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Intelegent wind turbine with Anemometer

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option: electrical machine control

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General Introduction

General introduction:

Electrical energy is one of the most commonly used forms of power in the world because it is easy to be converted into any other energy form and can be safely and efficiently transported over long distances. The fundamental principle of generating this energy is a loop of wire or disc of copper moving between the poles of a magnet; this movement is created nowadays using fossil as the most used method is using fossil energy.

A long time ago, the world knows that the climate on earth is changing, global warming, The Slowly Ice Melting, are the most known consequences of climate change; this change can make life harder on earth or even impossible. According to researchers, there is widespread proof that the increase in carbon dioxide concentration is one of the leading causes of the observed warming (climate change).

In 2018, if we took the total U.S. electricity generation as an exemplar, the 4.17 trillion kWh from all energy sources resulted in the emission of 1.87 billion metric tons—2.06 billion short tons (A unit of weight equal to 2,000 pounds)—of carbon dioxide (CO2) this equaled about 0.99 pounds of CO2 emissions per kWh. 99% of that electricity was generated using coal, natural gas, and petroleum fuels other than CO2 emissions current extent of fossil fuel availability can be calculated by dividing the known exploit-able reserves by current production. [1]

Back to CO2 emission and that the fossil fuel won't rest forever(for oil, it's just 43 years left. This availability could drop further if there is an increase in annual production), it's almost sure that we won't use it as an energy source at the end of this century. [2]

This challenging situation made the world looking up for another source of energy that is safe for the earth, a source that the world can use for centuries from now, so the world found nothing but renewable energy.

Renewable energy is also known as the permanent energies, clean energies, or energy of the future because it's a constant, available, clean, and free energy source.

The International Energy Agency defined it as " the energy produced from natural sources, which are constantly renewed directly or indirectly. [3]

Most experts agreed on the division of renewable energies to:

-Solar energy: using the silicon cells to transform the sun rays' hyphen to Planet Earth to electricity.

-Wind power: one of the oldest types of energy adopted by the Human (transform it to electrical or mechanical energy)

-Hydropower: this power is generated by the water movement, that spins the water turbines to generate electric power.

-Biomass energy: using the is plant or animal material with a chemical or biochemical way to generate heat or electricity. [3]

-Geothermal energy: The Principle of it is using the heat of the earth's interior in a controlled way so we can use it for heating or if it's hot enough to produce electricity.[2]

to use that energy it requires two boreholes, one to extract hot water from and the second it is where the water is reinjected after heat recovery. [4]

-Hydrogen energy: Hydrogen is the third most factor available in nature [3]. The main application of hydrogen today is in the chemical industry. it is used as an energy source globally, mainly in the aviation sector and in space travel (liquid hydrogen is used as rocket fuel).[2]

The hydrogen is also used to store and transport electricity [3].

This work is interested in the study of one of those forms of renewable energy which is wind energy, and how it can be used to produce electrical energy using an intelligent wind turbine.

In the first chapter, we will present the wind energy in general as one of the most promising options to produce electricity. This chapter allows us to present why we choose this project.

The second chapter is about the machines that convert the wind energy to electricity in general; we have talked about the types, parts of it, especially the generators usually used, and how does it generate electricity.

The second chapter is about the machines that transform the wind energy into electricity in general; we will present the types, parts of it, especially the generators' topology usually used to generate electricity.

The third chapter will be devoted to presenting the design of the different parts of our wind turbine and its control system based on Arduino Uno.

Chapter I:

Wind energy

Chapter I: Wind Energy

I.1. Introduction:

Wind energy becomes today a promising option to complement the conventional energy source, especially in regions where the existing power plants are not sufficient to match the increasing electricity demand.

If we wanted to give a simple definition for the wind energy, we could say that: it's the conversion of wind energy to a useful form of energy, such as using wind energy to produce electrical power, wind pumps for water pumping or drainage, windmills for mechanical power, or sails to propel ships.

In this chapter, we will present the wind energy in general, its history, and the current state of it in the world and Algeria.

I.2. History of wind energy:

The wind has played a long and important role in the history of human civilization. This energy was almost the only source of power for ships until the 18th Century were Watt invented the steam engine.

the ancient Egyptians have been harnessing the energy of the wind to propel boats along the Nile River as early as 5000 B.C.

By 200 B.C., in china the simple windmills were pumping water, while vertical-axis windmills with woven reed sails were grinding grain in Persia and the Middle East.[5]

By the 11th century, people in the Middle East were using windmills extensively for food production; returning merchants and crusaders carried this idea back to Europe.

Centuries later, in Holland the people improved the basic design of the windmill. They gave it propeller-type blades made of fabric sails and invented ways for it to change direction so that it could continually face the wind.[5]

The wind continued to be a major source of energy in Europe through the period just prior to the Industrial Revolution, but began to recede in importance after that time, the reason was the invention of the steam engine. [6]

In the 1930s, based on the Danish experience the Rural Electrification Administration's programs brought inexpensive electric power to most rural areas in the United States. [5]

In the 1940s the world's first megawatt-size wind turbine began operating on a Vermont hilltop known as Smith–Putnam wind turbine. This turbine, rated at 1.25 Mwh.[5]

Figure 1: Smith–Putnam Wind turbine

after the oil embargoes of the 1970s, the world started looking back for wind energy, the wind turbines had reached a high level of design sophistication, [6]

Over the last 25 years, the size of the largest commercial wind turbines has increased from approximately 50 kW to 2 MW, in 2001 The total installed capacity in the world was approximately 20,000 MW, with the majority of installations in Europe.[6]

So, the lessons learned from more than a decade of operating wind power plants, along with continuing R&D, have made wind-generated electricity very close in cost to the power from conventional utility generation in some locations. Wind energy is the world's fastest-growing energy source and will power industry, businesses and homes with clean, renewable electricity for many years to come.

I.3. Wind causes:

First, the wind is the motion of air gases (molecules) on a large scale, to understand what causes the wind we must know what the air molecules comprise are and what is the relation between that and air pressure.

Air comprises molecules of 78% nitrogen by volume, about 21% of oxygen, and other gases (water vapor, methane, ozone, carbon dioxide…). [7]

When the gases that make up our atmosphere warms-up (by the sun) the atoms and molecules move faster, spread out, and rise (low air pressure area), the opposite happens when the air gets colder the gases get slower and closer together (air pressure is high) [8]. Because the sun hits different parts of the Earth at different angles, and because Earth has oceans, high, and lower places, and other features, the temperature on earth is different (some places are warmer than others), as a fact this makes a difference in air pressure, this makes the gases move from high-pressure areas to low-pressure areas, that movement gets faster when the difference between high and low-pressure areas is bigger.[7]

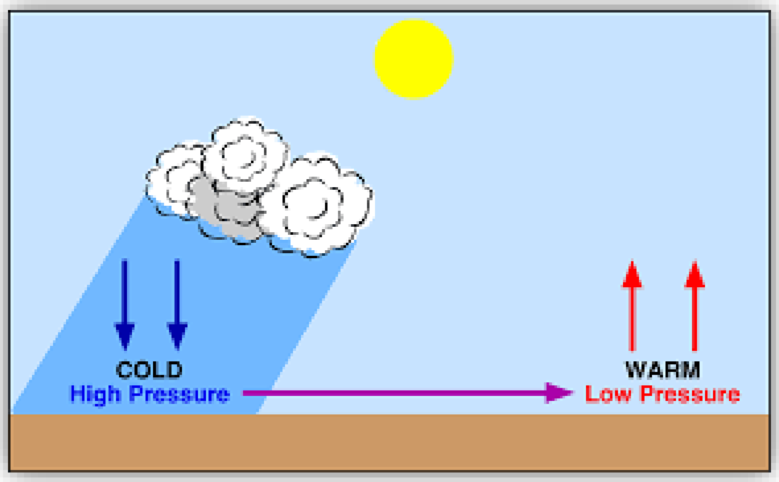


Figure 2: causes of wind

I.4. Wind power:

Kinetic energy exists whenever an object with a mass is in motion (translational or rotational). When air is in motion the kinetic energy can be determined as:

$$E_k = \frac{1}{2} m \bar{u}^2 \tag{1}$$

With:

m: the air mass.

$\bar{u}$: the mean wind speed over a suitable time period.

By differentiating the kinetic energy in wind from the last equation concerning time, we can obtain the wind power, i.e.:

$$P_w = \frac{dE_k}{dt} = \frac{1}{2} \dot{m} \bar{u}^2 \tag{2}$$

When the wind passes through the wind turbine and makes the blades turn, the corresponding wind mass flowrate is:

$$\dot{m} = \rho A \bar{u} \tag{3}$$

With: ρ: the air density

A: the swept area of blades

Substituting the last two equations, the available power in wind Pw can be expressed as:

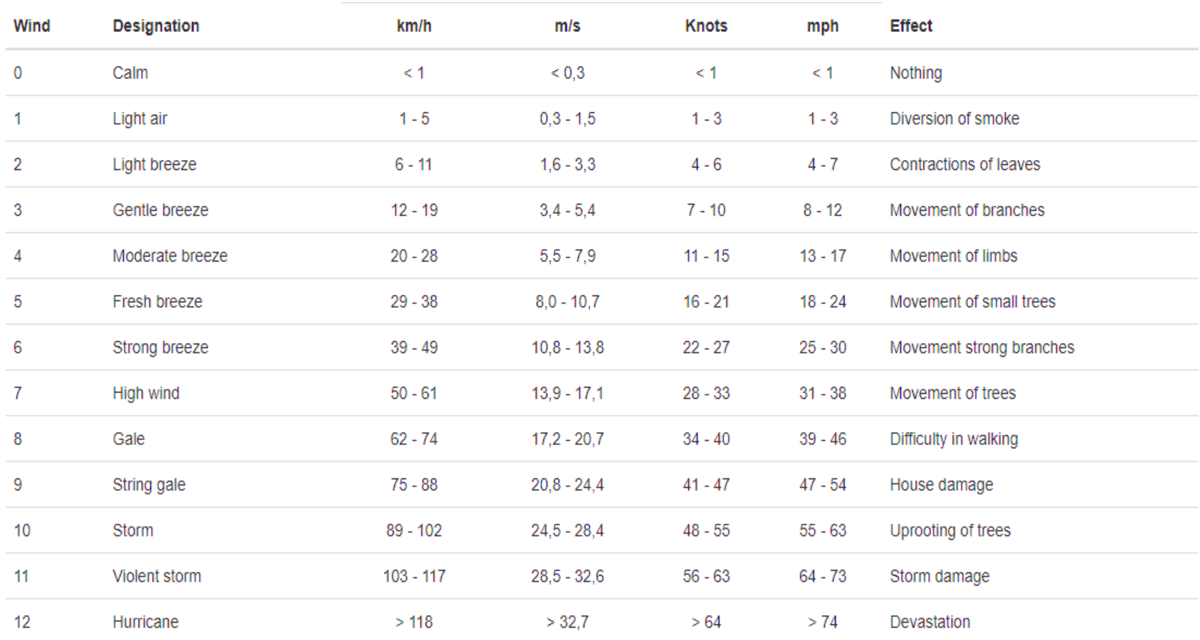
$$P_w = \frac{1}{2} \rho A \bar{u}^3 \tag{4}$$

from the last equation (*eq* 4) we can reveal that: to obtain higher wind power, it requires a higher wind speed, a higher air density, and a larger swept area that we improve using a longer length of blades [9].

