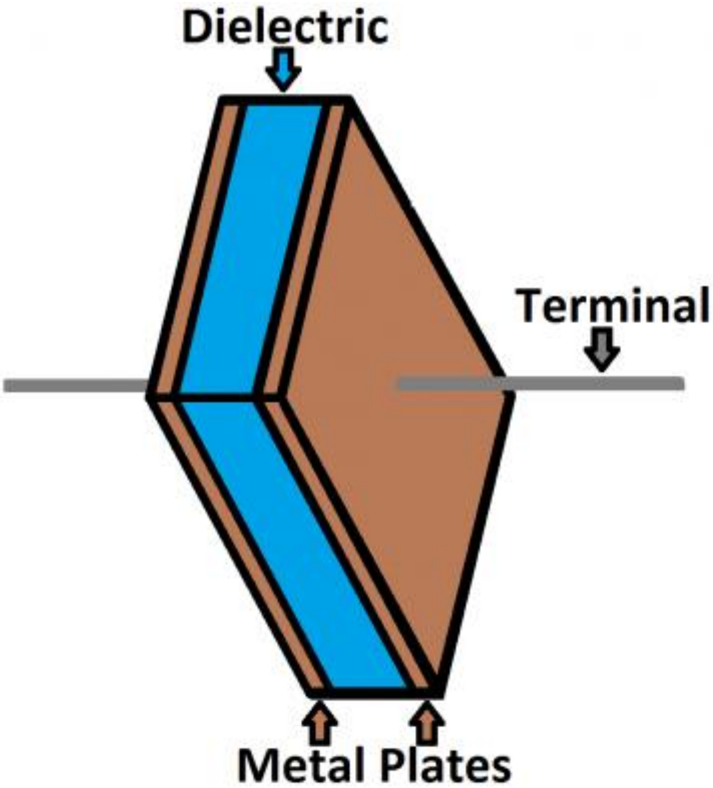
- This is a solder terminal type battery as shown in the image, these terminals are suitable for direct soldering.

3. CAPACITORS

A capacitor is a two-terminal, electrical component. Along with resistors and inductors, they are one of the most fundamental **passive** components we use. You would have to look very hard to find a circuit which *didn't* have a capacitor in it.

What makes capacitors special is their ability to **store energy**; they're like a fully charged electric battery. *Caps*, as we usually refer to them, have all sorts of critical applications in circuits. Common applications include local energy storage, voltage spike suppression, and complex signal filtering.

The schematic symbol for a capacitor actually closely resembles how it's made. A capacitor is created out of two metal plates and an insulating material called a **dielectric**. The metal plates are placed very close to each other, in parallel, but the dielectric sits between them to make sure they don't touch.



The dielectric can be made out of all sorts of insulating materials: project, glass, rubber, ceramic, plastic, or anything that will impede the flow of current.

The plates are made of a conductive material: aluminum, tantalum, silver, or other metals. They're each connected to a terminal wire, which is what eventually connects to the rest of the circuit.

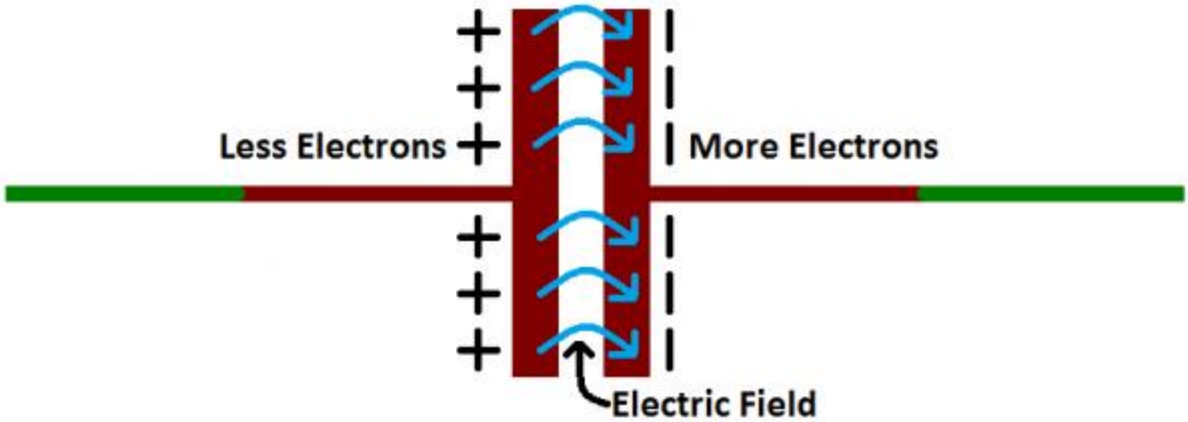
The capacitance of a capacitor -- how many farads it has -- depends on how it's constructed. More capacitance requires a larger capacitor. Plates with more overlapping surface area provide more capacitance, while more distance between the plates means less capacitance. The material of the dielectric even has an effect on how many farads a cap has. The total capacitance of a capacitor can be calculated with the equation:

$$C = \varepsilon_r \frac{A}{4\pi d}$$

Where ε_r is the dielectric's relative permittivity (a constant value determined by the dielectric material), *A* is the amount of area the plates overlap each other, and *d* is the distance between the plates.

How a Capacitor Works

Electric current is the flow of electric charge, which is what electrical components harness to light up, or spin, or do whatever they do. When current flows into a capacitor, the charges get "stuck" on the plates because they can't get past the insulating dielectric. Electrons -- negatively charged particles -- are sucked into one of the plates, and it becomes overall negatively charged. The large mass of negative charges on one plate pushes away like charges on the other plate, making it positively charged.



The positive and negative charges on each of these plates attract each other, because that's what opposite charges do. But, with the dielectric sitting between them, as much as they want to come together, the charges will forever be stuck on the plate (until they have somewhere else to go). The stationary charges on these plates create an electric field, which influence electric potential energy and voltage. When charges group together on a capacitor like this, the cap is storing electric energy just as a battery might store chemical energy.

Charging and Discharging

When positive and negative charges coalesce on the capacitor plates, the capacitor becomes **charged**. A capacitor can retain its electric field -- hold its charge -- because the positive and negative charges on each of the plates attract each other but never reach each other.

At some point the capacitor plates will be so full of charges that they just can't accept any more. There are enough negative charges on one plate that they can repel any others that try to join. This is where the **capacitance** (farads) of a capacitor comes into play, which tells you the maximum amount of charge the cap can store.

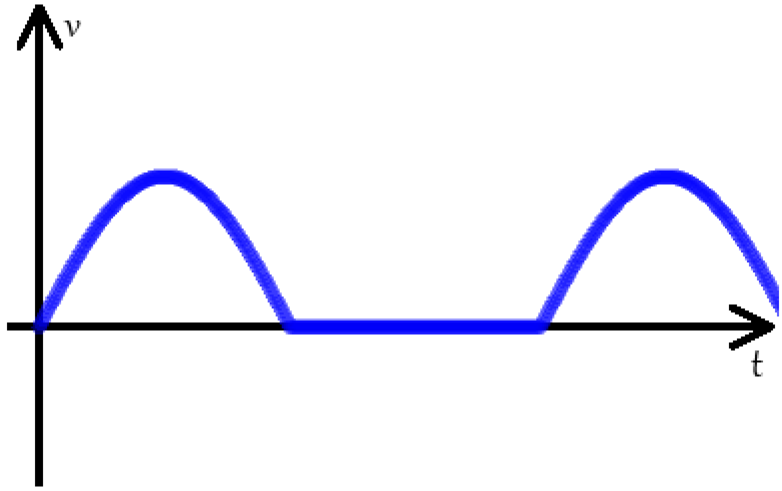
If a path in the circuit is created, which allows the charges to find another path to each other, they'll leave the capacitor, and it will **discharge**.

For example, in the circuit below, a battery can be used to induce an electric potential across the capacitor. This will cause equal but opposite charges to build up on each of the plates, until they're so full they repel any more current from flowing. An LED placed in series with the cap could provide a path for the current, and the energy stored in the capacitor could be used to briefly illuminate the LED.

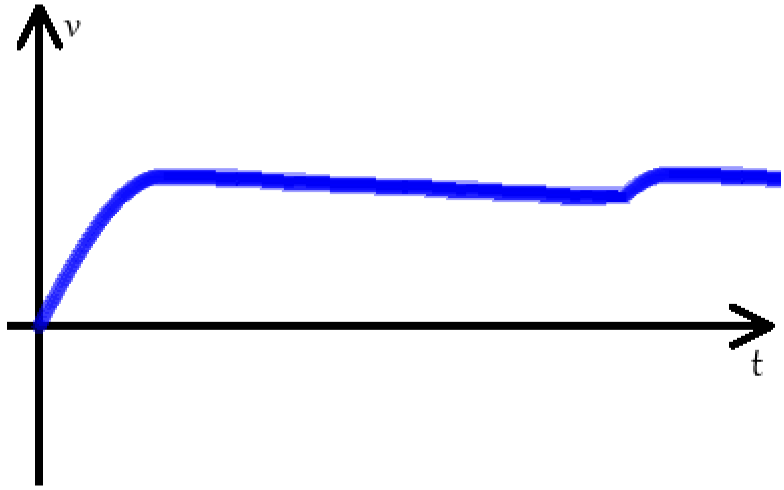
Power Supply Filtering

Diode rectifiers can be used to turn the AC voltage coming out of your wall into the DC voltage required by most electronics. But diodes alone can't turn an AC signal into a clean DC signal, they need the help of capacitors.

*By adding a **parallel capacitor** to a bridge rectifier, a rectified signal like this:*



Can be turned into a near-level DC signal like this:



Capacitors are stubborn components, they'll always try to resist sudden changes in voltage. The filter capacitor will charge up as the rectified voltage increases. When the rectified voltage coming into the cap starts its rapid decline, the capacitor will access its bank of stored energy, and it'll discharge very slowly, supplying energy to the load. The capacitor shouldn't fully discharge before the input rectified signal starts to increase again, recharging the cap. This dance plays out many times a second, over-and-over as long as the power supply is in use.

APPENDIX C

(DATA SHEETS)

LM317 3-Terminal Adjustable Regulator

1 Features

- Output Voltage Range Adjustable From 1.25 V to 37 V
- Output Current Greater Than 1.5 A
- Internal Short-Circuit Current Limiting
- Thermal Overload Protection
- Output Safe-Area Compensation

2 Applications

- ATCA Solutions
- DLP: 3D Biometrics, Hyperspectral Imaging, Optical Networking, and Spectroscopy
- DVR and DVS
- Desktop PC
- Digital Signage and Still Camera
- ECG Electrocardiogram
- EV HEV Charger: Level 1, 2, and 3
- Electronic Shelf Label
- Energy Harvesting
- Ethernet Switch
- Femto Base Station
- Fingerprint and Iris Biometrics
- HVAC: Heating, Ventilating, and Air Conditioning
- High-Speed Data Acquisition and Generation
- Hydraulic Valve
- IP Phone: Wired and Wireless
- Intelligent Occupancy Sensing
- Motor Control: Brushed DC, Brushless DC, Low-Voltage, Permanent Magnet, and Stepper Motor
- Point-to-Point Microwave Backhaul
- Power Bank Solutions
- Power Line Communication Modem
- Power Over Ethernet (PoE)
- Power Quality Meter
- Power Substation Control
- Private Branch Exchange (PBX)
- Programmable Logic Controller
- RFID Reader
- Refrigerator
- Signal or Waveform Generator
- Software Defined Radio (SDR)
- Washing Machine: High-End and Low-End
- X-ray: Baggage Scanner, Medical, and Dental

3 Description

The LM317 device is an adjustable three-terminal positive-voltage regulator capable of supplying more than 1.5 A over an output-voltage range of 1.25 V to 37 V. It requires only two external resistors to set the output voltage. The device features a typical line regulation of 0.01% and typical load regulation of 0.1%. It includes current limiting, thermal overload protection, and safe operating area protection. Overload protection remains functional even if the ADJUST terminal is disconnected.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM317DCY	SOT-223 (4)	6.50 mm × 3.50 mm
LM317KCS	TO-220 (3)	10.16 mm × 9.15 mm
LM317KCT	TO-220 (3)	10.16 mm × 8.59 mm
LM317KTT	TO-263 (3)	10.16 mm × 9.01 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Battery-Charger Circuit

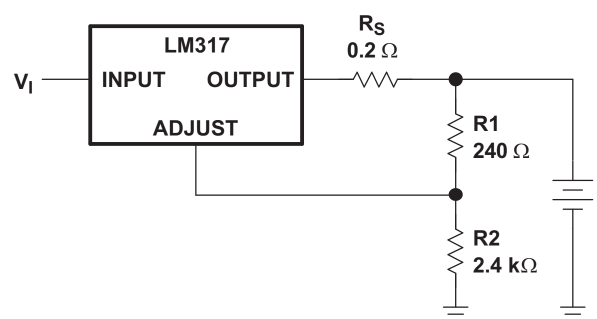


Table of Contents

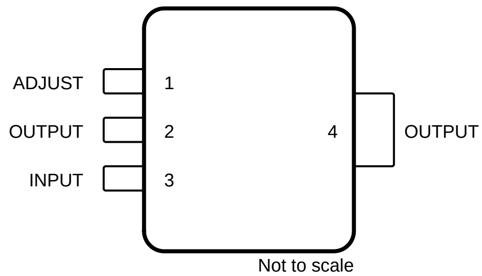
4 Revision History

Changes from Revision W (January 2015) to Revision X	Page
• Changed body size dimensions for KCS TO-220 Package on *Device information* table	1
• Changed body size dimensions for KTT TO-263 Package on *Device information* table	1
• Changed V_O Output Voltage max value from 7 to 37 on *Recommended Operating Conditions* table	4
• Added min value to I_O Output Current in *Recommended Operating Conditions* table	4
• Changed values in the Thermal Information table to align with JEDEC standards	4
• Added KCT package data to *Thermal Information* table	4
• Deleted Section 9.3.6 "Adjusting Multiple On-Card Regulators with a Single Control"	13
• Updated Adjustsable 4-A Regulator Circuit graphic	16
• Added *Receiving Notification of Documentation Updates* section and *Community Resources* section	19

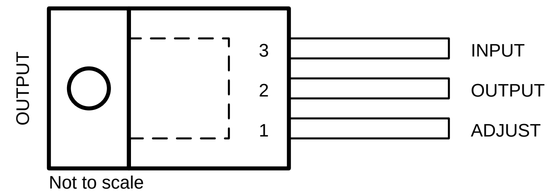
Changes from Revision V (February 2013) to Revision W	Page
• Added *Applications*, *Device Information* table, *Pin Functions* table, *ESD Ratings* table, *Thermal Information* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section.	1
• Deleted *Ordering Information* table.	1

5 Pin Configuration and Functions

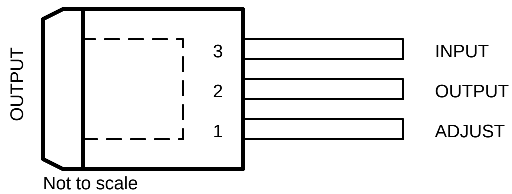
DCY Package
3-Pin SOT-223
Top View



KCS or KCT Package
3-Pin TO-220
Top View



KTT Package
3-Pin TO-263
Top View



Pin Functions

PIN			I/O	DESCRIPTION
NAME	TO-263, TO-220	SOT-223		
ADJUST	1	1	I	Output voltage adjustment pin. Connect to a resistor divider to set V_O
INPUT	3	3	I	Supply input pin
OUTPUT	2	2, 4	O	Voltage output pin

6 Specifications

6.1 Absolute Maximum Ratings

over virtual junction temperature range (unless otherwise noted)[1]

		MIN	MAX	UNIT
$V_I - V_O$	Input-to-output differential voltage		40	V
T_J	Operating virtual junction temperature		150	°C
	Lead temperature 1,6 mm (1/16 in) from case for 10 s		260	°C
T_{stg}	Storage temperature	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

			MAX	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	2500	V
		Charged device model (CDM), per JEDEC specification JESD22-C101[2]	1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

		MIN	MAX	UNIT
V_O	Output voltage	1.25	37	V
$V_I - V_O$	Input-to-output differential voltage	3	40	V
I_O	Output current	0.01	1.5	A
T_J	Operating virtual junction temperature	0	125	°C

6.4 Thermal Information

THERMAL METRIC[1]		LM317				UNIT
		DCY (SOT-223)	KCS (TO-220)	KCT (TO-220)	KTT (TO-263)	
		4 PINS	3 PINS	3 PINS	3 PINS	
$R_{\theta(JA)}$	Junction-to-ambient thermal resistance	66.8	23.5	37.9	38.0	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	43.2	15.9	51.1	36.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	16.9	7.9	23.2	18.9	°C/W
ψ_{JT}	Junction-to-top characterization parameter	3.6	3.0	13.0	6.9	°C/W
ψ_{JB}	Junction-to-board characterization parameter	16.8	7.8	22.8	17.9	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	NA	0.1	4.2	1.1	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

6.5 Electrical Characteristics

over recommended ranges of operating virtual junction temperature (unless otherwise noted)

PARAMETER	TEST CONDITIONS(1)	MIN	TYP	MAX	UNIT
Line regulation(2)	$V_I - V_O$ = 3 V to 40 V, T_J = 25°C		0.01	0.04	%/V
	$V_I - V_O$ = 3 V to 40 V, T_J = 0°C to 125°C		0.02	0.07	%/V
Load regulation	I_O = 10 mA to 1500 mA, C_{ADJ}(3) = 10 μF, T_J = 25°C, $V_O \le 5$ V			25	mV
	I_O = 10 mA to 1500 mA, C_{ADJ}(3) = 10 μF, T_J = 25°C, $V_O \ge 5$ V		0.1	0.5	$\%V_O$
	I_O = 10 mA to 1500 mA, T_J = 0°C to 125°C, $V_O \le 5$ V		20	70	mV
	I_O = 10 mA to 1500 mA, T_J = 0°C to 125°C, $V_O \ge 5$ V		0.3	1.5	$\%V_O$
Thermal regulation	20-ms pulse, T_J = 25°C		0.03	0.07	$\%V_O$/W
ADJUST terminal current			50	100	μA
Change in ADJUST terminal current	$V_I - V_O$ = 2.5 V to 40 V, $P_D \le$ 20 W, I_O = 10 mA to 1500 mA		0.2	5	μA
Reference voltage	$V_I - V_O$ = 3 V to 40 V, $P_D \le$ 20 W, I_O = 10 mA to 1500 mA	1.2	1.25	1.3	V
Output-voltage temperature stability	T_J = 0°C to 125°C		0.7		$\%V_O$
Minimum load current to maintain regulation	$V_I - V_O$ = 40 V		3.5	10	mA
Maximum output current	$V_I - V_O \le$ 15 V, $P_D < P_{MAX}$(4)	1.5	2.2		A
	$V_I - V_O \le$ 40 V, $P_D < P_{MAX}$(4), T_J = 25°C	0.15	0.4		A
RMS output noise voltage (% of V_O)	f = 10 Hz to 10 kHz, T_J = 25°C		0.003		$\%V_O$
Ripple rejection	V_O = 10 V, f = 120 Hz, C_{ADJ} = 0 μF(3)		57		dB
	V_O = 10 V, f = 120 Hz, C_{ADJ} = 10 μF(3)	62	64		dB
Long-term stability	T_J = 25°C		0.3	1	%/1k hr

(1) Unless otherwise noted, the following test conditions apply: $|V_I - V_O|$ = 5 V and I_{OMAX} = 1.5 A, T_J = 0°C to 125°C. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible.
(2) Line regulation is expressed here as the percentage change in output voltage per 1-V change at the input.
(3) C_{ADJ} is connected between the ADJUST terminal and GND.
(4) Maximum power dissipation is a function of T_J(max), θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) - T_A) / \theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.

6.6 Typical Characteristics

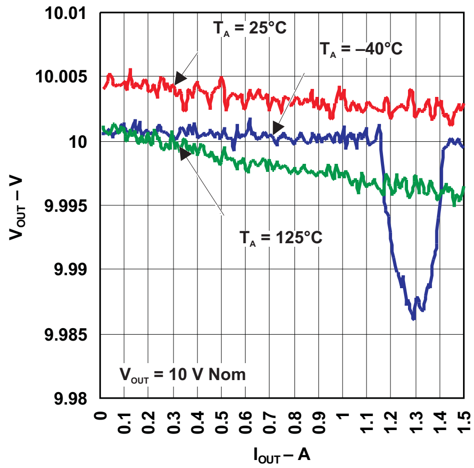


Figure 1. Load Regulation

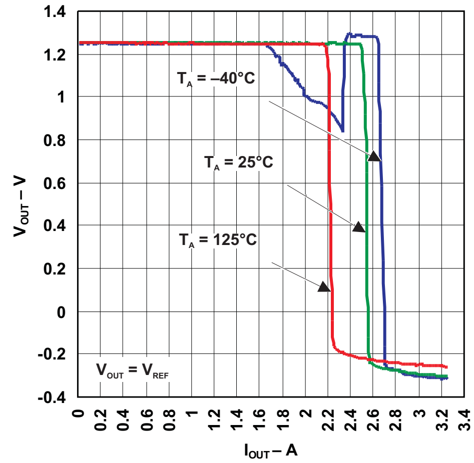


Figure 2. Load Regulation

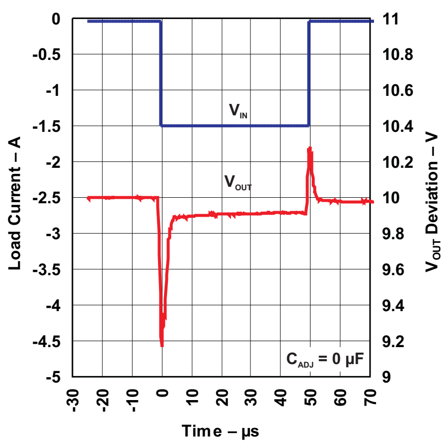


Figure 3. Load Transient Response

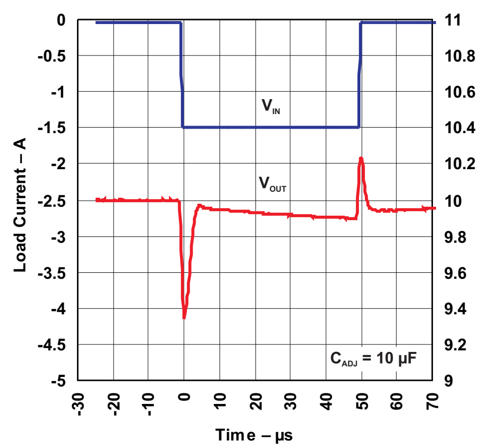


Figure 4. Load Transient Response

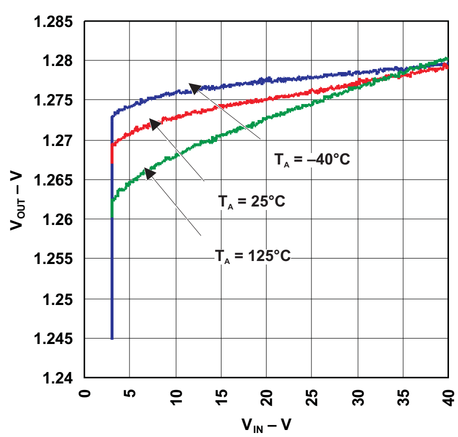


Figure 5. Line Regulation

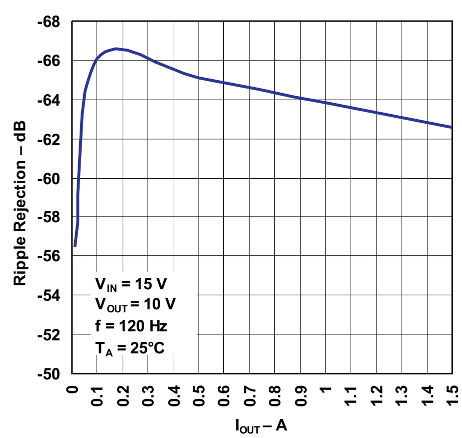


Figure 6. Ripple Rejection vs Output Current

Typical Characteristics (continued)

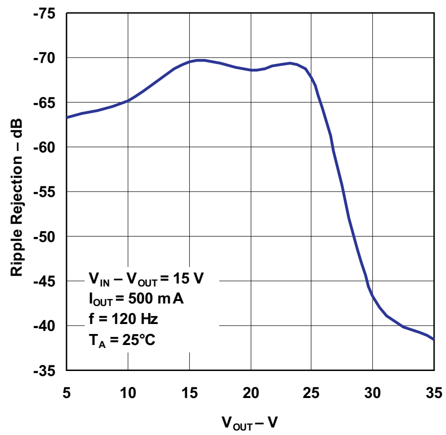


Figure 7. Ripple Rejection vs Output Voltage

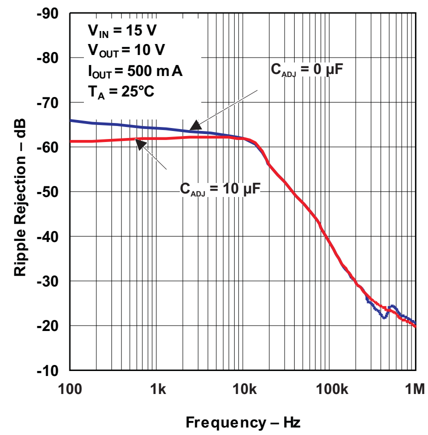


Figure 8. Ripple Rejection vs Frequency

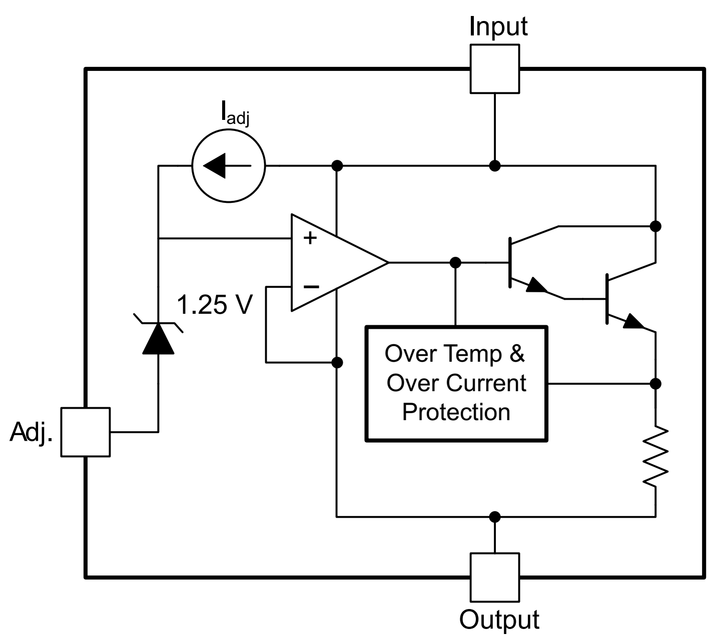
7 Detailed Description

7.1 Overview

The LM317 device is an adjustable three-terminal positive-voltage regulator capable of supplying up to 1.5 A over an output-voltage range of 1.25 V to 37 V. It requires only two external resistors to set the output voltage. The device features a typical line regulation of 0.01% and typical load regulation of 0.1%. It includes current limiting, thermal overload protection, and safe operating area protection. Overload protection remains functional even if the ADJUST terminal is disconnected.

The LM317 device is versatile in its applications, including uses in programmable output regulation and local on-card regulation. Or, by connecting a fixed resistor between the ADJUST and OUTPUT terminals, the LM317 device can function as a precision current regulator. An optional output capacitor can be added to improve transient response. The ADJUST terminal can be bypassed to achieve very high ripple-rejection ratios, which are difficult to achieve with standard three-terminal regulators.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 NPN Darlington Output Drive

NPN Darlington output topology provides naturally low output impedance and an output capacitor is optional. 3-V headroom is recommended ($V_I – V_O$) to support maximum current and lowest temperature.

7.3.2 Overload Block

Over-current and over-temperature shutdown protects the device against overload or damage from operating in excessive heat.

7.3.3 Programmable Feedback

Op amp with 1.25-V offset input at the ADJUST terminal provides easy output voltage or current (not both) programming. For current regulation applications, a single resistor whose resistance value is 1.25 V/I_O and power rating is greater than $(1.25\ V)^2/R$ should be used. For voltage regulation applications, two resistors set the output voltage.

7.4 Device Functional Modes

7.4.1 Normal Operation

The device OUTPUT pin will source current necessary to make OUTPUT pin 1.25 V greater than ADJUST terminal to provide output regulation.

7.4.2 Operation With Low Input Voltage

The device requires up to 3-V headroom (V_I – V_O) to operate in regulation. The device may drop out and OUTPUT voltage will be INPUT voltage minus drop out voltage with less headroom.

7.4.3 Operation at Light Loads

The device passes its bias current to the OUTPUT pin. The load or feedback must consume this minimum current for regulation or the output may be too high. See the *Electrical Characteristics* table for the minimum load current needed to maintain regulation.

7.4.4 Operation In Self Protection

When an overload occurs the device shuts down Darlington NPN output stage or reduces the output current to prevent device damage. The device will automatically reset from the overload. The output may be reduced or alternate between on and off until the overload is removed.

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The flexibility of the LM317 allows it to be configured to take on many different functions in DC power applications.