I.5. Wind energy characteristics:

Determining the characteristics of wind resources and developing techniques for accurate assessment of wind power potential at a site are increasingly gaining importance. This information can enhance economic power with advantageous projects in terms of competitiveness.[10]

The hydrographer Francis Beaufort devised a scale called the Beaufort scale; this scale is a result of empirical measure that relates wind speed. it's the most known scale for classification the wind according to their speed, it's used to give and precise and objective criteria to assess wind conditions.[11]



Wind	Designation	km/h	m/s	Knots	mph	Effect
0	Calm	< 1	< 0,3	< 1	< 1	Nothing
1	Light air	1 - 5	0,3 - 1,5	1 - 3	1 - 3	Diversion of smoke
2	Light breeze	6 - 11	1,6 - 3,3	4 - 6	4 - 7	Contractions of leaves
3	Gentle breeze	12 - 19	3,4 - 5,4	7 - 10	8 - 12	Movement of branches
4	Moderate breeze	20 - 28	5,5 - 7,9	11 - 15	13 - 17	Movement of limbs
5	Fresh breeze	29 - 38	8,0 - 10,7	16 - 21	18 - 24	Movement of small trees
6	Strong breeze	39 - 49	10,8 - 13,8	22 - 27	25 - 30	Movement strong branches
7	High wind	50 - 61	13,9 - 17,1	28 - 33	31 - 38	Movement of trees
8	Gale	62 - 74	17,2 - 20,7	34 - 40	39 - 46	Difficulty in walking
9	String gale	75 - 88	20,8 - 24,4	41 - 47	47 - 54	House damage
10	Storm	89 - 102	24,5 - 28,4	48 - 55	55 - 63	Uprooting of trees
11	Violent storm	103 - 117	28,5 - 32,6	56 - 63	64 - 73	Storm damage
12	Hurricane	> 118	> 32,7	> 64	> 74	Devastation

Table 1: : Beaufort scale [7]

I.5.1. Wind speed:

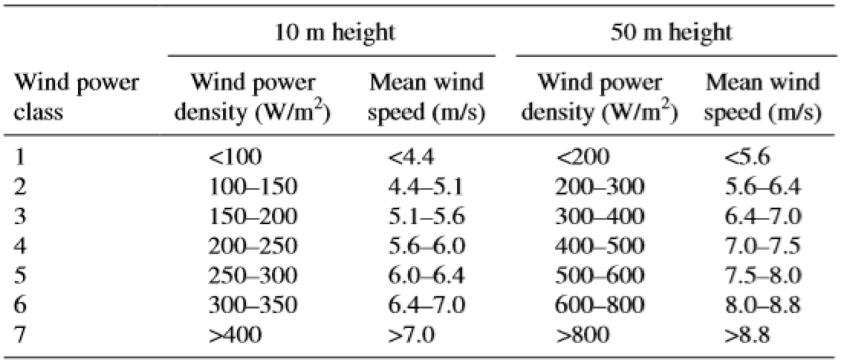
The wind speed is one of the things we need to know to calculate the total wind power, it can be measured using a wind gauge or anemometer.

From $eq4$ the amount of energy in the wind varies with the cube of the wind speed, so small changes in wind speed results in a larger increase in the wind power.[12]

1.5.2. Density of the air:

Air density is the available wind power in airflow through a perpendicular cross-sectional unit area in a unit time period [9]. The denser the air, the more energy received by the turbine, the temperature is the principal controller of the density of air (warm air is less dense than cold air).[12]

The classes of wind power density at two standard wind measurement heights are listed in Table [9]:



	10 m height		50 m height	
Wind power class	Wind power density (W/m^2)	Mean wind speed (m/s)	Wind power density (W/m^2)	Mean wind speed (m/s)
1	<100	<4.4	<200	<5.6
2	100–150	4.4–5.1	200–300	5.6–6.4
3	150–200	5.1–5.6	300–400	6.4–7.0
4	200–250	5.6–6.0	400–500	7.0–7.5
5	250–300	6.0–6.4	500–600	7.5–8.0
6	300–350	6.4–7.0	600–800	8.0–8.8
7	>400	>7.0	>800	>8.8

Table 2: Classes of wind power density[4]

I.5.3. Swept area of the turbine:

The swept area of the turbine is the area refers to the circle created by the blades as they turn.

the size of this area controls the power the turbine can capture from the wind, the larger the swept area the more power.[12]

To find the swept area, we use the equation to find the area of a circle:

$$Area = \prod r^2$$

With: r = radius of the circle. This is equal to the length of one of the blades.

We need to know the swept area of the wind turbine to calculate the total power in the wind the Intended turbine.

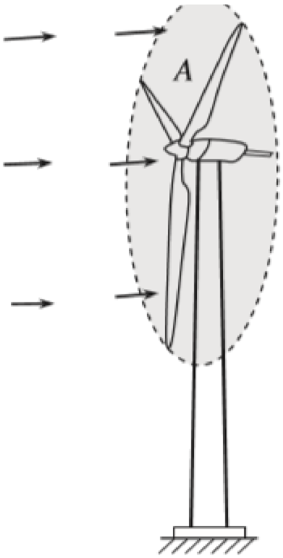


Figure 3: Swept area of wind turbine blades

I.6. wind energy in the world:

I.6.1. wind in the world:

The publishing of studies about the variation of the wind speed according to temporal and spatial variations started early in the USA as early as 1942, in 1981 the Northwest Laboratory (in Washington (USA)) published the first atlas of wind energy resources [4].

The objectify of it was to know where are the best places to invest in wind energy putting wind farms because the wind speed is the important variable in the wind power equation.[4]

the next figure (Fig.4) shows the atlas of mean wind speed at 100m from 1979 to 2013:

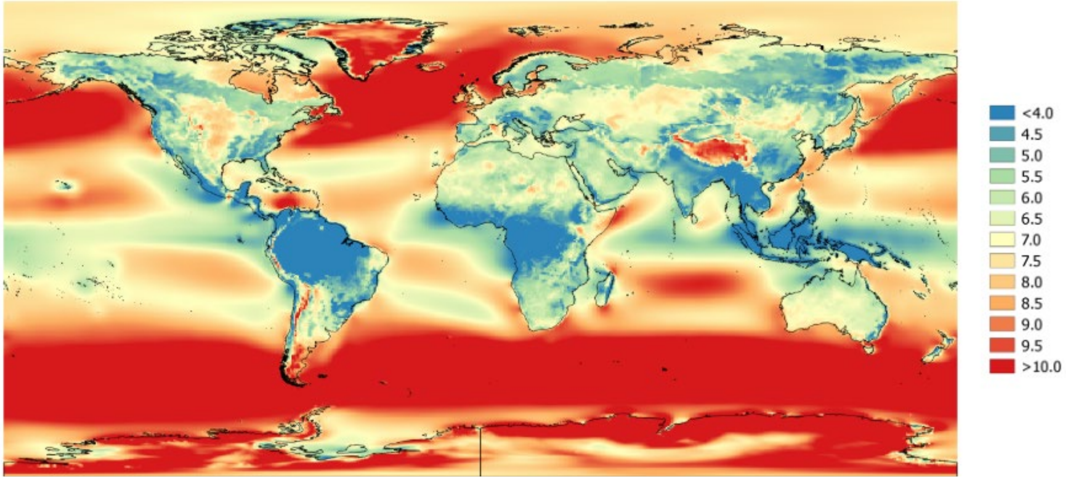


Figure 4: Mean wind speed at 100m from MERRA reanalysis. Period 1979-2013.

I.6.2. Wind energy in the world:

Since the modern wind industry was born when the first commercial wind farm started generating electricity at Crotched Mountain in Southwest New Hampshire at the end of 1980, the wind energy industry has been growing up fastly. Germany and Danish started just after the US investment in that industry, followed by Spain, and other countries like India in 1986.[14]

2017 was a good year for the global wind power, new records were set for hourly, daily, and annual wind-generated electricity. For example, Portugal covered 110% of national consumption with wind-generated electricity during three hours, from Asia the Chinese wind energy production increased by 26% to become 305.7 TWh. In Denmark, wind achieved a 43% share of the energy mix—the largest share of any IEA Wind TCP member countries. [15]

The wind energy continues its growing up in the world as one the most energies used to produce electricity, the GWEC Market Intelligence expects new installations for onshore and offshore of more than 55 GW each year until 2023.[39]

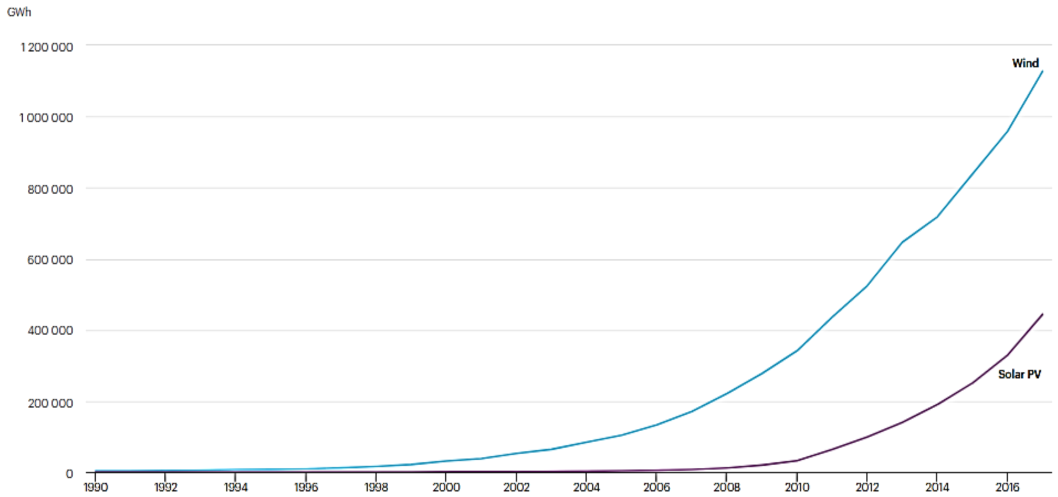


Figure 5:Electricity generation by source 1990-2017(IEA, Data and statistics)

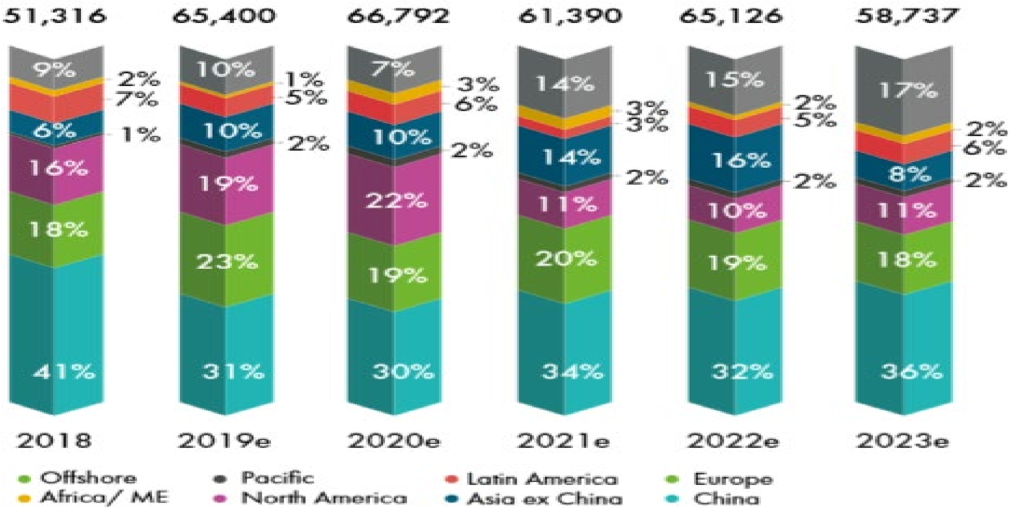


Figure 6: New installations outlook by region [16]

I.7. Wind Energy in Algeria:

I.7.1. Wind in Algeria:

Wind power usually changes from a topographic area to another, also it depends on the climate.