8.2 Typical Application

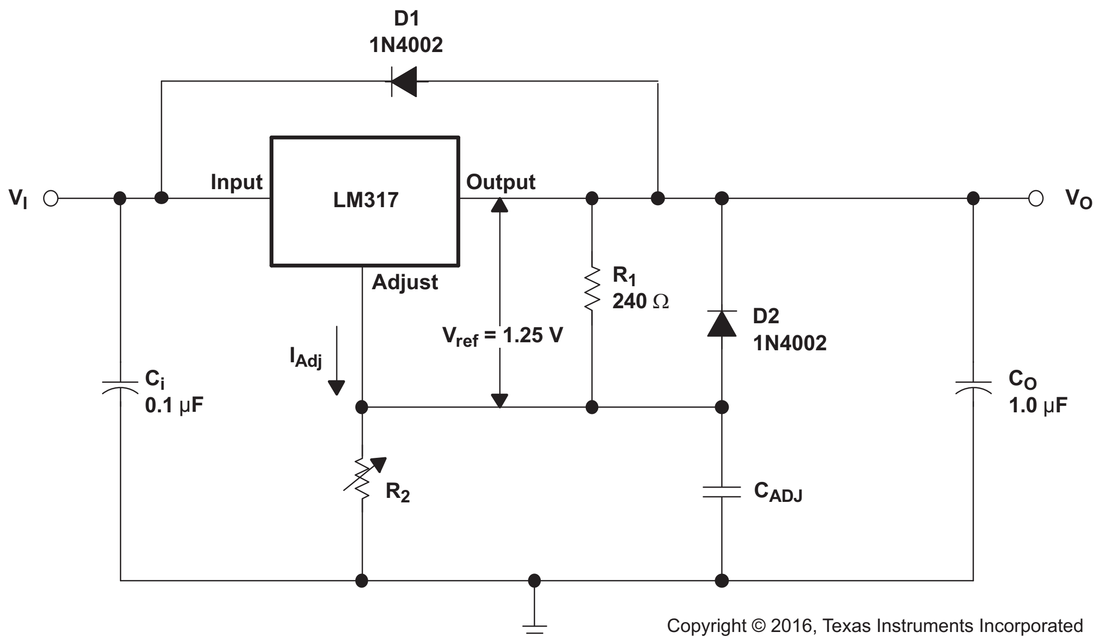


Figure 9. Adjustable Voltage Regulator

8.2.1 Design Requirements

- R1 and R2 are required to set the output voltage.
- C_{ADJ} is recommended to improve ripple rejection. It prevents amplification of the ripple as the output voltage is adjusted higher.
- C_i is recommended, particularly if the regulator is not in close proximity to the power-supply filter capacitors. A 0.1-µF or 1-µF ceramic or tantalum capacitor provides sufficient bypassing for most applications, especially when adjustment and output capacitors are used.
- C_O improves transient response, but is not needed for stability.
- Protection diode D2 is recommended if C_{ADJ} is used. The diode provides a low-impedance discharge path to prevent the capacitor from discharging into the output of the regulator.
- Protection diode D1 is recommended if C_O is used. The diode provides a low-impedance discharge path to prevent the capacitor from discharging into the output of the regulator.

8.2.2 Detailed Design Procedure

V_O is calculated as shown in Equation 1. I_{ADJ} is typically 50 µA and negligible in most applications.

$$V_O = V_{REF} (1 + R2 / R1) + (I_{ADJ} \times R2) \quad (1)$$

Typical Application (continued)

8.2.3 Application Curves

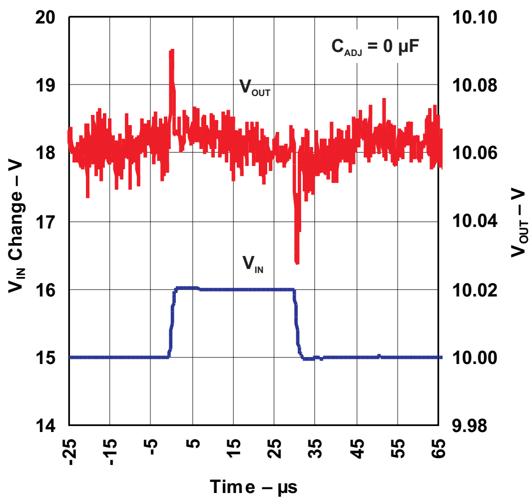


Figure 10. Line-Transient Response

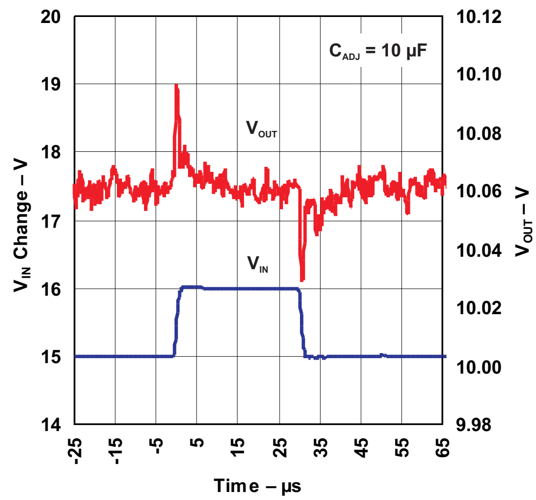


Figure 11. Line-Transient Response

8.3 System Examples

8.3.1 0-V to 30-V Regulator Circuit

Here, the voltage is determined by $$V_{OUT} = V_{REF}\left(1 + \frac{R_2 + R_3}{R_1}\right) - 10\,V$$

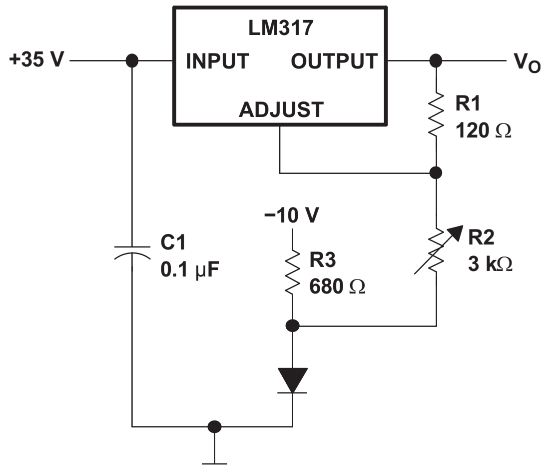


Figure 12. 0-V to 30-V Regulator Circuit

System Examples (continued)

8.3.2 Adjustable Regulator Circuit With Improved Ripple Rejection

C2 helps to stabilize the voltage at the adjustment pin, which helps reject noise. Diode D1 exists to discharge C2 in case the output is shorted to ground.

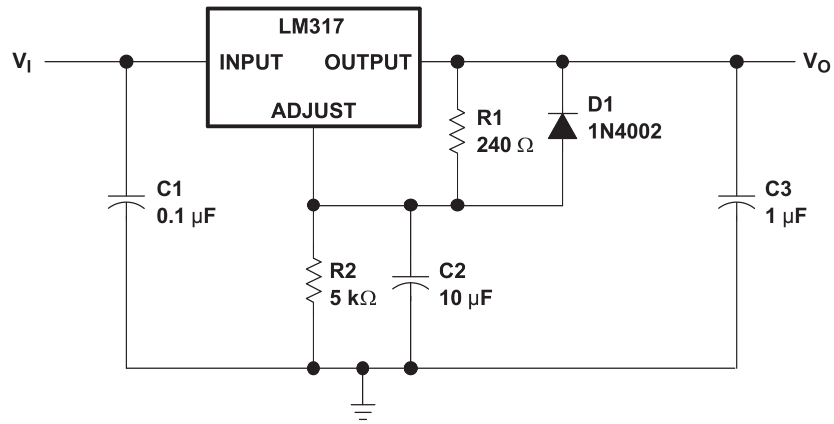


Figure 13. Adjustable Regulator Circuit with Improved Ripple Rejection

8.3.3 Precision Current-Limiter Circuit

This application limits the output current to the I_{LIMIT} in the diagram.

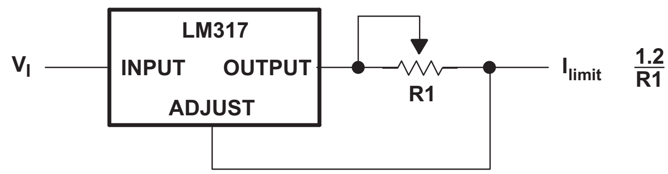


Figure 14. Precision Current-Limiter Circuit

8.3.4 Tracking Preregulator Circuit

This application keeps a constant voltage across the second LM317 in the circuit.

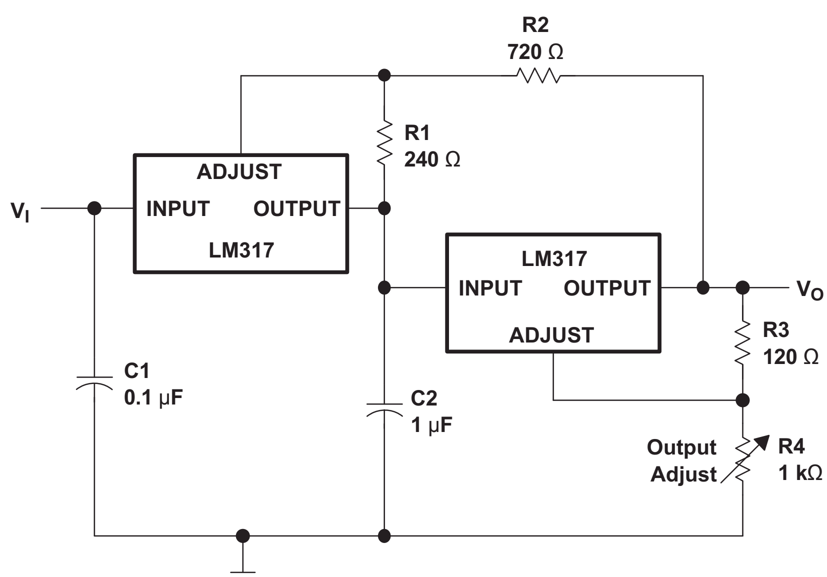


Figure 15. Tracking Preregulator Circuit

System Examples (continued)

8.3.5 1.25-V to 20-V Regulator Circuit With Minimum Program Current

Because the value of V_{REF} is constant, the value of R1 determines the amount of current that flows through R1 and R2. The size of R2 determines the IR drop from ADJUSTMENT to GND. Higher values of R2 translate to higher V_{OUT}.

$$V_{OUT} = V_{REF}\left(1 + \frac{R_2 + R_3}{R_1}\right) - 10\,V \quad (2)$$

$$(R1 + R2)min = V_O I_{reg(min)} \quad (3)$$

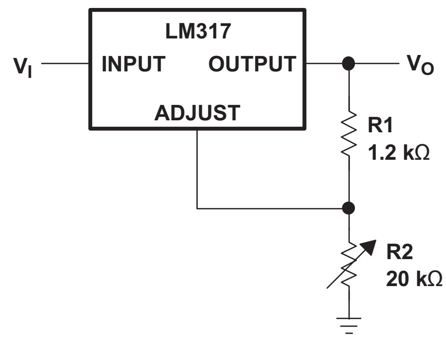


Figure 16. 1.25-V to 20-V Regulator Circuit With Minimum Program Current

8.3.6 Battery-Charger Circuit

The series resistor limits the current output of the LM317, minimizing damage to the battery cell.

$$V_{OUT} = 1.25V \times \left(\frac{R2}{R1 + 1}\right) \quad (4)$$

$$I_{OUT}(short) = \frac{1.25V}{RS} \quad (5)$$

$$\text{Output impendance} = RS \times \left(\frac{R2}{R1 + 1}\right) \quad (6)$$

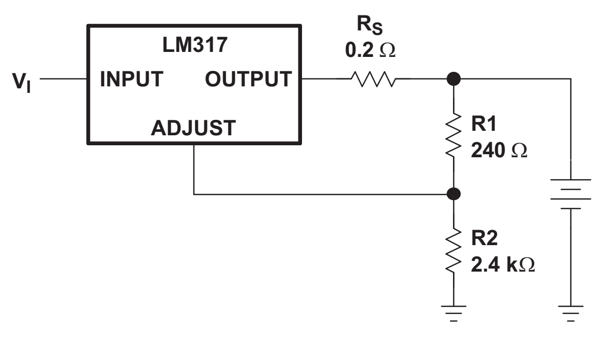


Figure 17. Battery-Charger Circuit

System Examples (continued)

8.3.7 50-mA Constant-Current Battery-Charger Circuit

The current limit operation mode can be used to trickle charge a battery at a fixed current. I_{CHG} = 1.25 V ÷ 24 Ω. V_I should be greater than V_{BAT} + 4.25 V. (1.25 V [V_{REF}] + 3 V [headroom])

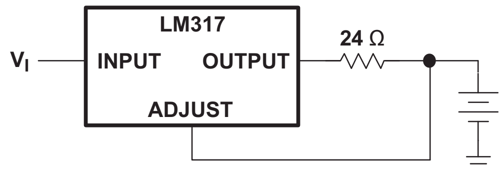


Figure 18. 50-mA Constant-Current Battery-Charger Circuit

8.3.8 Slow Turn-On 15-V Regulator Circuit

The capacitor C1, in combination with the PNP transistor, helps the circuit to slowly start supplying voltage. In the beginning, the capacitor is not charged. Therefore output voltage starts at V_{C1}+ V_{BE} + 1.25 V = 0 V + 0.65 V + 1.25 V = 1.9 V. As the capacitor voltage rises, V_{OUT} rises at the same rate. When the output voltage reaches the value determined by R1 and R2, the PNP will be turned off.

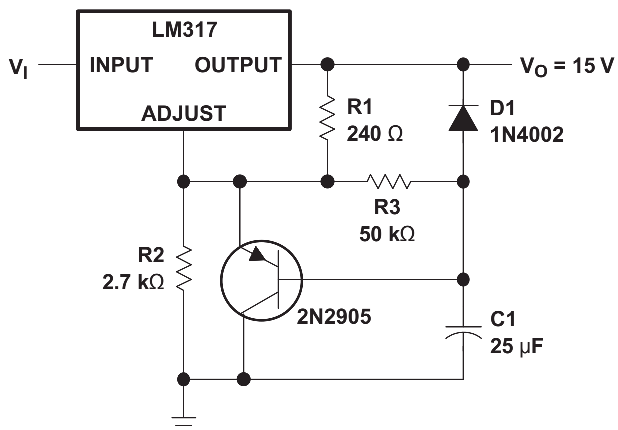


Figure 19. Slow Turn-On 15-V Regulator Circuit

8.3.9 AC Voltage-Regulator Circuit

These two LM317s can regulate both the positive and negative swings of a sinusoidal AC input.

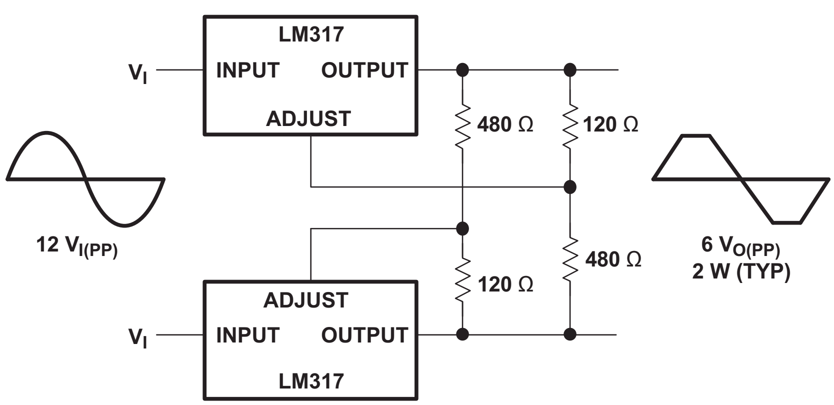


Figure 20. AC Voltage-Regulator Circuit

System Examples (continued)

8.3.10 Current-Limited 6-V Charger Circuit

As the charge current increases, the voltage at the bottom resistor increases until the NPN starts sinking current from the adjustment pin. The voltage at the adjustment pin drops, and consequently the output voltage decreases until the NPN stops conducting.

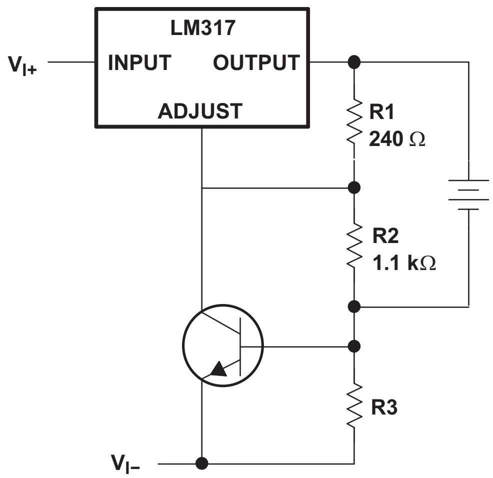


Figure 21. Current-Limited 6-V Charger Circuit

8.3.11 Adjustable 4-A Regulator Circuit

This application keeps the output current at 4 A while having the ability to adjust the output voltage using the adjustable (1.5 kΩ in schematic) resistor.

System Examples (continued)

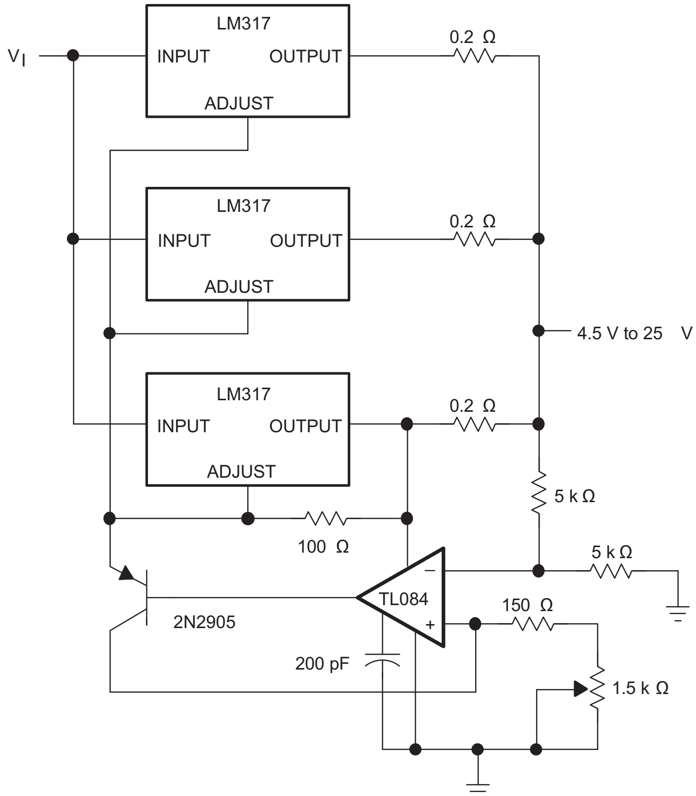


Figure 22. Adjustable 4-A Regulator Circuit

System Examples (continued)

8.3.12 High-Current Adjustable Regulator Circuit

The NPNs at the top of the schematic allow higher currents at V_{OUT} than the LM317 can provide, while still keeping the output voltage at levels determined by the adjustment pin resistor divider of the LM317.

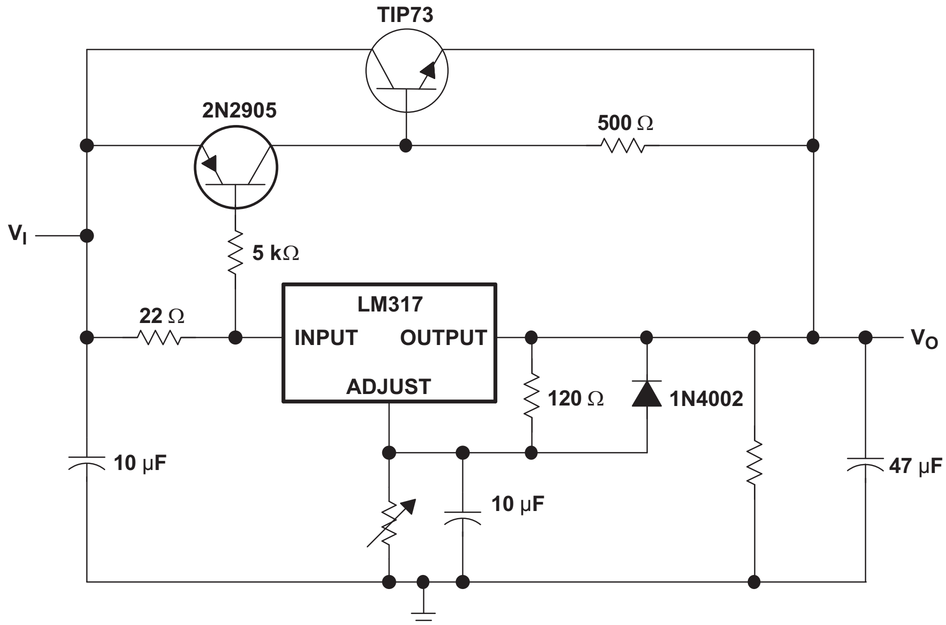


Figure 23. High-Current Adjustable Regulator Circuit

9 Power Supply Recommendations

The LM317 is designed to operate from an input voltage supply range between 1.25 V to 37 V greater than the output voltage. If the device is more than six inches from the input filter capacitors, an input bypass capacitor, 0.1 µF or greater, of any type is needed for stability.

10 Layout

10.1 Layout Guidelines

- TI recommends that the input terminal be bypassed to ground with a bypass capacitor.
- The optimum placement is closest to the input terminal of the device and the system GND. Take care to minimize the loop area formed by the bypass-capacitor connection, the input terminal, and the system GND.
- For operation at full rated load, TI recommends to use wide trace lengths to eliminate I × R drop and heat dissipation.

10.2 Layout Example

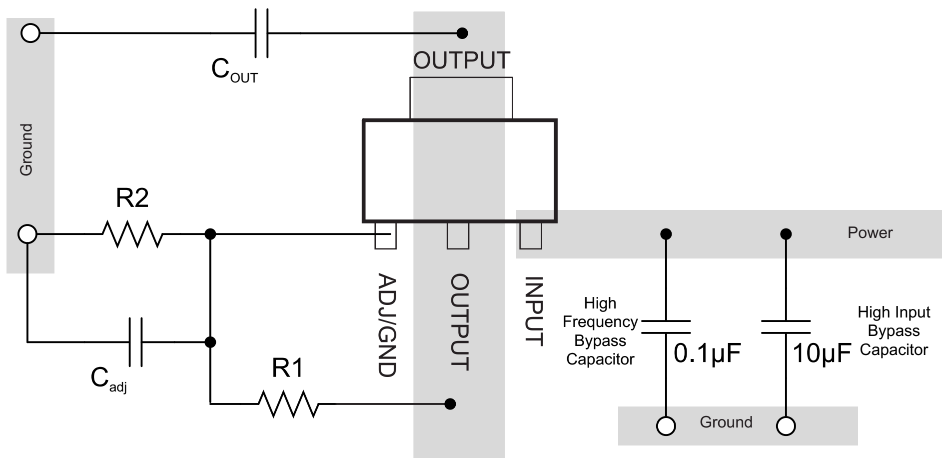


Figure 24. Layout Example

11 Device and Documentation Support

11.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.2 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.3 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

11.4 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

11.5 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM317DCY	ACTIVE	SOT-223	DCY	4	80	Green (RoHS & no Sb/Br)	SN	Level-2-260C-1 YEAR	0 to 125	L3	Samples
LM317DCYG3	ACTIVE	SOT-223	DCY	4	80	Green (RoHS & no Sb/Br)	SN	Level-2-260C-1 YEAR	0 to 125	L3	Samples
LM317DCYR	ACTIVE	SOT-223	DCY	4	2500	Green (RoHS & no Sb/Br)	SN	Level-2-260C-1 YEAR	0 to 125	L3	Samples
LM317DCYRG3	ACTIVE	SOT-223	DCY	4	2500	Green (RoHS & no Sb/Br)	SN	Level-2-260C-1 YEAR	0 to 125	L3	Samples
LM317KCS	ACTIVE	TO-220	KCS	3	50	Pb-Free (RoHS)	SN	N / A for Pkg Type	0 to 125	LM317	Samples
LM317KCSE3	ACTIVE	TO-220	KCS	3	50	Pb-Free (RoHS)	SN	N / A for Pkg Type	0 to 125	LM317	Samples
LM317KCT	ACTIVE	TO-220	KCT	3	50	Pb-Free (RoHS)	SN	N / A for Pkg Type	0 to 125	LM317	Samples
LM317KTTR	ACTIVE	DDPAK/ TO-263	KTT	3	500	Green (RoHS & no Sb/Br)	SN	Level-3-245C-168 HR	0 to 125	LM317	Samples
LM317KTTRG3	ACTIVE	DDPAK/ TO-263	KTT	3	500	Green (RoHS & no Sb/Br)	SN	Level-3-245C-168 HR	0 to 125	LM317	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

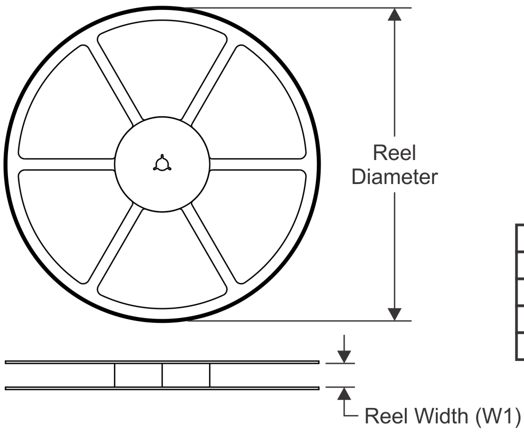
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

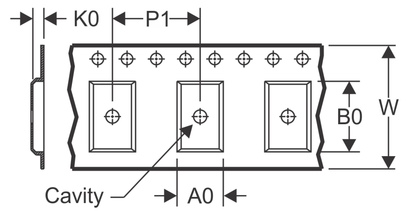
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

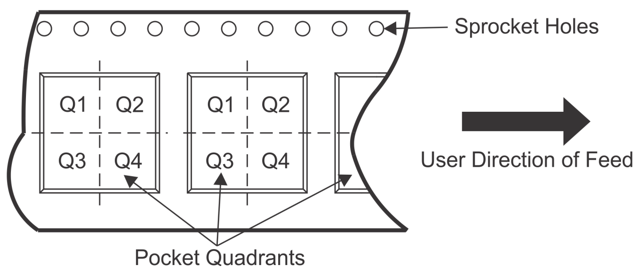


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

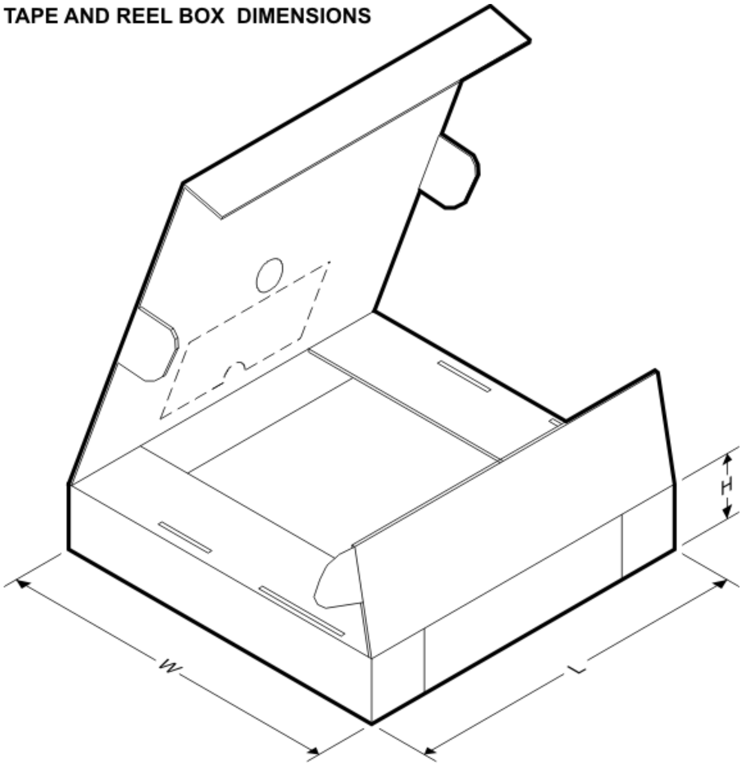
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM317DCYR	SOT-223	DCY	4	2500	330.0	12.4	7.0	7.42	2.0	8.0	12.0	Q3
LM317DCYR	SOT-223	DCY	4	2500	330.0	12.4	7.05	7.4	1.9	8.0	12.0	Q3
LM317DCYR	SOT-223	DCY	4	2500	330.0	12.4	6.55	7.25	1.9	8.0	12.0	Q3
LM317KTTR	DDPAK/ TO-263	KTT	3	500	330.0	24.4	10.8	16.1	4.9	16.0	24.0	Q2