Algeria as one of the biggest countries in the world there is a big difference in climate between the northern and the southern halves, the difference in climate. The northern half has a mild Mediterranean climate, the winds aren't strong in this part of the country as the southern ones, in the Sahara which is the southern part the climate is the desert climate. The southern winds speeds range from 4m/s - 6m/s. [16]

The first Algerian works on the wind potential were published by M. Said M and A. Ibrahim in 1984 [4].

The Algerian first wind map, related to measured data at 10 m above ground level (fig7), shows that a maximum of mean wind speed is reached in a South – West (Adrar region) of the country with a value of 6.5 m/s. [17]

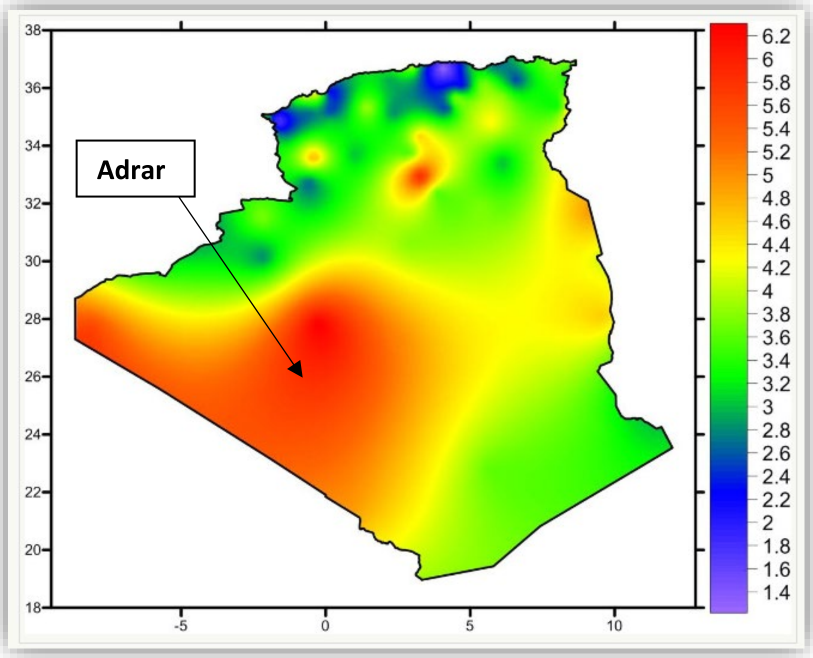


Figure 7: Annual winds map (m/s) in 10m estimated by Dr Boudia (2013)

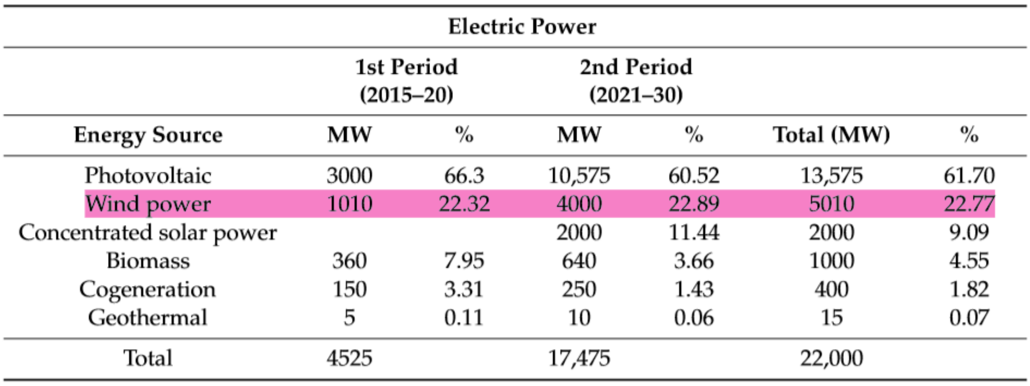
I.7.2. Wind Energy in Algeria:

Algeria is considered to be one of the most energy-consuming countries, with the contribution of fossil fuels in electricity generation at more than 98.75% in 2016.[14]

In that context, the Algerian government's renewable energies strategy the wind energy is the second axis of it [18], In 2011, Algeria adopted the Algerian Renewable Energy and Energy Efficiency Development Plan. The main objective of the government's plan was to increase the usage of renewable energy, the plan was on three stages, it meant to produce 12,000 MW for the national market. [19]

In 2014 The country's first and only wind farm was constructed in Kabertene (Adrar), with a generation capacity of 10 MW. There are also plans to install two wind farms of 20 MW generating capacity each, but these have yet to be built.

The government plan for the wind energy for 2030 is to reach 1.7 GW. [18]



Electric Power						
	1st Period (2015–20)		2nd Period (2021–30)			
Energy Source	**MW**	**%**	**MW**	**%**	**Total (MW)**	**%**
Photovoltaic	3000	66.3	10,575	60.52	13,575	61.70
Wind power	1010	22.32	4000	22.89	5010	22.77
Concentrated solar power			2000	11.44	2000	9.09
Biomass	360	7.95	640	3.66	1000	4.55
Cogeneration	150	3.31	250	1.43	400	1.82
Geothermal	5	0.11	10	0.06	15	0.07
Total	4525		17,475		22,000	

Table3: RE targets for the electricity production of the Algerian national program of RE and energy efficiency (2015–30) [13].

Figure 8: Wind farm (Kabertene Adrar)

I.7.3. Wind energy challenges in Algeria:

Just like the other renewable energy, developers and investors can face some challenges:

- Algeria has less experience in wind generation.
- Intermittency: like solar power, wind energy is dependent on the weather, so if the wind energy isn't available all time.[19]

- Grid integration: make a connection to the grid will be hard the reason goes back to geographies of the Algerian desert.[19]
- the location of the wind farms (Sahara) makes the imply higher-than-normal maintenance costs.[18]
- Wind development may be slower to take off due to lower levels of competition than solar. [18]

I.8. Conclusion:

In this chapter, we have discussed the wind energy as one of the most promising renewable energies, and its uses threw history, its causes, how it is created, and some statistics about its growth globally and especially in Algeria.

In what follows, we will focus on wind turbines and electricity production by wind energy.

Chapter II:

Wind turbines

Chapter II: Wind turbines

II.1. Introduction:

Using conventional Fossil energy sources such as natural gas, oil, coal, or nuclear to produce electricity is based on transforming the power that they can give to kinetic energy using heat engines. That energy rotates the electromechanical generators to produce finally electricity based on Faraday's law. On the same law, to produce electricity from the wind it needs a wind turbine, a converter of the kinetic energy associated with the wind.

Two great classes of wind turbines exist, the horizontal- and vertical-axis ones. The conventional wind turbines, horizontal-axis wind turbines (HAWT), spin about a horizontal axis. As the name implies, a vertical-axis wind turbine (VAWT) spins about a vertical axis.

The most common designs of wind turbines and detailed information about them will be given in this chapter.

II.2. Wind turbines:

A wind turbine is a rotating machine that converts the wind kinetic energy into mechanical energy. If the mechanical energy is converted to electricity, the machine is called a wind turbine.

Wind turbines can be separated into two types based on the axis in which the turbine rotates as Horizontal Axis Wind Turbines and Vertical Axis Wind Turbines. The former is more commonly used due to several inherent advantages, the latter being used on a small scale.[20]

Figure 9: wind turbine

II.3. Classification of wind turbines:

II.3.1. Vertical Axis Wind Turbine:

VAWTs were the first structures developed to generate electricity. Many technological variants have been tested, of which only two structures have reached the industrialization stage, the Savonius rotor, and the Darrieux rotor, the axis of rotation of this type is vertical to the ground and perpendicular to the direction of the wind.[20]

Nowadays, this type of wind turbine is rather marginal, and its use is much less widespread.[21]

II.3.1.1. Types of VAWT:

A wide variety of VAWTs have been proposed over the past few decades and a number of excellent bibliographies on VAWTs have been published that summarize research and development of these devices, including the survey by Abramovich (Abramovic, 1987). the most tow important types of rotor design are highlighted in the following sections.[20]

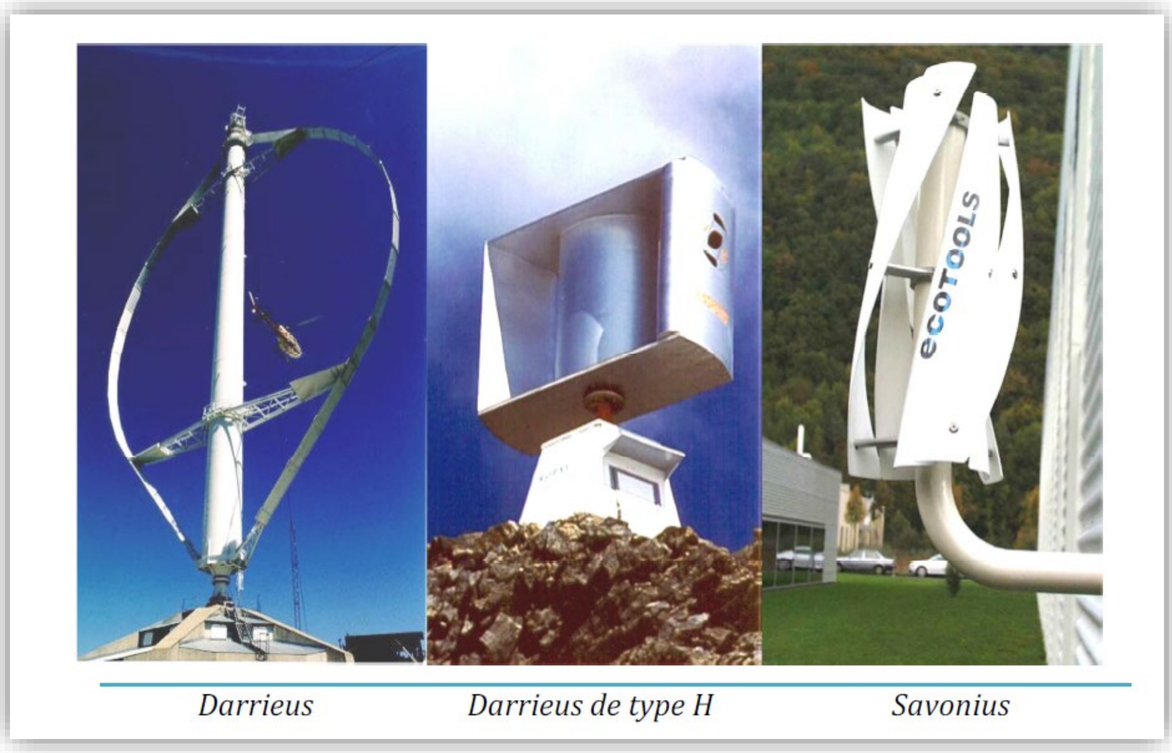


Figure 10: Vertical Axis Wind Turbines

a). Savonius rotor:

S.J. Savonius patented the Savonius turbine in 1929[22], it has been popular with both professional and amateur wind turbine developers over the years, not least because of its simple and robust construction.