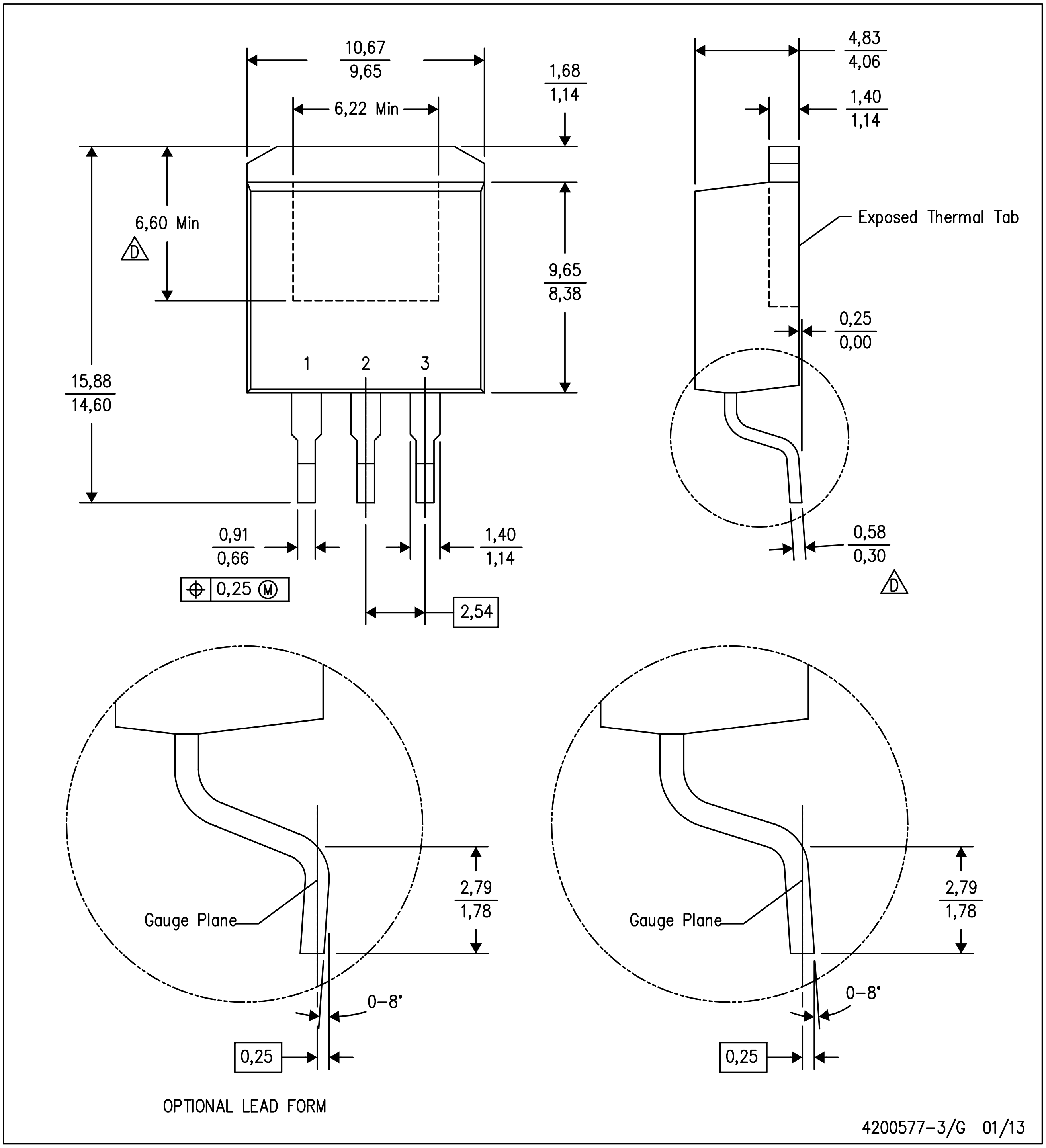
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

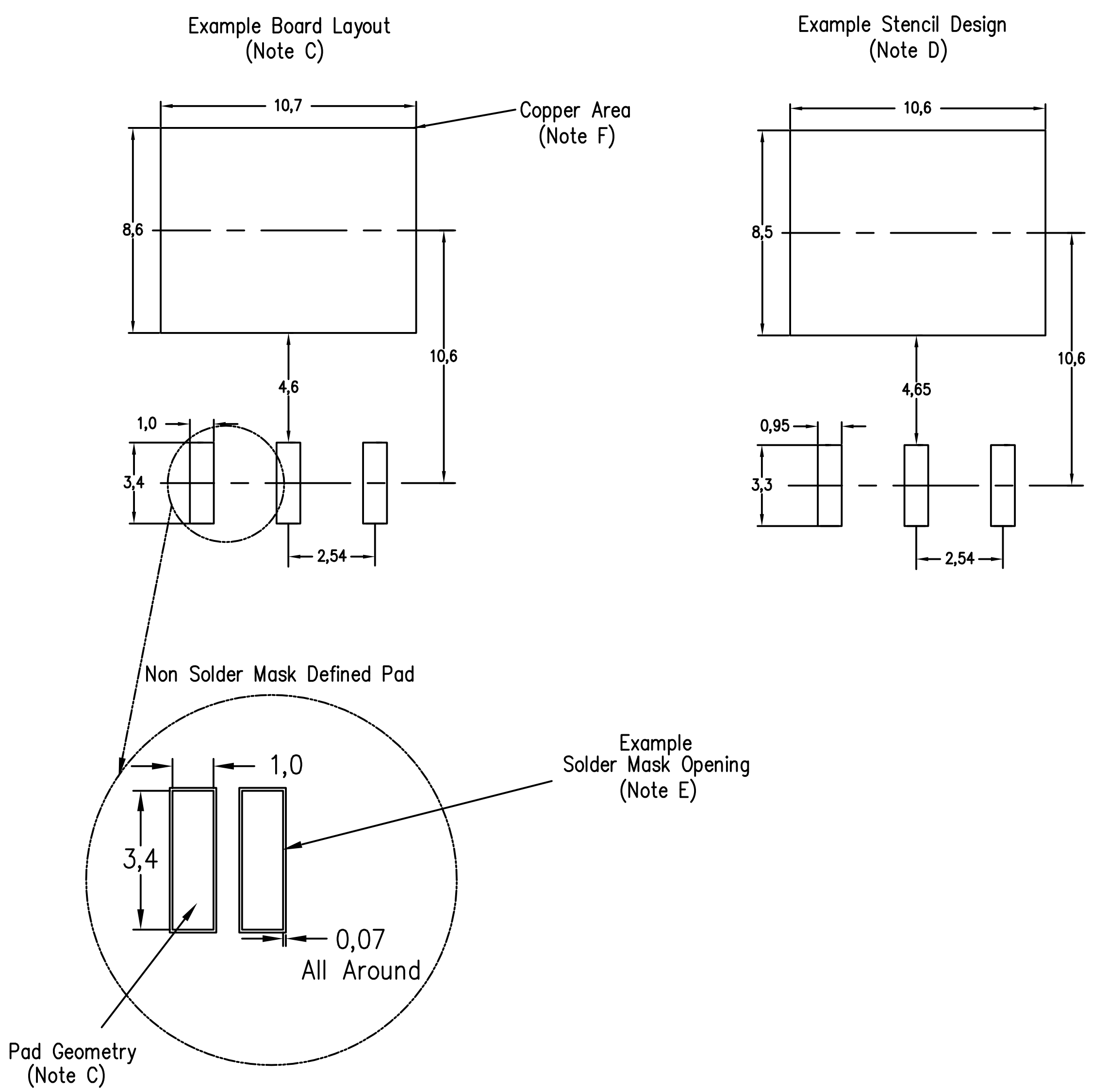
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM317DCYR	SOT-223	DCY	4	2500	350.0	334.0	47.0
LM317DCYR	SOT-223	DCY	4	2500	340.0	340.0	38.0
LM317DCYR	SOT-223	DCY	4	2500	336.0	336.0	48.0
LM317KTTR	DDPAK/TO-263	KTT	3	500	350.0	334.0	47.0

KTT (R-PSFM-G3) PLASTIC FLANGE-MOUNT PACKAGE



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash or protrusion not to exceed 0.005 (0,13) per side.
D. Falls within JEDEC TO-263 variation AA, except minimum lead thickness and minimum exposed pad length.

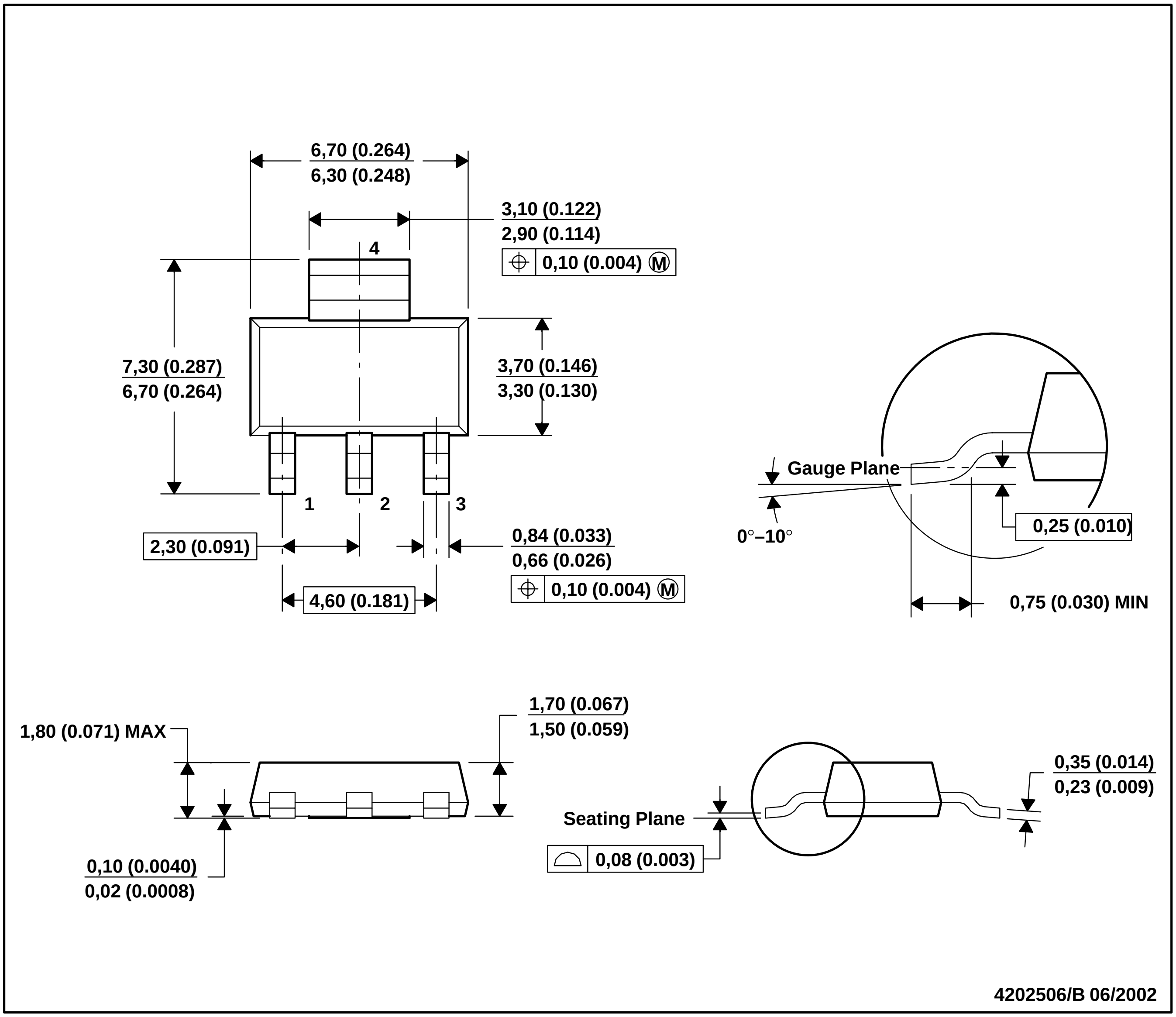
KTT (R–PSFM–G3) PLASTIC FLANGE–MOUNT PACKAGE



4208208–2/C 08/12

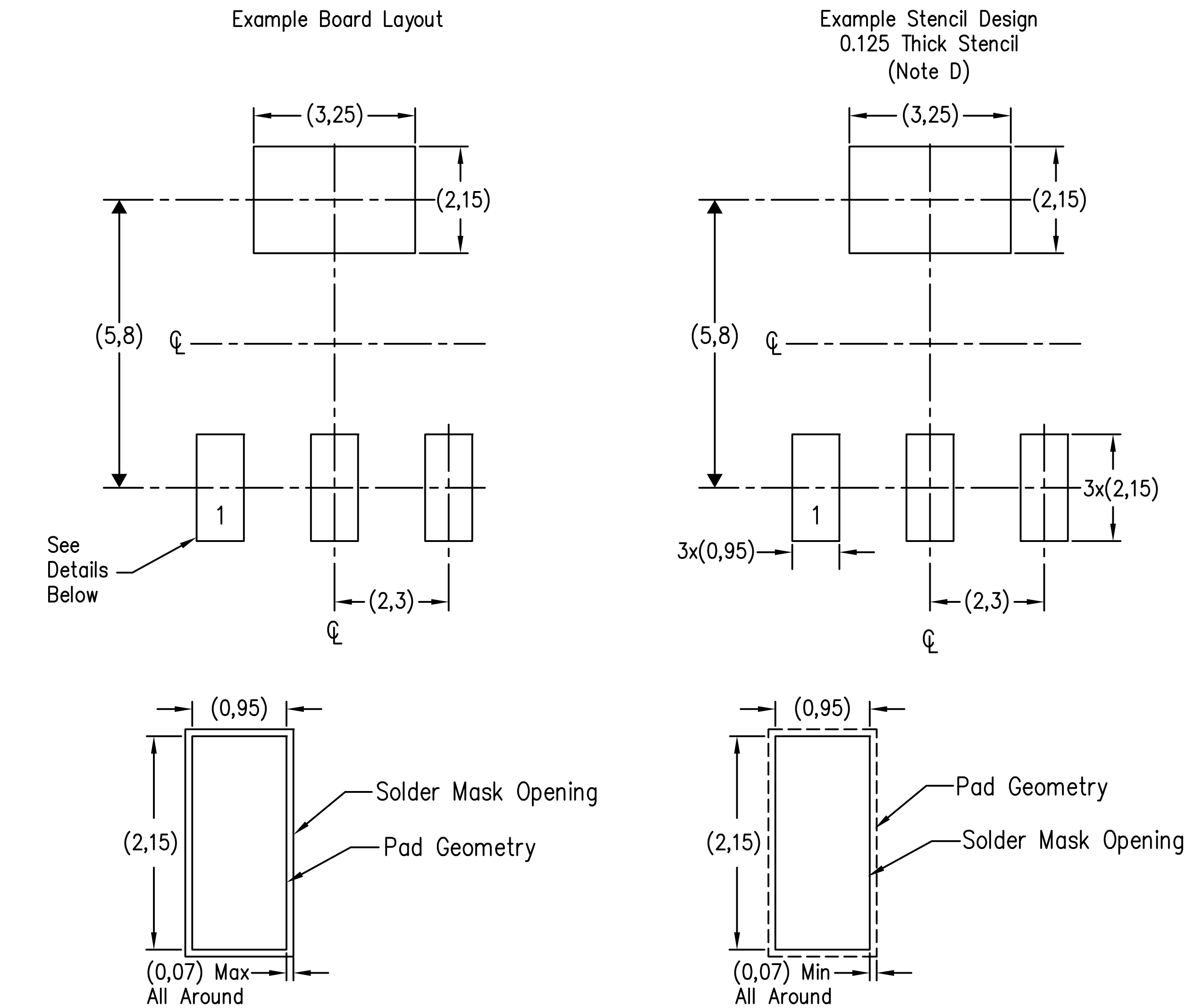
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–SM–782 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.
F. This package is designed to be soldered to a thermal pad on the board. Refer to the Product Datasheet for specific thermal information, via requirements, and recommended thermal pad size. For thermal pad sizes larger than shown a solder mask defined pad is recommended in order to maintain the solderable pad geometry while increasing copper area.

DCY (R-PDSO-G4) **PLASTIC SMALL-OUTLINE**



NOTES: A. All linear dimensions are in millimeters (inches).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC TO-261 Variation AA.

DCY (R–PDSO–G4) PLASTIC SMALL OUTLINE



Example, non–solder mask defined pad. (Preferred)

Example, solder mask defined pad.

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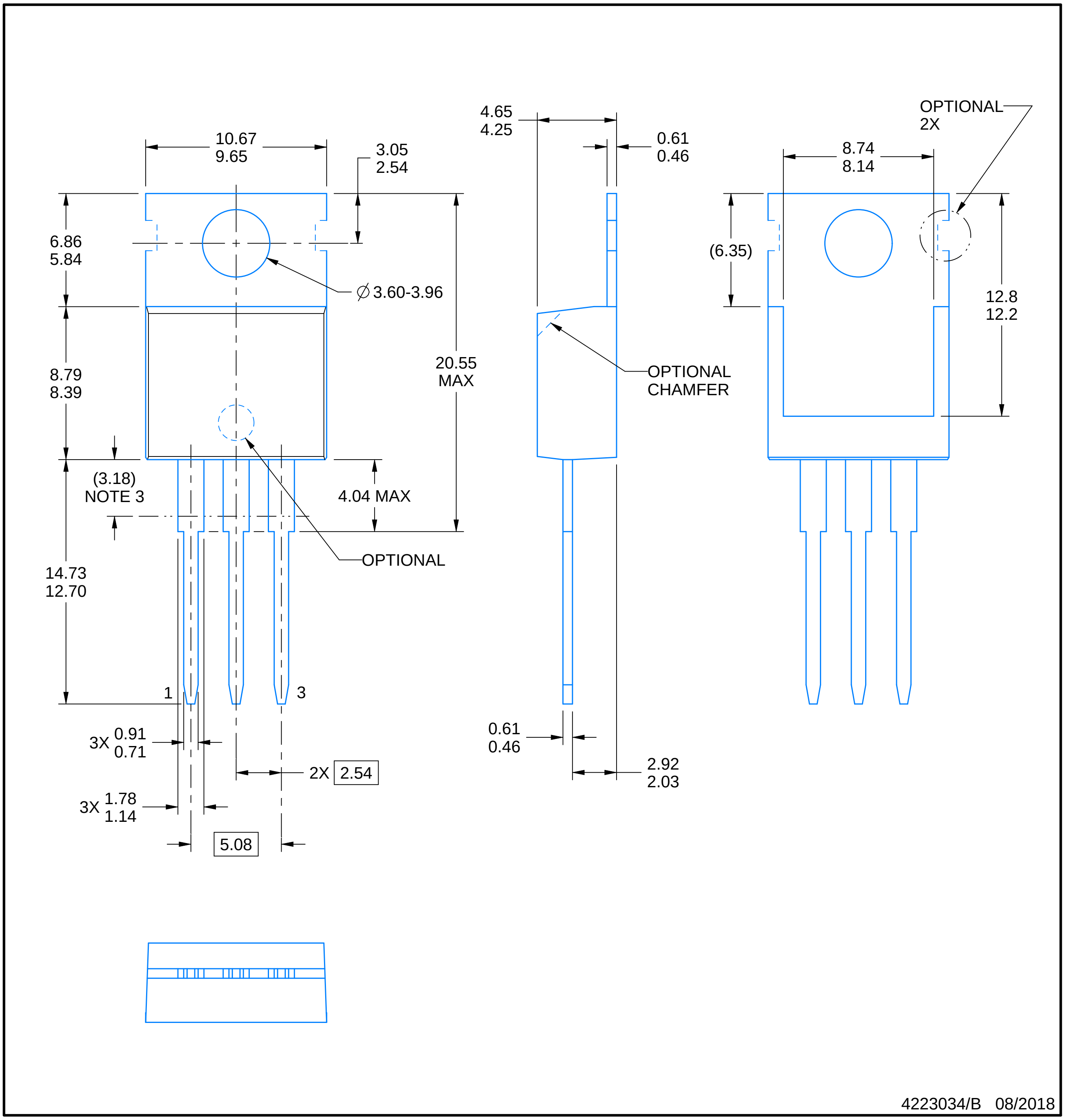
NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Publication IPC–7351 is recommended for alternate designs.
- D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil recommendations. Refer to IPC 7525 for stencil design considerations.

PACKAGE OUTLINE

KCT0003A

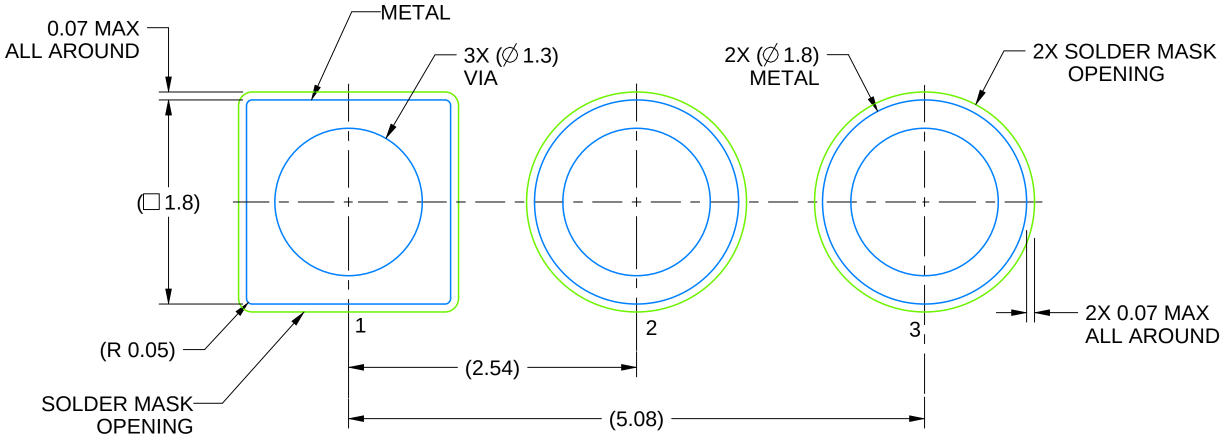
TO-220 - 20.55 mm max height

TO-220

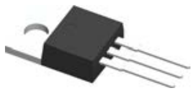


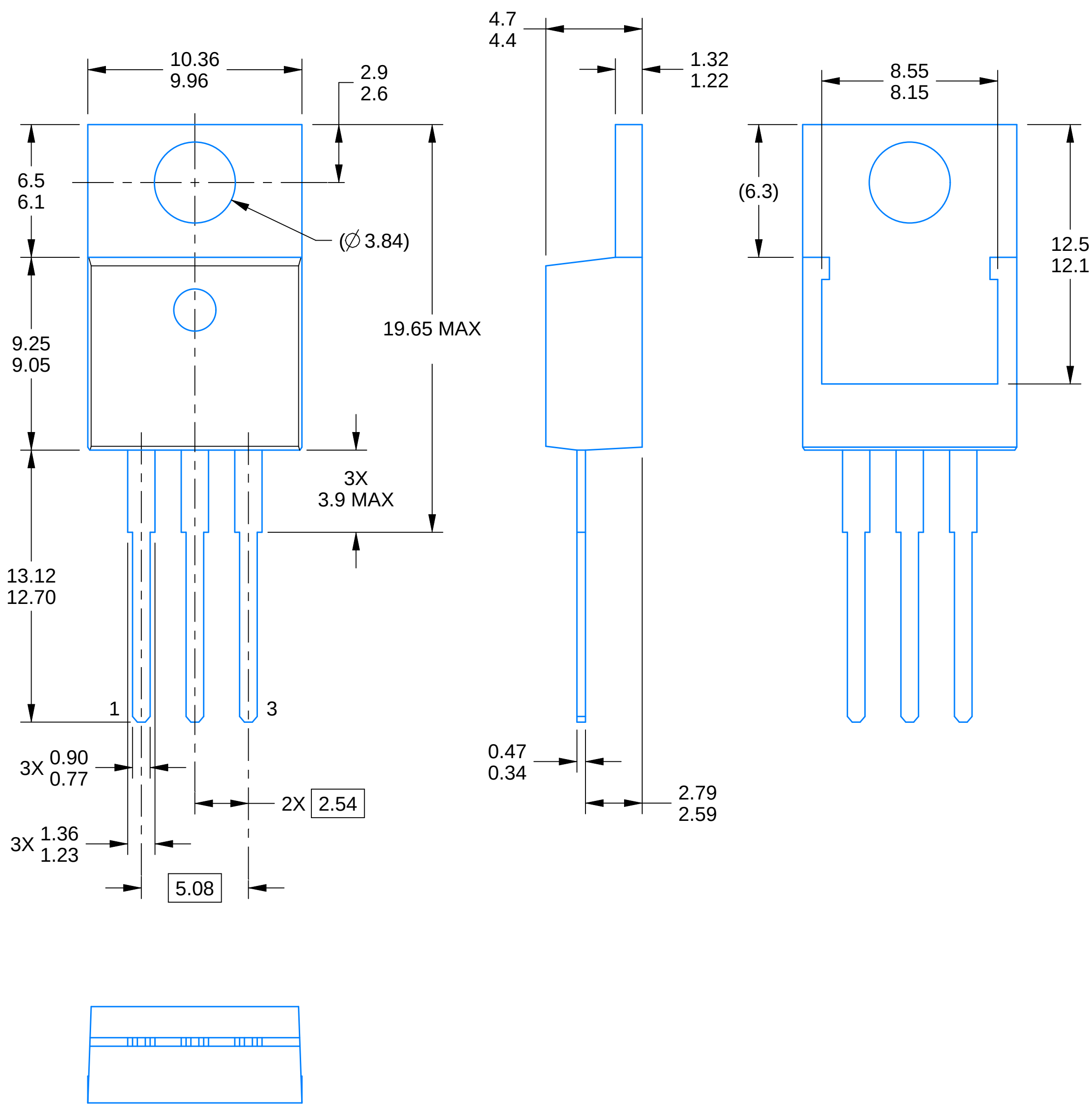
NOTES:

1. Dimensions are in millimeters. Any dimension in brackets or parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Lead dimensions are not controlled within this area.
4. Reference JEDEC registration TO-220.



LAND PATTERN EXAMPLE
NON-SOLDER MASK DEFINED
SCALE:15X





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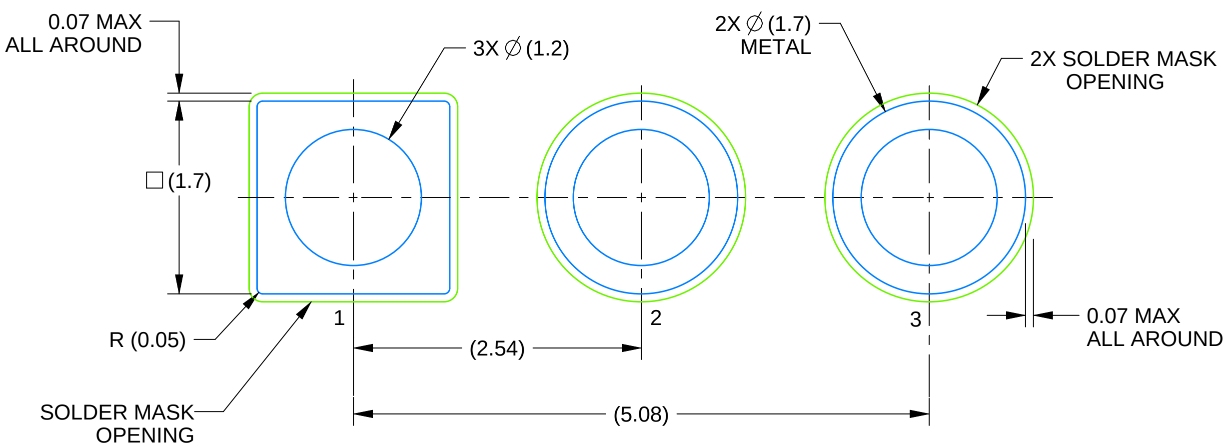
NOTES:

1. Dimensions are in millimeters. Any dimension in brackets or parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration TO-220.



LAND PATTERN EXAMPLE
NON-SOLDER MASK DEFINED
SCALE:15X

4222214/B 08/2018

1N4001, 1N4002, 1N4003, 1N4004, 1N4005, 1N4006, 1N4007

1N4004 and 1N4007 are Preferred Devices

Axial Lead Standard Recovery Rectifiers

This data sheet provides information on subminiature size, axial lead mounted rectifiers for general−purpose low−power applications.

Features

- Shipped in plastic bags, 1000 per bag
- Available Tape and Reeled, 5000 per reel, by adding a "RL" suffix to the part number
- Available in Fan−Fold Packaging, 3000 per box, by adding a "FF" suffix to the part number
- Pb−Free Packages are Available

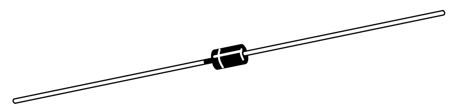
Mechanical Characteristics

- Case: Epoxy, Molded
- Weight: 0.4 gram (approximately)
- Finish: All External Surfaces Corrosion Resistant and Terminal Leads are Readily Solderable
- Lead and Mounting Surface Temperature for Soldering Purposes: 260°C Max. for 10 Seconds, 1/16 in. from case
- Polarity: Cathode Indicated by Polarity Band

*For additional information on our Pb−Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

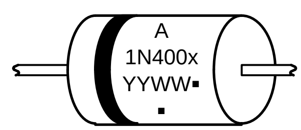
ON Semiconductor®

LEAD MOUNTED RECTIFIERS
50−1000 VOLTS
DIFFUSED JUNCTION



CASE 59−10
AXIAL LEAD
PLASTIC

MARKING DIAGRAM



A = Assembly Location
1N400x = Device Number
x = 1, 2, 3, 4, 5, 6 or 7
YY = Year
WW = Work Week
▪ = Pb−Free Package
(Note: Microdot may be in either location)

ORDERING INFORMATION

See detailed ordering and shipping information on page 4 of this data sheet.

Preferred devices are recommended choices for future use and best overall value.

MAXIMUM RATINGS

Rating	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
†Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
†Non−Repetitive Peak Reverse Voltage (halfwave, single phase, 60 Hz)	V_{RSM}	60	120	240	480	720	1000	1200	V
†RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
†Average Rectified Forward Current (single phase, resistive load, 60 Hz, T_A = 75°C)	I_O	1.0							A
†Non−Repetitive Peak Surge Current (surge applied at rated load conditions)	I_{FSM}	30 (for 1 cycle)							A
Operating and Storage Junction Temperature Range	T_J T_{stg}	−65 to +175							°C

Maximum ratings are those values beyond which device damage can occur. Maximum ratings applied to the device are individual stress limit values (not normal operating conditions) and are not valid simultaneously. If these limits are exceeded, device functional operation is not implied, damage may occur and reliability may be affected.