Many variations of the Savonius rotor have been developed and tested. However, because of the high solidity and hence the high mass of the Savonius turbine, it has not been used for large-scale electricity production.[20]

The work operation of this type is based on the principle of differential drag. The forces exerted by the wind on each of the faces of a hollow body are of different intensities. This results in a torque causing the rotate of the turbine.[]

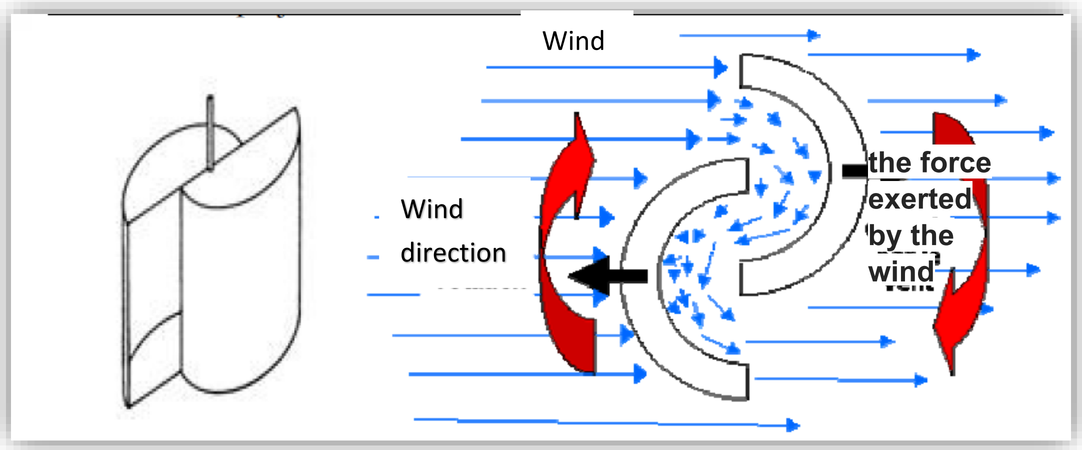


Figure 11:Savonius rotor:

b). Darrieus Rotor:

The Darrieus turbine type is theoretically just as efficient as the propeller type if the wind speed is constant. Still, in practice, this efficiency is rarely realized due to the physical stresses and limitations imposed by a practical design and wind speed variation.[23]

It's composed of It consists of 2 or 3 convex blades with airfoil cross-section the blades are mounted symmetrically on a vertical shaft. A small powered motor is required to start its rotation since it is not self-starting. When it already has enough speed, the wind passing through the airfoils generates torque, and thus, the rotor is driven around by the wind. The Darrieus turbine is then powered by the lift forces produced by the airfoils. The blades allow the turbine to reach speeds that are higher than the actual speed of the wind; this makes them well-suited to electricity generation when there is a turbulent wind.[24]

Figure 12: Darrieus Type rotor (VAWT)

II.3.1.2. Advantages of VAWTs:

Just like the HAWT, the VAWT also comes with a handful of advantages over the HAWT, namely:

- since VAWT components are placed nearer to the ground, it is more accessible access to maintenance.
- These have lower startup speeds than their horizontal counterparts. These can start at speeds as low as 10Kmph.
- These have a lower noise signature.
- The vertical design offers the advantage of putting the multiplier, generator, and control units directly on the ground.
- the VAWTs are cross-flow devices and therefore accept wind from any direction.

II.3.1.3. Disadvantages of VAWTs:

The disadvantages of the VAWT, on the other hand, are:

- VAWTs' have lower efficiency as compared to HAWTs' because of the additional drag produced due to the rotation of blades.
- airflow near the ground and other objects can create turbulent flow, introducing issues of vibration.

- Because of their low height, they cannot capture the wind energy stored in higher altitudes.

II.3.2. Horizontal Axis Wind Turbines:

The HAWT (horizontal axis wind turbine) is the most familiar turbine configuration. consists of a tower and a nacelle that is mounted on the top of a tower which is based on a pedestal. the reason why it called horizontal axis turbines is that the axis of the rotor's rotation is parallel to the wind stream and the ground.[25]

The working Principe of HAWT is when the wind passes over the blades it creates aerodynamic lift, causing rotation. Lift is formed because of the difference in the pressures of the top and bottom surfaces this difference is created when the wind passes more rapidly on one side of the blade more than the other side, which means that the air pressure on one side is higher than the pressure on the other side. the rotation is transmitted via the rotating shaft at the center of the wind turbine. [24]

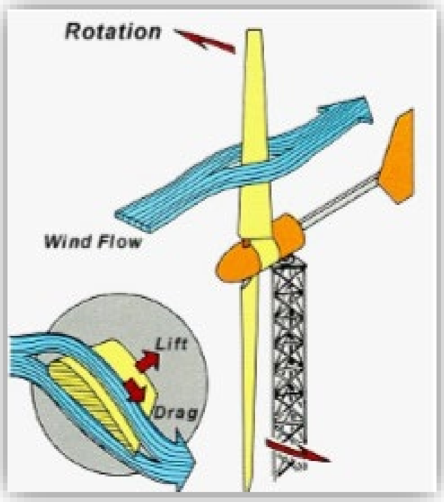


Figure 13: Principle behind HAWTS

Most often, the rotor of these wind turbines is three-bladed because three blades constitute a good compromise between the power coefficient, the cost, and the speed of rotation of the wind generator as well as the aspect aesthetic compared to two-bales.

Horizontal Axis Wind Turbines have two kinds: the upwind wind turbine (the rotor is on the upwind side of the tower) and the downwind wind turbine (fig.14) where the rotor is on the downwind side of the tower. these turbines are two- or three-bladed, though some may have fewer or more blades.[24]

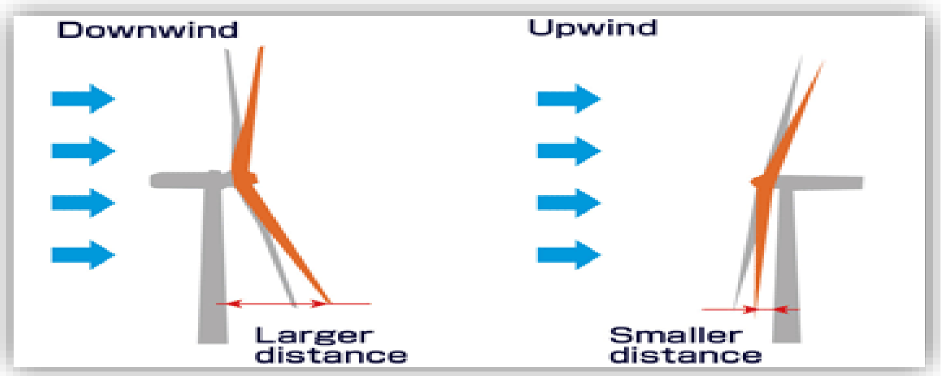


Figure 14: Upwind and Downwind Wind Turbine Upwind and Downwind Wind

II.3.2.1. Advantages of HAWTs:

The advantages of the HAWT over the VAWT, can be summarized in:

- Variable blade pitch, which gives the turbine blades the optimum angle of attack. Changing the angle of attack provides greater control over power generated and enables maximum efficiency.[22]
- As wind energy increases with height, the tall tower allows access to the stronger wind in sites with wind shear and placement on uneven land or in offshore locations.[22]
- blades are to the side of the turbine's center of gravity, helping stability.
- A minimal footprint compared to vertical axis wind turbines. [26]
- The generator and control units are in the nacelle at the top of the tower. Thus, it is not necessary to add a room for the equipment [26].
- can be cheaper because of the higher production volume. [26]

II.3.2.2. Disadvantages: [22]

On the other hand, the disadvantages of the HAWT compared to the VAWT is that:

- Due to inherent large structures, construction costs are very high, and so are transportation costs.
- Civil construction is costly due to the erection of large towers.
- Wind turbine operation often leads to the production of electronic noise, which affects radar sites.

- In the case of downwind, HAWT's regular turbulence produced leads to structural failure.
- HAWTs require an additional yaw control mechanism to turn the blades toward the wind.
- it has difficulties operating near the ground.

Despite its drawbacks, this structure is the most used type nowadays. However, vertical axis structures are still used for power generation in isolated areas. They are low power intended for permanent uses such as battery charging, for example [26]

II.4. Overview of Wind Turbine Components:

Developments and improvements have taken place since the commercialization of wind technology in the early 1980s, but the basic architecture of the mainstream design has changed very little. [27] A wind turbine consists of a tower and a nacelle that is mounted on the top of a tower. The nacelle contains several components, which contribute with their specific function in the energy conversion process from wind energy into electrical energy. Fig.15 shows the main components of a wind turbine, including the turbine rotor, transmission system (gearbox), generator, possible power electronics, a control system, transformer, and finally, its connection to the grid.[28]

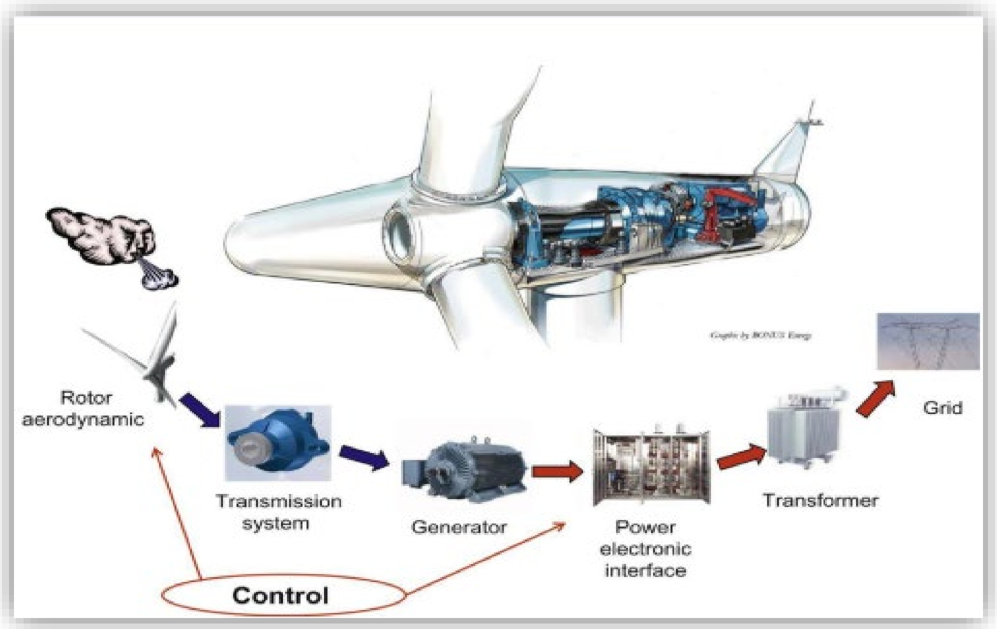


Figure 15:: Wind turbine components

II.4.1. Aerodynamic Rotor:

Most wind turbines have upwind rotors and are actively yawed to preserve alignment with the wind direction so they can capture the power from the wind and converts it to kinetic mechanical energy. The aerodynamic rotor is mainly made up of a hub and blades, with the latter attached to the hub by mechanical joints. Modern wind turbines typically have two or three blades, made up by a matrix of fiberglass mats impregnated with polyester.[28]

II.4.2. Transmission System:

The transmission system is all hosted in the nacelle, which is positioned on the top of a wind tower. The kinetic mechanical power from the aerodynamic rotor is transmitted to the generator through a transmission system, which typically consists of the rotor shaft, mechanical brake(s), and a gearbox.[28]

The mechanical brakes are usually used as a backup system for the aerodynamic braking system of the wind turbine in high wind conditions and/or as a parking brake once the turbine is stopped. it is either a mechanical, electrical. [28]

The primary purpose of the gearbox is to act as a rotational speed increaser; the gearbox of a wind turbine steps-up or steps down the speed of the torque rotation of the aerodynamic rotor into the much faster or slower rotation and with suitable coupling transmits rotating mechanical energy at an appropriate speed to the generator.[22]

As a result, in some of the newer wind turbines technologies, the gearbox has been removed, by designing generators, with a multipolar structure to adapt the rotor speed to the generator speed. The generator speed decreases by increasing the number of pole pairs. Therefore, the gearbox may not be necessary for multipole wind turbine generator systems, i.e., where the number of pole pairs may be higher than 100.[28]

II.4.3. Generator:

Wind turbines are categorized by generator form which is an electromechanical component that converts the mechanical power into electrical power. Even though there are a range of machines that can do the job, each one provides different advantages and disadvantages [29]

Some machines require precise control of the terminal voltages and currents, while others do not. Some are capable of operating over a wide range of conditions, while others are quite limited. In general, the use of power electronic converters is essential to maintaining the efficient operation of the generator.[29]

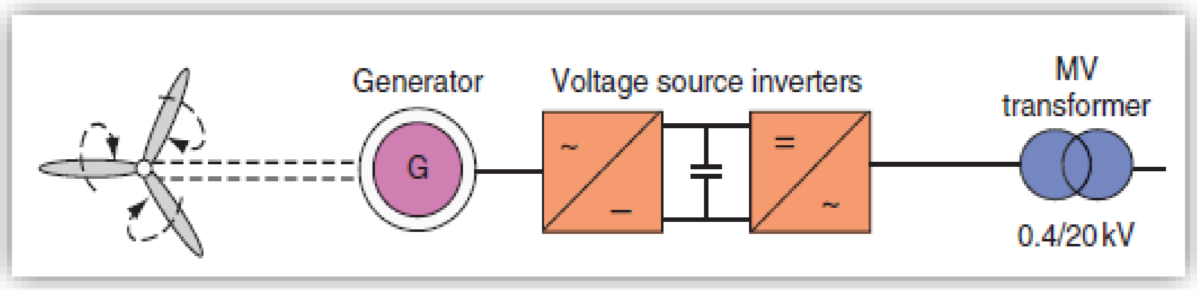


Figure 16: Wind turbine electrical system.