ELECTRICAL CHARACTERISTICS†

Rating	Symbol	Typ	Max	Unit
Maximum Instantaneous Forward Voltage Drop, (i_F = 1.0 Amp, T_J = 25°C)	v_F	0.93	1.1	V
Maximum Full−Cycle Average Forward Voltage Drop, (I_O = 1.0 Amp, T_L = 75°C, 1 inch leads)	$V_{F(AV)}$	−	0.8	V
Maximum Reverse Current (rated DC voltage) (T_J = 25°C) (T_J = 100°C)	I_R	 0.05 1.0	 10 50	μA
Maximum Full−Cycle Average Reverse Current, (I_O = 1.0 Amp, T_L = 75°C, 1 inch leads)	$I_{R(AV)}$	−	30	μA

†Indicates JEDEC Registered Data

ORDERING INFORMATION

Device	Package	Shipping†
1N4001	Axial Lead*	1000 Units/Bag
1N4001G	Axial Lead* (Pb−Free)	1000 Units/Bag
1N4001FF	Axial Lead*	3000 Units/Box
1N4001FFG	Axial Lead* (Pb−Free)	3000 Units/Box
1N4001RL	Axial Lead*	5000/Tape & Reel
1N4001RLG	Axial Lead* (Pb−Free)	5000/Tape & Reel
1N4002	Axial Lead*	1000 Units/Bag
1N4002G	Axial Lead* (Pb−Free)	1000 Units/Bag
1N4002FF	Axial Lead*	3000 Units/Box
1N4002FFG	Axial Lead* (Pb−Free)	3000 Units/Box
1N4002RL	Axial Lead*	5000/Tape & Reel
1N4002RLG	Axial Lead* (Pb−Free)	5000/Tape & Reel
1N4003	Axial Lead*	1000 Units/Bag
1N4003G	Axial Lead* (Pb−Free)	1000 Units/Bag
1N4003FF	Axial Lead*	3000 Units/Box
1N4003FFG	Axial Lead* (Pb−Free)	3000 Units/Box
1N4003RL	Axial Lead*	5000/Tape & Reel
1N4003RLG	Axial Lead* (Pb−Free)	5000/Tape & Reel
1N4004	Axial Lead*	1000 Units/Bag
1N4004G	Axial Lead* (Pb−Free)	1000 Units/Bag
1N4004FF	Axial Lead*	3000 Units/Box
1N4004FFG	Axial Lead* (Pb−Free)	3000 Units/Box
1N4004RL	Axial Lead*	5000/Tape & Reel
1N4004RLG	Axial Lead* (Pb−Free)	5000/Tape & Reel
1N4005	Axial Lead*	1000 Units/Bag
1N4005G	Axial Lead* (Pb−Free)	1000 Units/Bag
1N4005FF	Axial Lead*	3000 Units/Box
1N4005FFG	Axial Lead* (Pb−Free)	3000 Units/Box
1N4005RL	Axial Lead*	5000/Tape & Reel
1N4005RLG	Axial Lead* (Pb−Free)	5000/Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.
*This package is inherently Pb−Free.

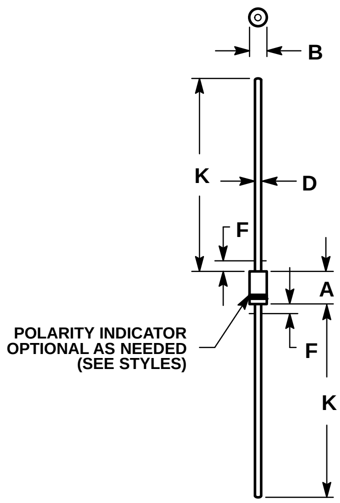
ORDERING INFORMATION

Device	Package	Shipping†
1N4006	Axial Lead*	1000 Units/Bag
1N4006G	Axial Lead* (Pb−Free)	1000 Units/Bag
1N4006FF	Axial Lead*	3000 Units/Box
1N4006FFG	Axial Lead* (Pb−Free)	3000 Units/Box
1N4006RL	Axial Lead*	5000/Tape & Reel
1N4006RLG	Axial Lead* (Pb−Free)	5000/Tape & Reel
1N4007	Axial Lead*	1000 Units/Bag
1N4007G	Axial Lead* (Pb−Free)	1000 Units/Bag
1N4007FF	Axial Lead*	3000 Units/Box
1N4007FFG	Axial Lead* (Pb−Free)	3000 Units/Box
1N4007RL	Axial Lead*	5000/Tape & Reel
1N4007RLG	Axial Lead* (Pb−Free)	5000/Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.
*This package is inherently Pb−Free.

PACKAGE DIMENSIONS

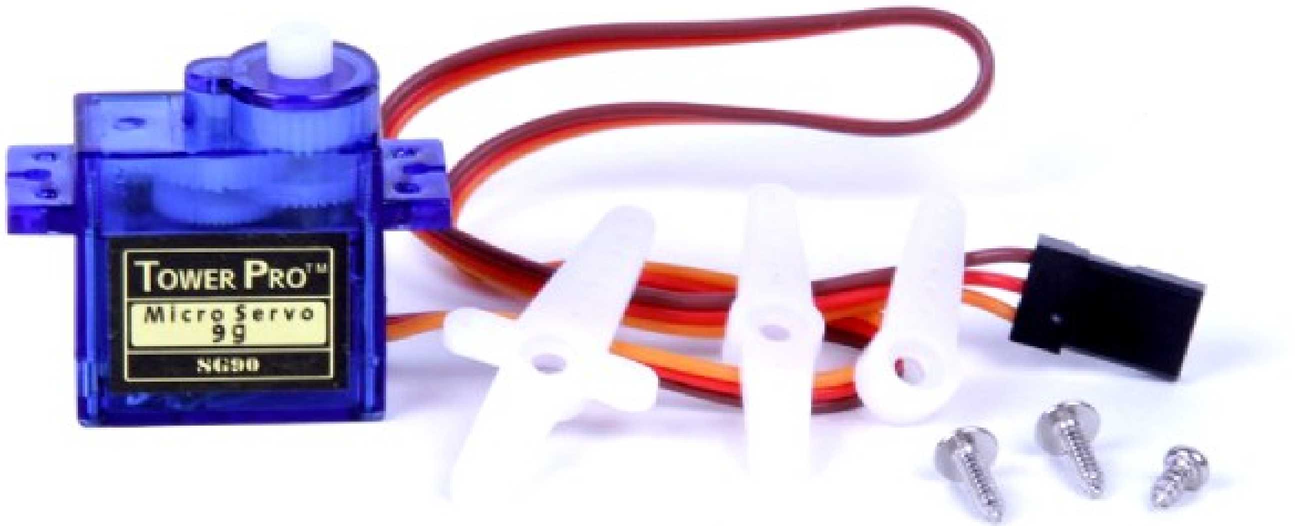
AXIAL LEAD
CASE 59−10
ISSUE U



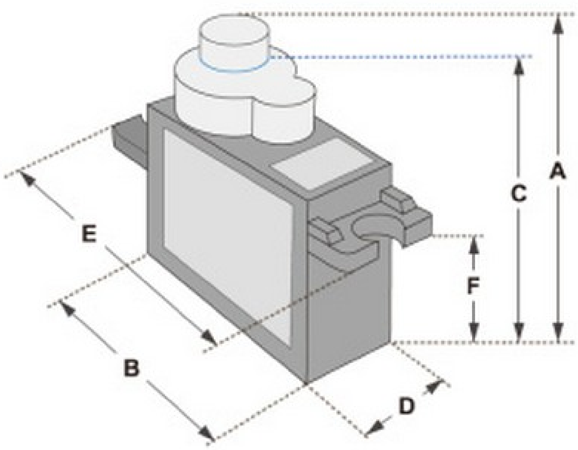
NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. ALL RULES AND NOTES ASSOCIATED WITH JEDEC DO−41 OUTLINE SHALL APPLY
4. POLARITY DENOTED BY CATHODE BAND.
5. LEAD DIAMETER NOT CONTROLLED WITHIN F DIMENSION.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.161	0.205	4.10	5.20
B	0.079	0.106	2.00	2.70
D	0.028	0.034	0.71	0.86
F	−−−	0.050	−−−	1.27
K	1.000	−−−	25.40	−−−

SERVO MOTOR SG90 DATA SHEET

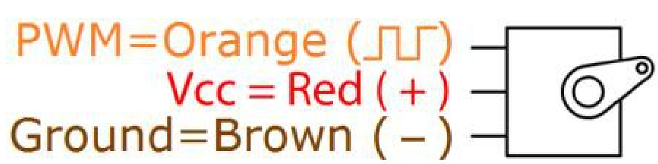


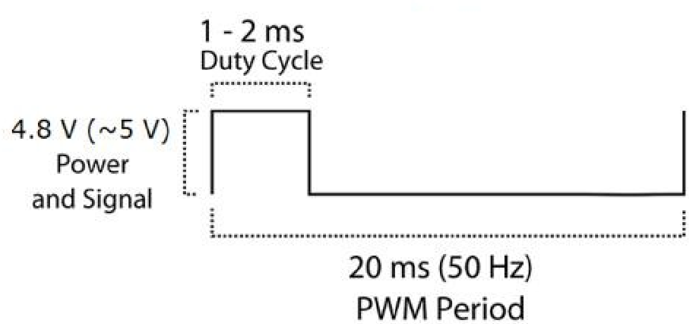
Tiny and lightweight with high output power. Servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kinds but smaller. You can use any servo code, hardware or library to control these servos. Good for beginners who want to make stuff move without building a motor controller with feedback & gear box, especially since it will fit in small places. It comes with a 3 horns (arms) and hardware.



Dimensions & Specifications
A (mm) : 32
B (mm) : 23
C (mm) : 28.5
D (mm) : 12
E (mm) : 32
F (mm) : 19.5
Speed (sec) : 0.1
Torque (kg-cm) : 2.5
Weight (g) : 14.7
Voltage : 4.8 - 6

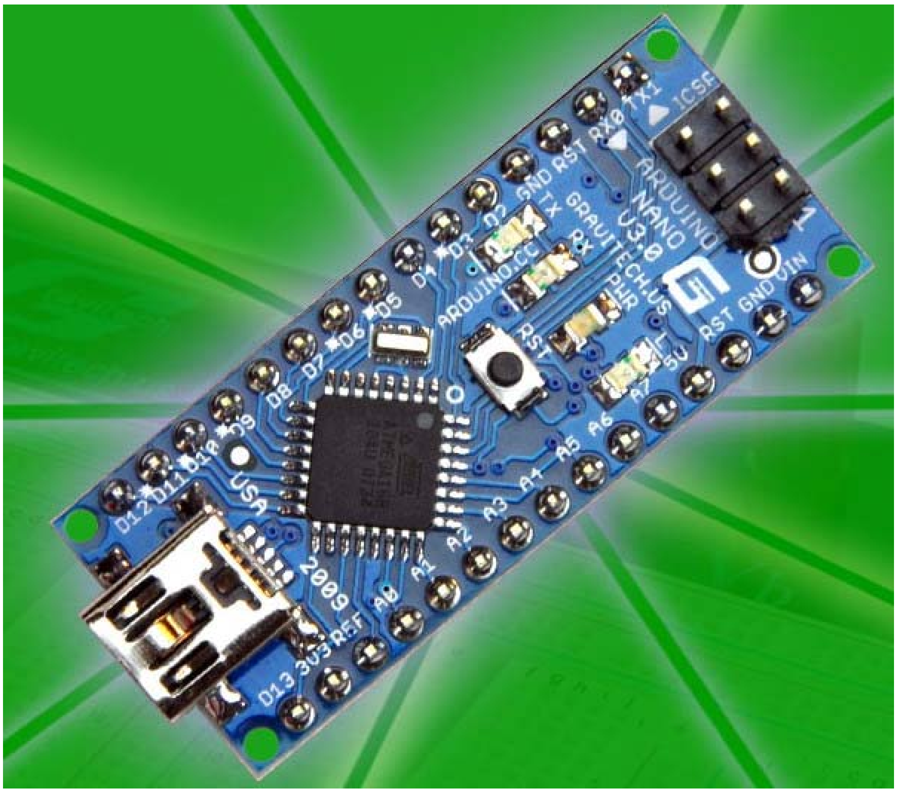
Position "0" (1.5 ms pulse) is middle, "90" (~2ms pulse) is middle, is all the way to the right, "-90" (~1ms pulse) is all the way to the left.





Arduino Nano (V3.0)

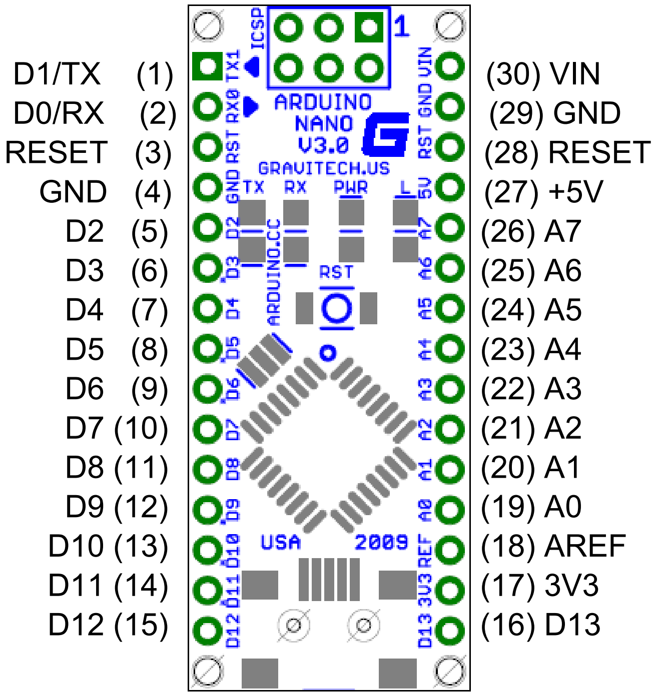
User Manual



More information:

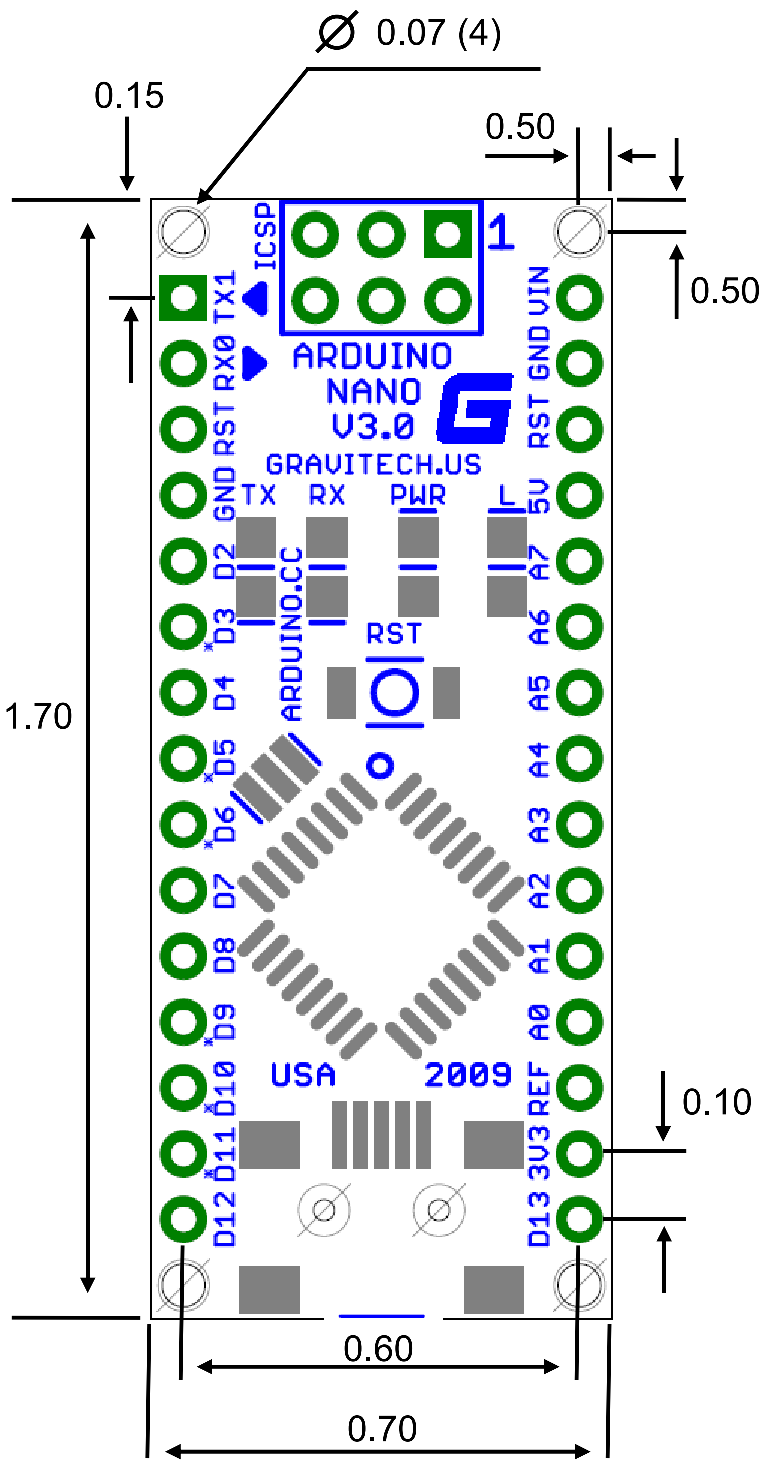
www.arduino.cc Rev 3.0

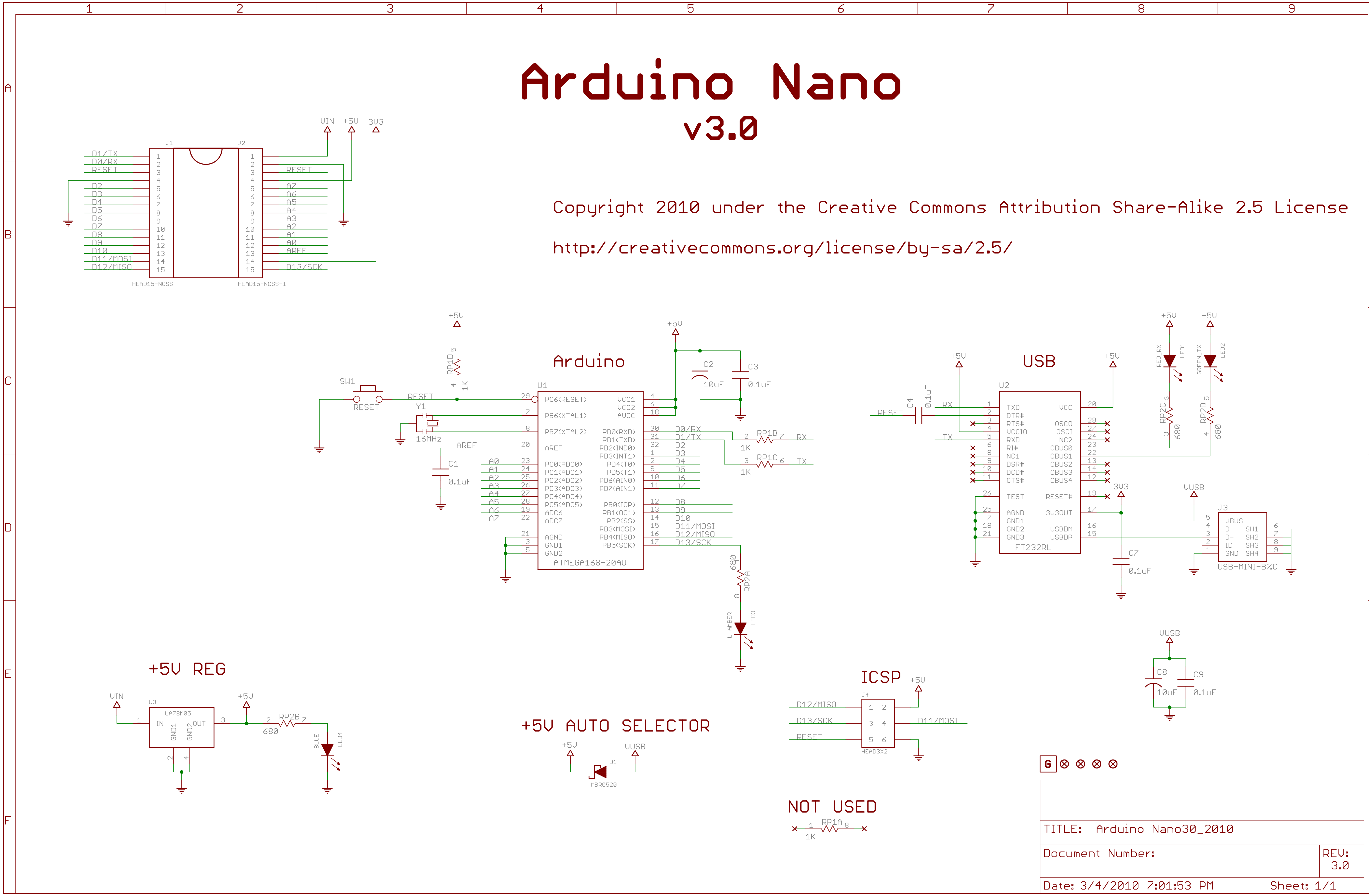
Arduino Nano Pin Layout



Pin No.	Name	Type	Description
1-2, 5-16	D0-D13	I/O	Digital input/output port 0 to 13
3, 28	RESET	Input	Reset (active low)
4, 29	GND	PWR	Supply ground
17	3V3	Output	+3.3V output (from FTDI)
18	AREF	Input	ADC reference
19-26	A0-A7	Input	Analog input channel 0 to 7
27	+5V	Output or Input	+5V output (from on-board regulator) or +5V (input from external power supply)
30	VIN	PWR	Supply voltage

Arduino Nano Mechanical Drawing





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Specifications:

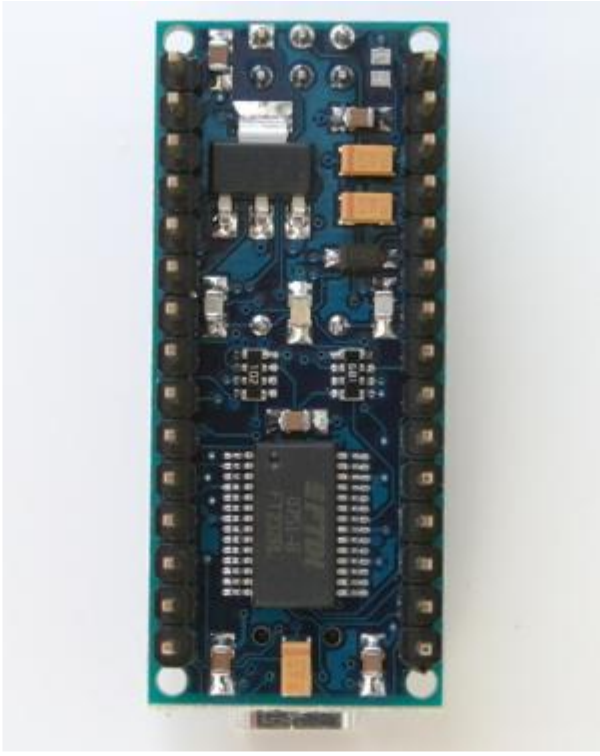
Microcontroller	Atmel ATmega328
Operating Voltage (logic level)	5 V
Input Voltage (recommended)	7-12 V
Input Voltage (limits)	6-20 V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	8
DC Current per I/O Pin	40 mA
Flash Memory	32 KB (of which 2KB used by bootloader)
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz
Dimensions	0.70" x 1.70"

Electronics Source Co.,Ltd
7/129 Central Pinklao Bldg., 17FL., Unit 1702
Baromrachonnee Rd., Bangkok-noi, Bangkok 10700

Website : http://www.es.co.th
Email : info@es.co.th
Tel : (662) 884-9210 (6 line)
Fax : (662) 884-9213-4

Arduino Nano

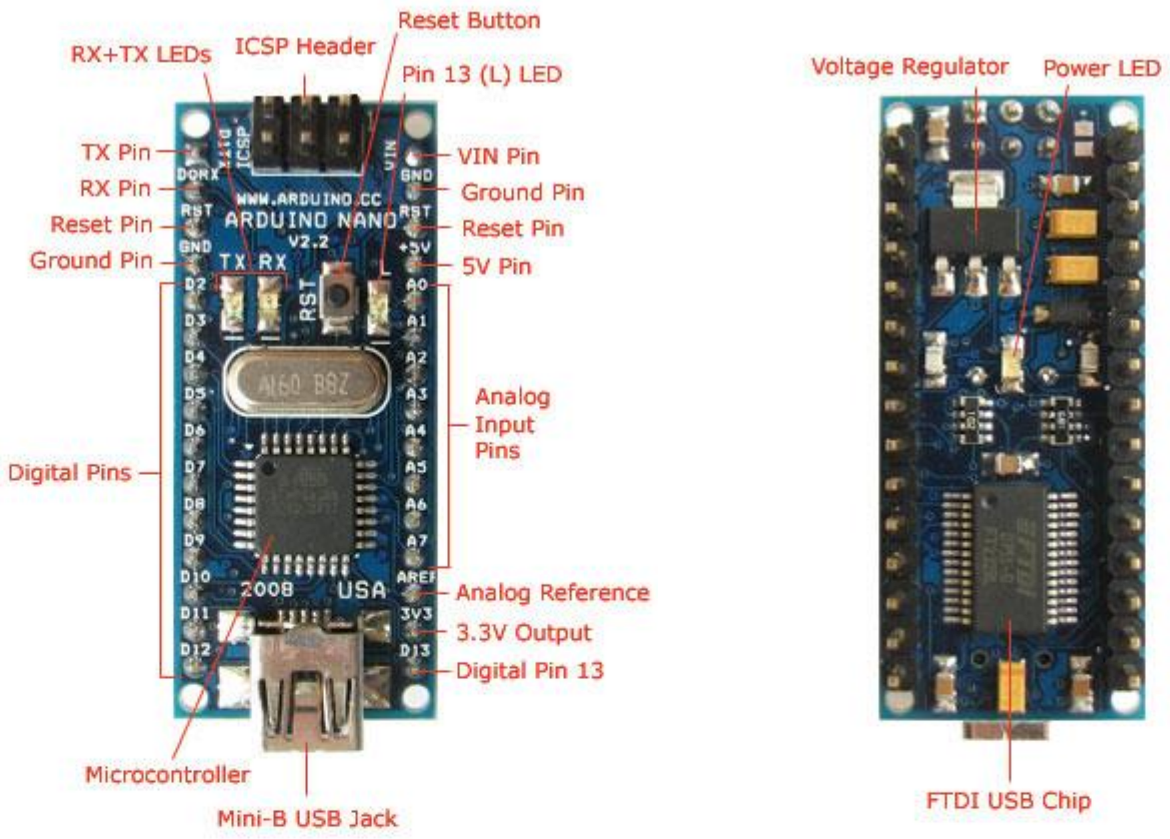
Arduino Nano Front



Arduino Nano Rear

Overview

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.0) or ATmega168 (Arduino Nano 2.x). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one. The Nano was designed and is being produced by Gravitech.



Schematic and Design

Arduino Nano 3.0 (ATmega328): schematic, Eagle files.
Arduino Nano 2.3 (ATmega168): manual (pdf), Eagle files. *Note:* since the free version of Eagle does not handle more than 2 layers, and this version of the Nano is 4 layers, it is published here unrouted, so users can open and use it in the free version of Eagle.

Specifications:

Microcontroller	Atmel ATmega168 or ATmega328
Operating Voltage (logic level)	5 V
Input Voltage (recommended)	7-12 V
Input Voltage (limits)	6-20 V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	8
DC Current per I/O Pin	40 mA
Flash Memory	16 KB (ATmega168) or 32 KB (ATmega328) of which 2 KB used by bootloader
SRAM	1 KB (ATmega168) or 2 KB (ATmega328)
EEPROM	512 bytes (ATmega168) or 1 KB (ATmega328)
Clock Speed	16 MHz
Dimensions	0.73" x 1.70"

Power:

The Arduino Nano can be powered via the Mini-B USB connection, 6-20V unregulated external power supply (pin 30), or 5V regulated external power supply (pin 27). The power source is automatically selected to the highest voltage source.

The FTDI FT232RL chip on the Nano is only powered if the board is being powered over USB. As a result, when running on external (non-USB) power, the 3.3V output (which is supplied by the FTDI chip) is not available and the RX and TX LEDs will flicker if digital pins 0 or 1 are high.

Memory

The ATmega168 has 16 KB of flash memory for storing code (of which 2 KB is used for the bootloader); the ATmega328 has 32 KB, (also with 2 KB used for the bootloader). The ATmega168 has 1 KB of SRAM and 512 bytes of EEPROM (which can be read and written with the EEPROM library); the ATmega328 has 2 KB of SRAM and 1 KB of EEPROM.

Input and Output

Each of the 14 digital pins on the Nano can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the FTDI USB-to-TTL Serial chip.
- **External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK).** These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Nano has 8 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the analogReference() function. Additionally, some pins have specialized functionality:

I^2C: 4 (SDA) and 5 (SCL). Support I^2C (TWI) communication using the Wire library (documentation on the Wiring website).

There are a couple of other pins on the board:

AREF. Reference voltage for the analog inputs. Used with analogReference().
Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

See also the mapping between Arduino pins and ATmega168 ports.

Communication

The Arduino Nano has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega168 and ATmega328 provide UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An FTDI FT232RL on the board channels this serial communication over USB and the FTDI drivers (included with the Arduino software) provide a virtual com port to software on the computer. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the FTDI chip and USB connection to the computer (but not for serial communication on pins 0 and 1).
A SoftwareSerial library allows for serial communication on any of the Nano's digital pins.
The ATmega168 and ATmega328 also support I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. To use the SPI communication, please see the ATmega168 or ATmega328 datasheet.

Programming

The Arduino Nano can be programmed with the Arduino software (download). Select "Arduino Diecimila, Duemilanove, or Nano w/ ATmega168" or "Arduino Duemilanove or Nano w/ ATmega328" from the **Tools**

> **Board** menu (according to the microcontroller on your board). For details, see the reference and tutorials.
The ATmega168 or ATmega328 on the Arduino Nano comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).
You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.

Automatic (Software) Reset

Rather then requiring a physical press of the reset button before an upload, the Arduino Nano is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the FT232RL is connected to the reset line of the ATmega168 or ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.
This setup has other implications. When the Nano is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Nano. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.