The generators usually used in wind turbines are listed in the paragraphs below:

II.4.3.1 Synchronous Generator:

The SG is a generator, which operates at the synchronous speed, dictated by the frequency of the connected grid, regardless of the magnitude of the applied torque. The magnetic field in the SG can be created by using permanent magnets or with a conventional field winding.

The speed of the SG is determined by the frequency of the rotating field and by the number of pole pairs of the rotor. If the SG has a suitable large number of poles (i.e., multipole structure) it can be used for direct-drive applications without the need of a gearbox.[28]

The SG is more expensive and mechanically more complicated than an asynchronous generator of a similar size. However, it has one significant advantage compared with the asynchronous generator, namely, that it does not need reactive magnetizing current and thus no further power compensation equipment.[28]

Two classical types of SGs are often used in the wind turbine industry:

a). Wound rotor synchronous generator (WRSG): Its stator windings are connected directly to the grid and hence the rotational speed is strictly fixed by the frequency of the supply grid. The rotor winding, through which direct current (DC) flows, generates the exciter field, which rotates with synchronous speed.[28]

SCHEMATIC DIAGRAM (WRSG direct-drive wind turbine):

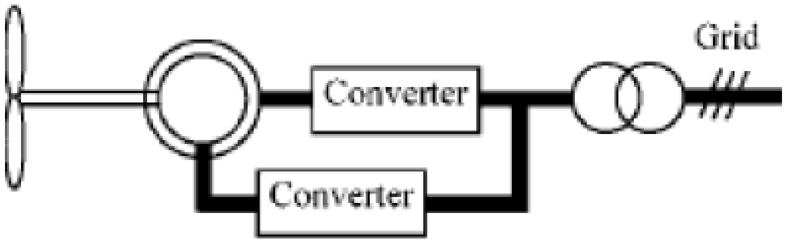


Figure 17:SCHEMATIC DIAGRAM (WRSG direct-drive wind turbine)

The amplitude and frequency of the voltage can be fully controlled by the power electronic converter at the generator side, so that the generator is fully controllable over a very wide range, even to very low speeds addition, the WRSG has the opportunity of controlling the flux for minimized loss in different power ranges, because the excitation current can be controlled by means of the power converter on the rotor side.[30]

The detailed description of the converter used is:

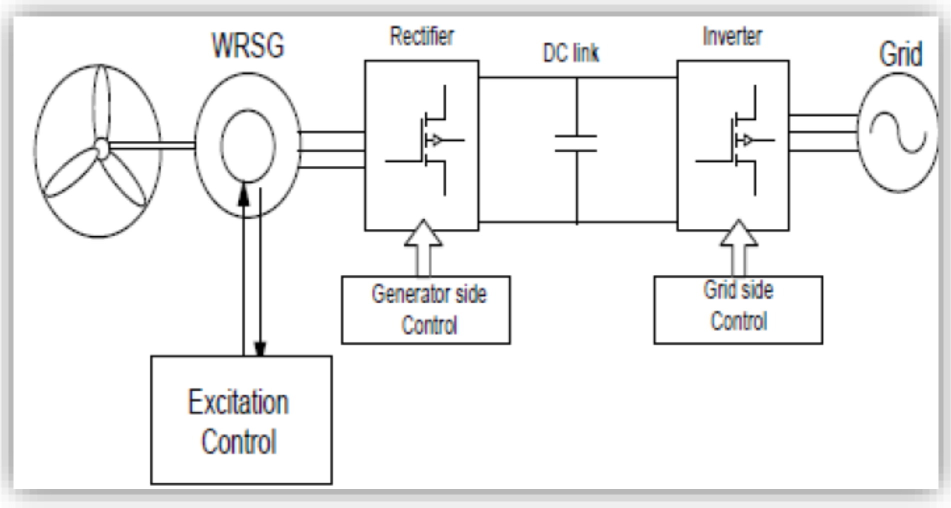


Figure 18:detailed description of the converter used

The load characteristics and power factor can be controlled by controlling magnetizing current i.e DC excitation provided to rotor winding. A back to back converter is used to improve the performance [30].

b) Permanent magnet synchronous generator (PMSG) :

Permanent magnet synchronous generator (PMSG) has a wound stator, while its rotor is provided with a permanent magnet pole system. It has high efficiency as its excitation is provided without any energy supply. However, the materials used for producing permanent magnets are expensive and they are difficult to manufacture. Additionally, the use of permanent magnets excitation requires the use of a full-scale power converter in order to adjust the voltage and frequency of generation to the voltage and the frequency of transmission the most common types are the radial flux machine, the axial flux machine, and the transversal flux machine.[28]

SCHEMATIC DIAGRAM (Simple model):

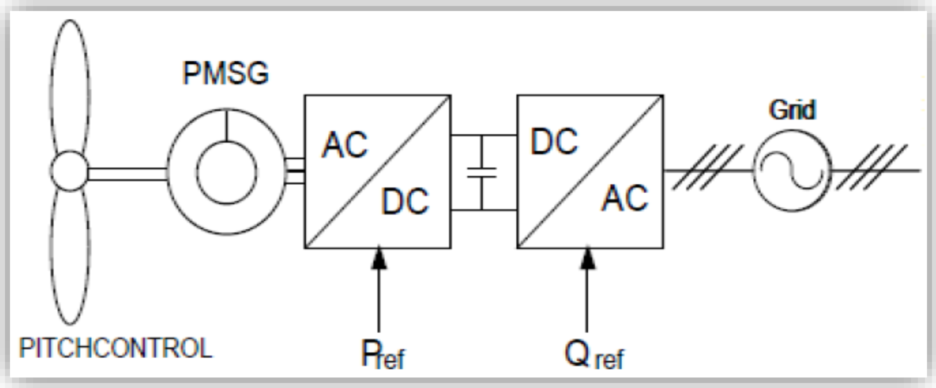


Figure 19:SCHEMATIC DIAGRAM (PMSG Simple model)

the most popular converter topology for PMSG based WECS (wind energy conversion systems) is back to back frequency converter. Advantages of this technology are that, it provides active and reactive power control and also increases power factor because of Pulse Width Modulation techniques. The schematic diagram showing the use of this converter is shown in the fig.20: [30]

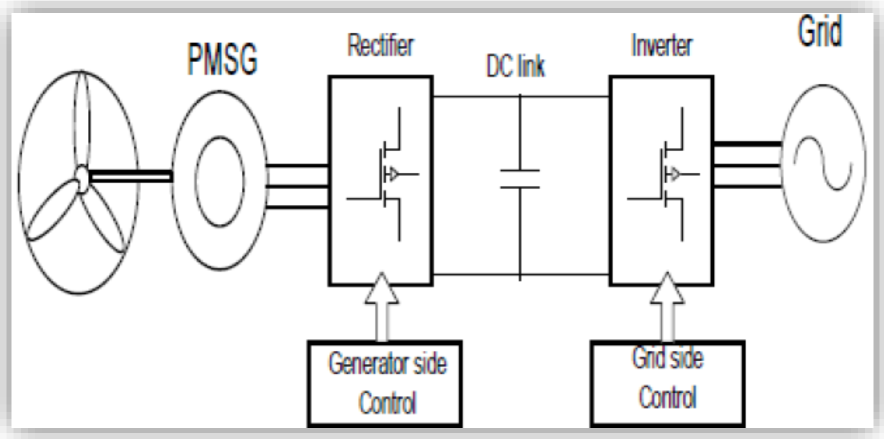


Figure 20: The popular converter topology for PMSG

II.4.3.2. Asynchronous (induction) generators:[31]

‘Asynchronous’ or ‘induction’ generators were not the first choice for most applications until the wind power industry found a suitable use for them.

In the induction generator, the stator windings are essentially the same as those of asynchronous ones. However, the rotor windings are electrically short-circuited and frequently have no external connections; currents are ‘induced’ by transformer action from the stator windings.

The synchronous speed, n_s, of the rotor of an induction generator is given by:

$$n_s = \frac{f}{p}$$

where f is grid frequency in Hz and p the number of poles. Due to slip, s, the generator rotor speed is a few percent above the slip,

$$s = \frac{n_s - n_m}{n_s}$$

where n_m denotes mechanical speed. The electrical efficiency of induction generators is a function of the nominal slip. In megawatt turbines, the nominal slip is below 1%. Due to absorption of reactive power from the grid, power factor $cos\,\varphi$ is comparatively low (~0.87). Smaller induction machines have higher nominal slip with correspondingly poorer efficiency.

a). Constant speed wind turbine with squirrel cage induction generator:

For fixed-speed induction generators, the stator is connected to the grid via a transformer, and the rotor is connected to the wind turbine through a gearbox. The rotor speed is considered to be fixed.

Up until 1998, most wind turbine manufacturers built fixed-speed induction generators of 1.5 MW and below. These generators normally operated at 1500 revolutions per minute (rpm) for the 50 Hz utility grid, with a three-stage gearbox.[32]

SCHEMATIC DIAGRAM:

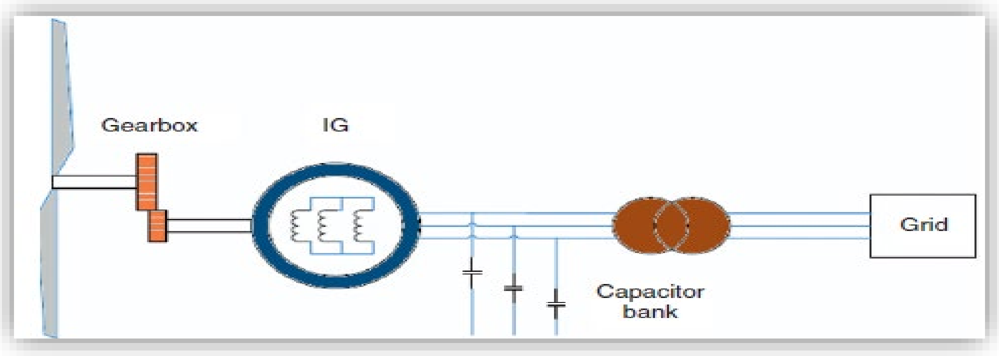


Figure 21: Squirrel-cage generator interconnection

b). doubly fed induction generator:

A doubly-fed induction generator (DFIG) is basically a standard, wound rotor induction machine with its stator windings directly connected to the grid and its rotor windings connected to the grid through a converter.

The AC/DC/AC converter is divided into two components: the rotor side and the grid side. These converters are voltage-sourced converters that use forced-commutated power electronic devices to synthesize an AC voltage from a DC source, which is a capacitor. A coupling inductor is used to connect the grid-side converter to the grid. The three-phase rotor winding is connected to the rotor-side converter by slip rings and brushes and the three-phase stator windings are directly connected to the grid.[31]

SCHEMATIC DIAGRAM:

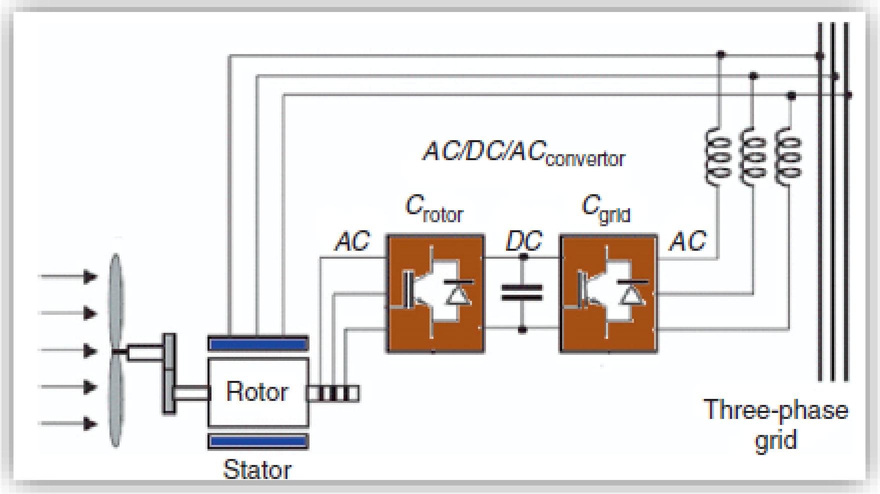


Figure 22: Geared double-fed induction generator

c). WOUND ROTOR INDUCTION GENERATOR (WRIG):

In the case of a WRIG, the electrical characteristics of the rotor can be controlled from the outside, and thereby a rotor voltage can be impressed. The windings of the wound rotor can be externally connected through slip rings and brushes or by means of power electronic equipment, which may or may not require slip rings and brushes. By using power electronics, the power can be extracted or impressed to the rotor circuit and the generator can be magnetized from either the stator circuit or the rotor circuit. It is thus also possible to recover slip energy from the rotor circuit and feed it into the output of the stator. The disadvantage of the WRIG is that it is more expensive and not as robust as the SCIG.[33]

SCHEMATIC DIAGRAM:

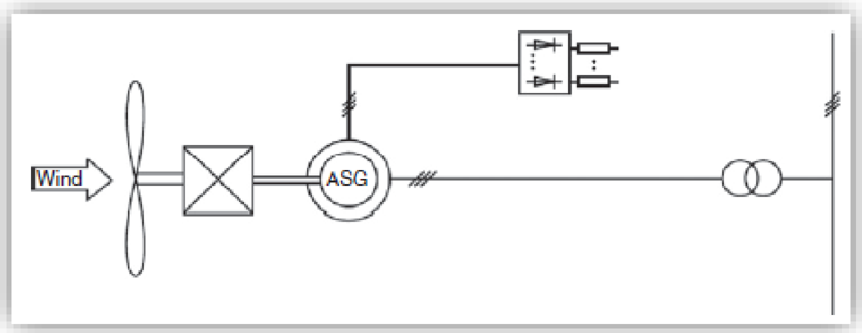


Figure 23:Slip-ring induction generator with resistors.

The external resistors will only be connected in order to produce the desired slip when the load on the wind turbine increases.

Using external resistors instead of a rotor with higher slip has a positive effect on the cooling of the generator. [31]

II.4.3.3. DC Generator Technologies: [32],[34]

In conventional DC machines, the field is on the stator, and the armature is on the rotor. The stator comprises a number of poles which are excited either by permanent magnets or by DC field windings. If the machine is electrically excited, it tends to follow the shunt-wound DC generator concept.

An example of the DC wind generator system is illustrated in Fig.24. It consists of a wind turbine, a DC generator, an insulated gate bipolar transistor (IGBT) inverter, a controller, a transformer, and a power grid. For shunt-wound DC generators, the field current (and thus magnetic field) increases with operational speed whilst the actual speed of the wind turbine is determined by the balance between the WT drive torque and the load torque. The rotor includes conductors wound on an armature which are connected to a split-slip ring commentator.

Electrical power is extracted through brushes connecting the commentator which is used to rectify the generated AC power into DC output. Clearly, they require regular maintenance and are relatively costly due to the use of commutators and brushes.

In general, these DC WTGs are unusual in wind turbine applications except in low power demand situations where the load is physically close to the wind turbine, in heating applications, or in battery charging.

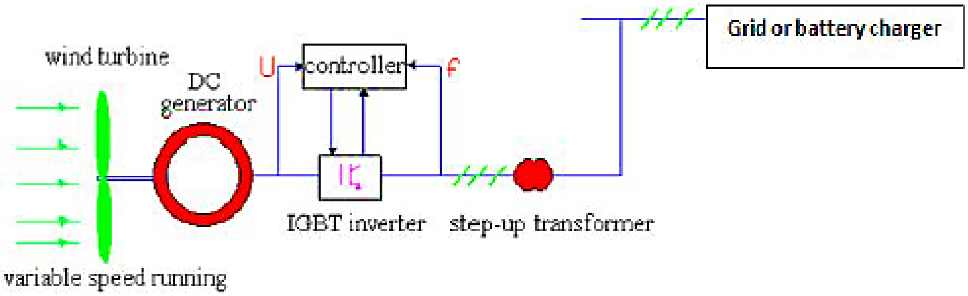
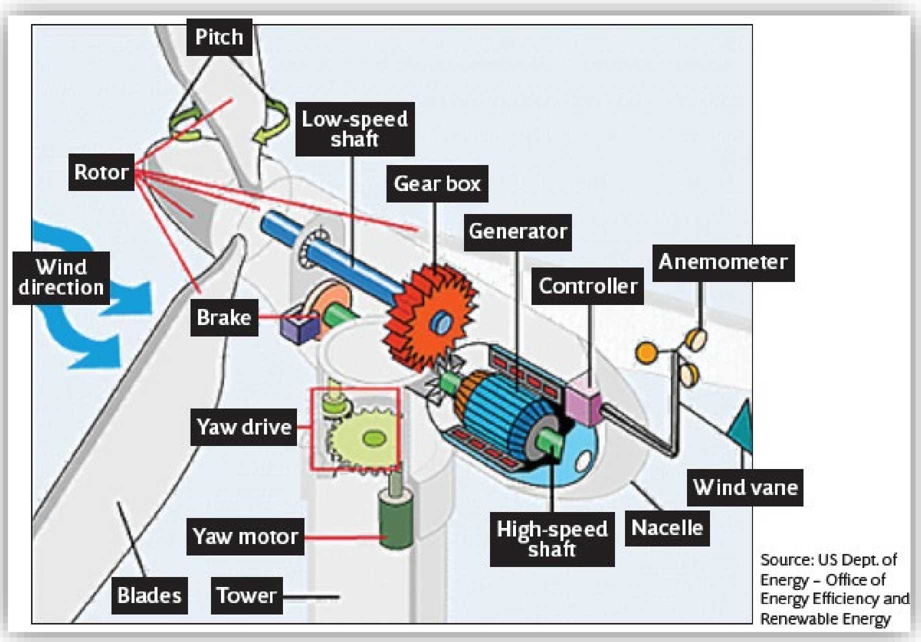


Figure 24:Schematic of a DC generator system.

II.4. Internal Components of a Wind Turbine: [22]



Source: US Dept. of Energy – Office of Energy Efficiency and Renewable Energy

Figure 25: wind turbine components

Anemometer: This device is used for measurement of speed. The wind speed is also fed to the controller as it is one of the variables for controlling pitch angle and yaw.

Blades: These are aerodynamically designed structures such that when wind flows over them, they are lifted as in airplane wings. The blades are also slightly turned for greater aerodynamic efficiency.

Brake: This is either a mechanical, electrical, or hydraulic brake used for stopping the turbine in high wind conditions.

Controller: This is the most important part of the turbine as it controls everything from power output to pitch angle. The controller senses wind speed, wind direction, shaft speed and torque at one or more points. Also, the temp of generator and power output produced is sensed.

Gearbox: This steps-up or steps down the speed of the turbine and with suitable coupling transmits rotating mechanical energy at a suitable speed to the generator. Typically, a gearbox system steps up rotation speed from 50 to 60 rpm to 1200 to 1500 rpm

Generator: This can be a synchronous or asynchronous Ac machine producing power at 50Hz, we talked about it in 2.4. Generator.

High-speed shaft: Its function is to drive the generator.

Low-speed shaft: The rotor turns the low-speed shaft at about 30 to 60 rotations per minute.

Nacelle: The nacelle is the housing structure for high-speed shaft, low-speed shaft, gearbox, generator, converter equipment, etc. It is located atop the tower structure mostly in the shadow of the blades.

Pitch: This is basically the angle the blades make with the wind. Changing the pitch angle changes weather the blades turn in or turn out of the wind stream.

Rotor: The hub and the blades together compose the rotor.

Tower: Towers are basically made up of tubular steel or steel lattice. Taller the towers greater is the amount of power generated as the wind speed generally goes on increasing with height.

Wind direction: Generally erratic in nature, hence the rotor is made to face into the wind by means of control systems.

Wind vane: Basically, the job of a wind sensor, measuring the wind speed and communicating the same to the yaw drive, so as to turn the turbine into the wind flow direction.

Yaw drive: This drive controls the orientation of the blades towards the wind. In case the turbine is out of the wind, then the yaw drive rotates the turbine in the wind direction

Yaw motor: Powers the yaw drive.

II.5. How Do Wind Turbines Generate Electricity?

Wind turbines generate electrical power in the same way as all other generation technologies. The only difference is in the source of the mechanical power supplied to the electrical generator: wind, rather than a diesel engine or steam turbine, provides the energy.

Blades capture energy in the wind and turn the turbines. Typically, a gearbox connects the shaft from the blades (rotor) to the electrical generator. The yaw control controls the mechanisms point the blades into the wind, and on large wind turbines, the pitch of the blades is adjusted (blade angle) as wind speeds change.

The electrical generators used on wind turbines may either be induction generators or synchronous generators. The electrical power from the generator is typical 60 Hz, AC power with 600V output for large wind turbines. A transformer may be required to increase or decrease the voltage so it is compatible with the endues, distribution, or transmission voltage, depending on the type of interconnection.

Small wind turbines produce a variety of voltages, and some produce DC power generally it requires an inverter to match the power output with the load and/or interconnection frequency and voltage.[35]

II.6. Energy produced by wind turbines: [33],[35]

The nameplate rating of a wind turbine should indicate the capacity or maximum power output of the turbine in kilowatts (kW) this usually occurs at very high wind speeds and is not representative of the average power production over time. Energy production is commonly estimated as the annual average energy or the amount of energy produced for one year. The power generated by a wind turbine at any moment is related to the wind speed at that moment as a fact the available energy in the wind varies with the cube of the wind speed. Hence a 10% increase in wind speed will result in a 30% increase in available energy.

The power curve of a wind turbine follows the relationship between cut-in wind speed (the speed at which the wind turbine starts to operate) and the rated capacity, approximately. (fig26)

Below the cut-in wind speed, there is not enough energy in the wind to produce electrical power.

At wind speeds higher than the rated wind speed (cut-in speed), the maximum power production will be limited, or, in other words, some parts of the available energy in the wind will be 'spilled.' The power output regulation can be achieved with pitch-control (i.e., by feathering the blades to control the power) or with stall control (i.e., the aerodynamic design of the rotor blade will regulate the power of the wind turbine). Hence, a wind turbine produces maximum power within a specific wind interval that has its upper limit at the cut-out wind speed, at that range of wind speed (very high wind speed) the wind turbine will shut down to protect itself from damage.

Energy production is estimated from the wind turbine power curve together with an estimation of the amount of time in a year that the wind will be blowing at each specified speed.

The wind speed distribution is a function of location. Good wind sites have high and steady wind speed while others have low average wind speed with considerable variability over a day, month, and year.

The capacity factor (CF) is a single number that is used to estimate annual average energy production from a wind turbine as a percentage of its maximum capacity:

$$\begin{aligned} &Capacity\ (kW)\ x\ Capacity\ Factor\ x\ 8760\ hrs/yr \\ &\qquad = \ Estimated\ annual\ energy\ production\ (kWh/yr) \end{aligned}$$

Large turbines located at good wind sites can achieve capacity factors of 40% or more. Small wind turbines located at poor sites can have capacity factors of 20% or less.

We must mention that the rated power is a property of the wind turbine.

At the same time, the capacity factor is a property of the location of the wind turbine (a measure of the available wind energy at this location).

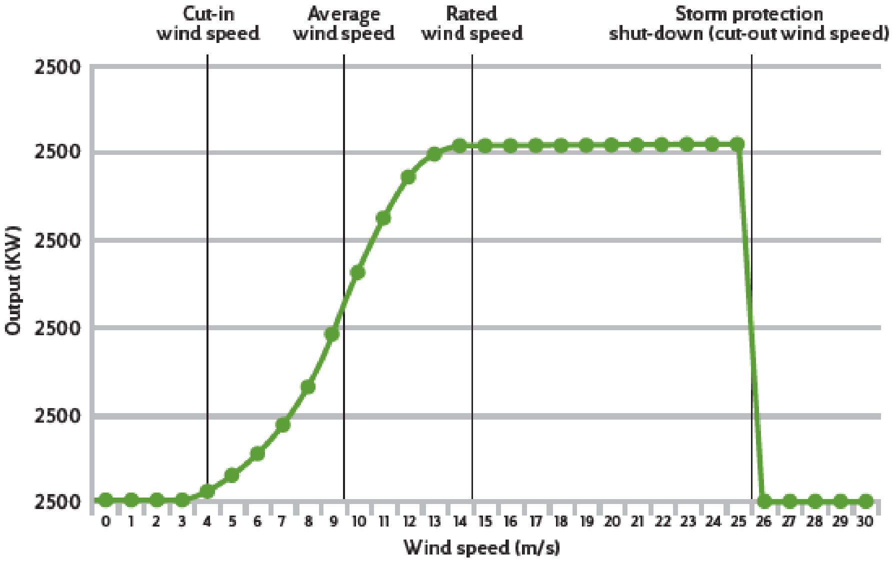


Figure 26:Example of a wind turbine power curve.

II.7. Wind turbine Aerodynamics:

II.7.1. Power coefficient:

The conversion of wind energy to electrical energy involves primarily two stages: in the first stage, kinetic energy in wind is converted into mechanical energy to drive the shaft of a wind generator. The critical converting devices in this stage are wind blades. For maximizing the capture of wind energy, wind blades need to be carefully designed [9].

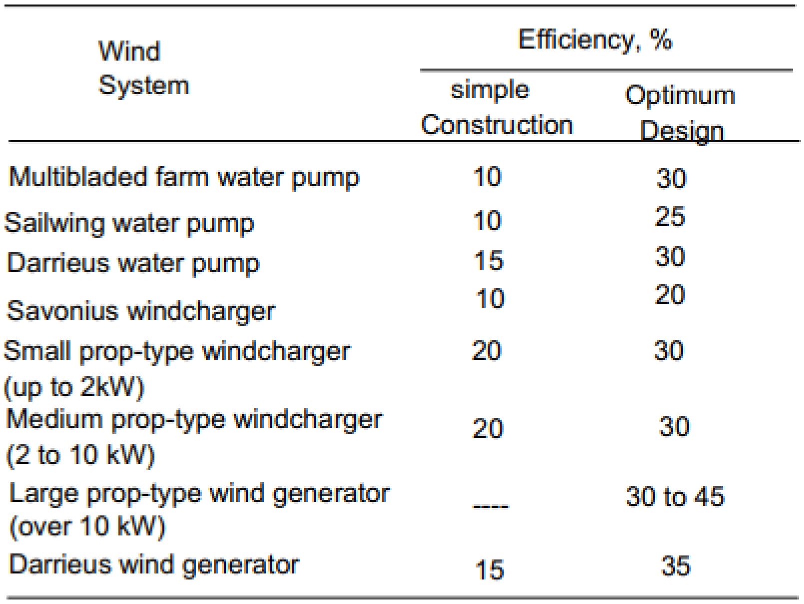
The power coefficient Cp deals with the converting efficiency in the first stage, defined as the ratio of the actually captured mechanical power by blades to the available power in wind:

$$C_p = \frac{P_{mech,out}}{P}$$

Because there are various aerodynamic losses in wind turbine systems, for instance, blade-tip, blade-root, profile, and wake rotation losses, etc., the real power coefficient Cp is much lower than its theoretical limit, usually ranging from 30 to 45%.[20]

There is a theoretical limit in the efficiency of a wind turbine determined by the deceleration the wind suffers when going across the turbine. For HAWT, the limit is 19/27 (59.3%) and is called Lanchester-Betz limit [9].

For VAWT, the limit is 16/25 (64%) (Paraschivoiu, 2002). These limits come from the actuator disk momentum theory which assumes steady, inviscid and without swirl flow.[20]



Wind System	Efficiency, %	
	simple Construction	Optimum Design
Multibladed farm water pump	10	30
Sailwing water pump	10	25
Darrieus water pump	15	30
Savonius windcharger	10	20
Small prop-type windcharger (up to 2kW)	20	30
Medium prop-type windcharger (2 to 10 kW)	20	30
Large prop-type wind generator (over 10 kW)	----	30 to 45
Darrieus wind generator	15	35

Table 3: Typical Cp values for various wind turbines [25

II.7.2. Betz limit:

Albert Betz was a German physicist who estimated that no wind turbine was able to transform more than 59.3% of the wind 's kinetic energy into mechanical energy that would turn a rotor. It is known as the Betz Limit, which is the maximum theoretical power coefficient for any wind turbine. according to him, the theoretical maximum power that can be extracted from the wind is:

$$P_{Betz} = \frac{1}{2}\rho A V^3 C_{p\ Betz} = \frac{1}{2}\rho A V^3 \times 0.59$$

Therefore, even if power extraction was possible without any losses, a wind turbine could only use 59% of the wind power. [33]

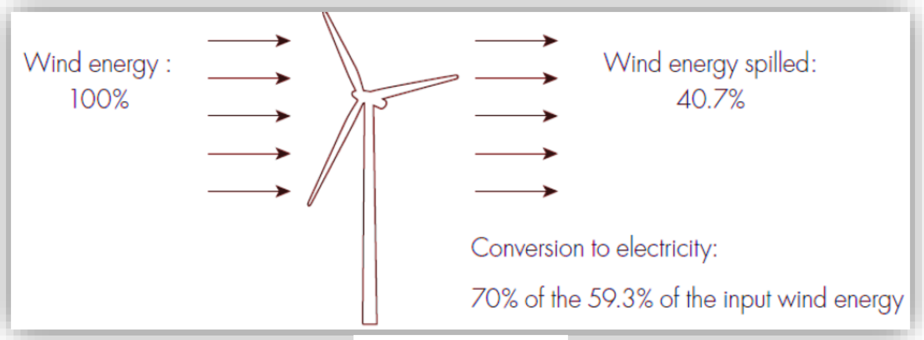


Figure 27: betz limit

In the diagram shown above, the wind turbine converts 70% of the Betz Limit into electricity. Therefore, the Cp of this wind turbine would be 0.7 x 0.59 = 0.41. So this wind turbine converts 41% of the available wind energy into electricity. This is actually a pretty good coefficient of power. Good wind turbines generally fall in the 35-45% range.[23]

II.7.3. Tip speed ratio of wind turbine:

The Tip Speed Ratio (TSR) is a significant factor in wind turbine design. TSR refers to the ratio between the wind speed and the speed of the tips of the wind turbine blades.

$$\text{TSR } (\lambda) = \frac{\text{Tip Speed of Blade}}{\text{Wind Speed}}$$

If the rotor of the wind turbine spins too slowly, most of the wind will pass straight through the gap between the blades, therefore giving it no power. But if the rotor spins too fast, the blades will blur and act as a solid wall to the wind.

Also, rotor blades create turbulence as they spin through the air. If the next blade arrives too quickly, it will hit that turbulent air. So, sometimes it is better to slow down the blades.[23] The Tip Speed Ratio of a wind turbine is an essential factor in how efficient that turbine will perform. Fig.28 shows the relationship between the tip-speed ratio (TSR) and the coefficient of power (Cp).

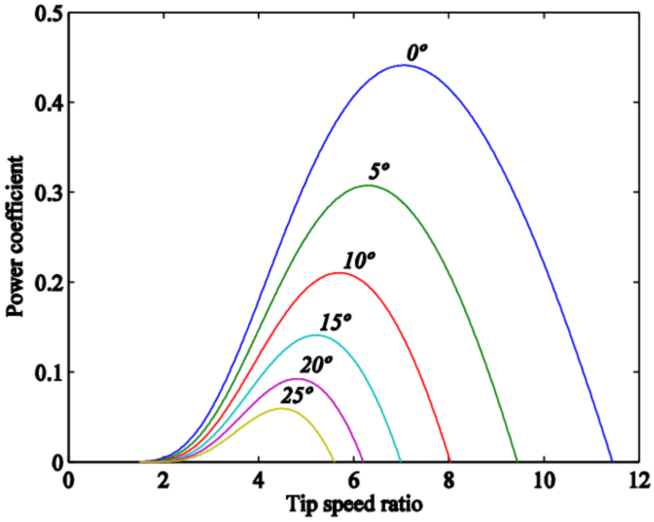


Figure 28:Power coefficient as a function of the tip speed ratio, parameterized in function of the pitch angle.

II.8. Size of Wind turbines:

Builders and researchers are developing wind turbines that are increasingly powerful and therefore larger (fig.29) to use the maximum amount of wind because we want the propeller to sweep a surface where the wind is maximum so that they are perched very high so as not to be subjected to the effects of the ground, which slow down the wind [36].

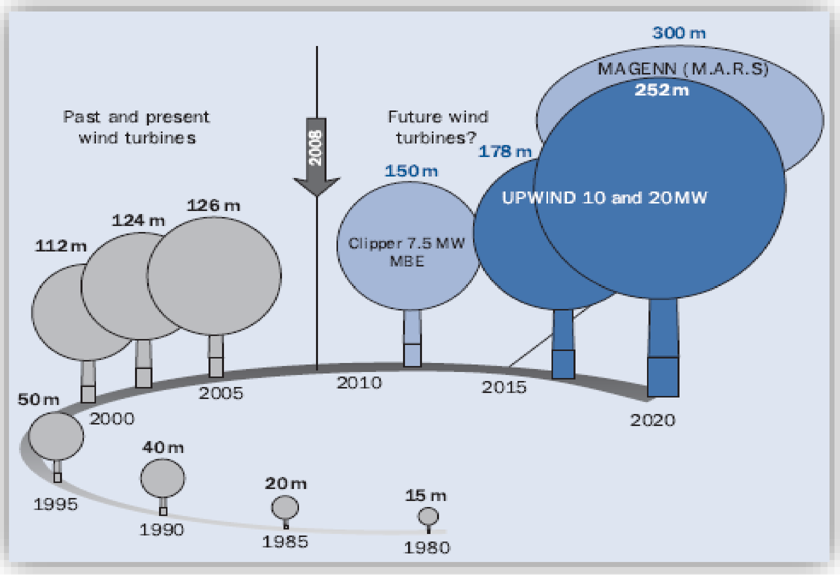


Figure 29: growth in size of wind turbines

II.9. Conclusion:

This chapter discussed the system used to transform wind energy into electricity, the wind turbine. We started the chapter with the most common types of it (VAWT and HAWT), types of them, advantages and disadvantages of both, an overview over the components of the wind turbine in general; in that title, we mentioned the different types of generators used in wind turbines industry, finally, Wind turbine Aerodynamics and the size development.

The next chapter will be about our wind turbine, how we made it using some of the wind turbines math, and the information we gathered in this chapter.

Chapter III:

design and fabrication of an intelligent wind turbine

Chapter III: design and fabrication of an intelligent wind turbine

III.1. Introduction:

After talking about wind energy and wind turbines, the system converts this power to electricity in the first two chapters.

In this chapter, we will discuss the design steps that we followed to do our intelligent wind turbine, some issues that we faced, and the solutions to it.

III.2. Project overview:

Our project's primary goal is to design an intelligent small-scale model of an actual size industrial wind turbine in operation. The intelligence was also planned to have a similar function mainly by detecting wind direction and its speed. These requirements demanded us to follow a specific and original design for mechanical components from scratch, so the whole structure is unlike a conventional small wind turbine.

Figure 30:Wind Turbine

III.2. The different components of the system:

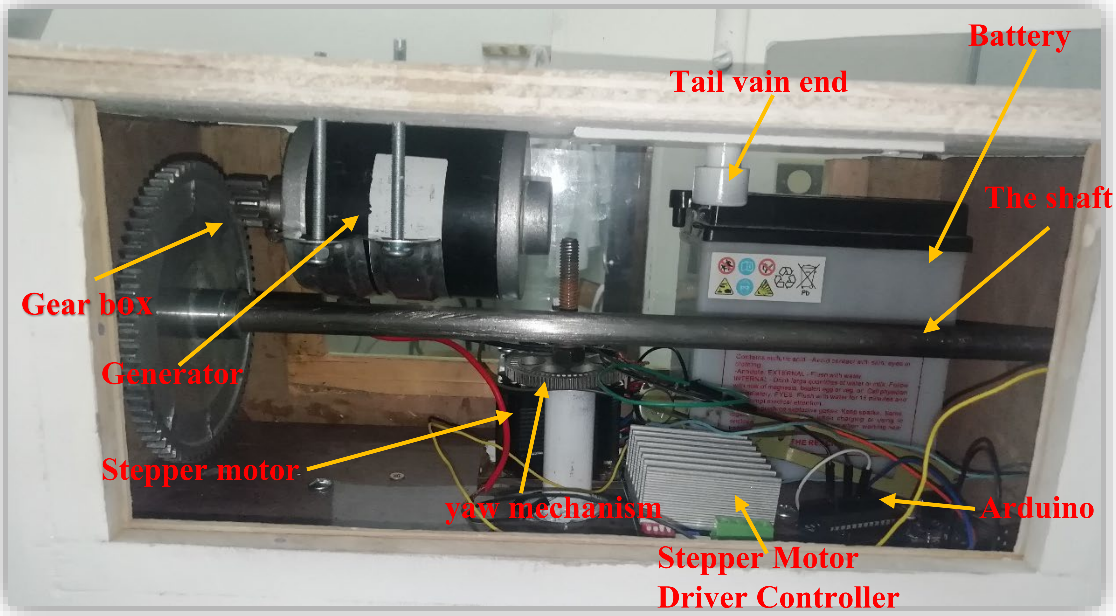


Figure 31:internal components

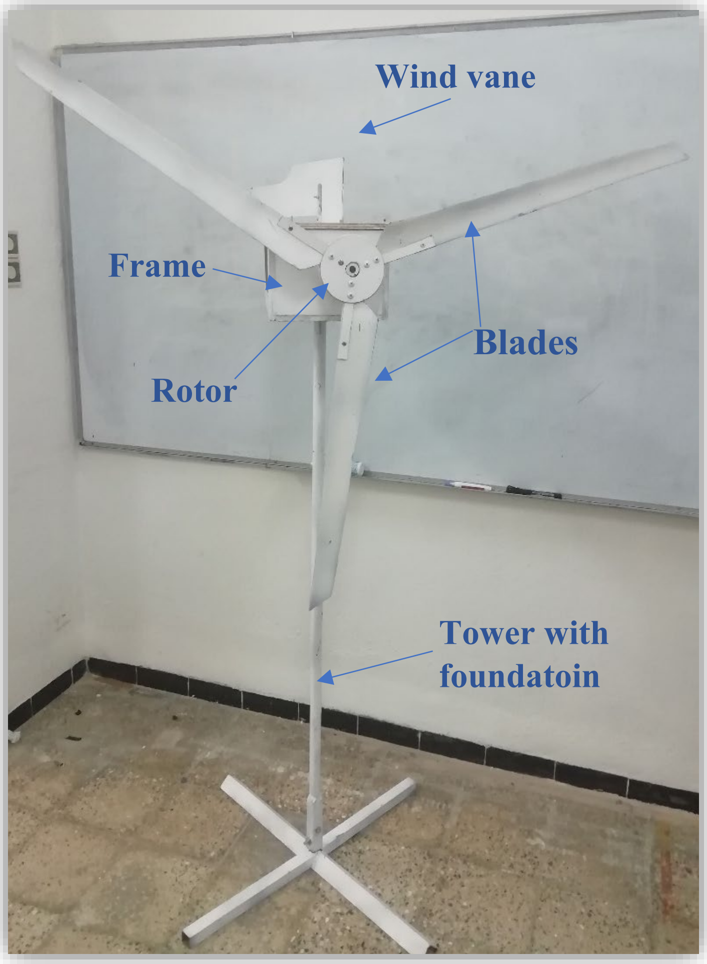


Figure 32: external components

III.2.1. Electrical parts:

III.2.1.1. Stepper motor and the driver:

To get the maximum energy from the wind, our wind turbine has to be able to adapt itself with regards to the wind direction (turning the nacelle to the wind direction). To do that, we need a stepper motor that will rotate depending on the data received from the Arduino.

a). definition of stepper motor:

A stepper motor, also known as step motor or stepping motor is a brushless DC special electric motor that divides a full rotation into a number of equal steps (move in discrete steps). With a computer-controlled stepping, you can attain a very precise positioning and speed regulator.[37]

b). Features of Stepper Motor:

- -Excellent response to starting/stopping/reversing.
  - SMs relatively inexpensive and simple in construction and can be made to step in equal increments in either direction.
  - Low maintenance
  - Low cost for control achieved
  - A wide range of rotational speeds can be realized as the speed is proportional to the frequency of the input pulses.

In our project we have used the Nema 23 Bipolar stepper motor. It’s a motor of 2.5V voltage and 2.8A current with step angle of 1.8 deg.

more details about this Nema 23 motor are included in the annex.

We choose this type of motors back to the features we mentioned before. and this particular motor for its good torque (1.26Nm) that can move the nacelle, which is a heavy box made of wood carry other parts heavy (battery, the generator…).

Another reason is the low voltage and current value it needs to work, because of we are using a battery of 12V with 5A current this motor is perfect for the system needs and for the budget.

Figure 33:Nema 23 stepper motor

III.2.1.2. The driver:

To control the stepper motor we used a driver, the main aspects of this it includes intelligent current control and the use of PWM modulation, which makes it possible to connect stepper motors of any supply voltage and current to the driver – at a fixed level.

The electronic driver is used (TB6600 Stepper Motor Driver Controller) to do two tasks; first, it supplies the stepper motor with power, to do this we connected the paired wires of our stepper motor to drive's A+ A- and B+ B- terminals.

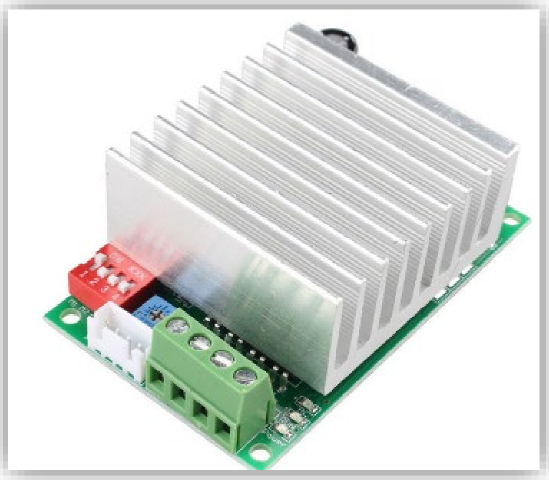


Figure 34:TB6600 Stepper Motor Driver Controller

Secondly, the driver receives commands from the control system (Arduino). It is a basic driver that requires clock and direction signals. The clock is needed to generate pulse-width modulated (PWM) signals for driving the motor and controlling its rotational frequency. The direction signal sets the direction of rotation, i.e., clockwise or counterclockwise. so for that, we connected the Arduino to the driver as it is shown in the Fig.36

Figure 35:driver input / output diagram

III.2.1.3. The generator:

One of the main parts of the wind turbine is the generator, which converts motive power (mechanical energy transferred from the turbines rotor) into electrical power to use in an external circuit. For this project, we used a DC permanent magnet motor as a generator, which is an electromechanical converter for the bidirectional conversion of energy. It consists of two parts the rotor, (rotating part), consists of a metal core with a copper winding, the stator has permanent magnets which generate a magnetic field whose flux passes through the rotor.

the MCC we used is a 24V motor with 1200tr/min.

Figure 36: DC generator

III.2.1.4. *Limitation input voltage circuit:*

In the output of the DC motor, a continuous current is available. Still, before using it to supply battery and the other parts, the voltage must be limited with a regulator to not damage these components.

For our application, we used a 12V battery (2 battery of 6V); the output voltage is then 12V, but to supply the battery, the voltage has to be superior (mainly between 13 and 13.6V for a 12V battery).

For this, the regulator chosen is an LM317L, which makes it easy to parameter the limit voltage using two resistances as the fig 37 shows.

The component has then to be connected between the DC motor (Vin) and the battery (Vout).

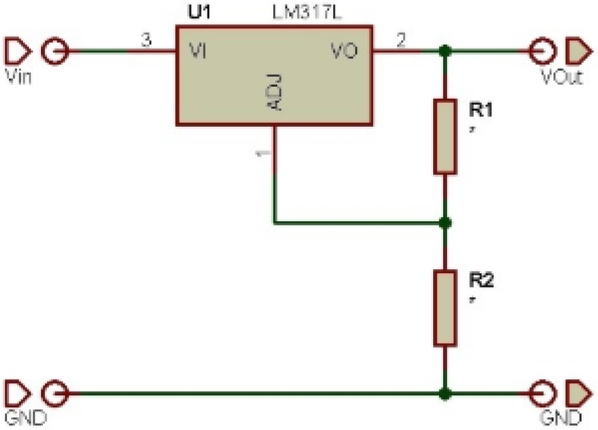


Figure 37: Circuit diagram for limitation of input voltage

3.2.1.5. *Microcontroller Arduino:*

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs (light on a sensor, a finger on a button, or a Twitter message ...) and turn it into an output (activating a motor, turning on an LED, publishing something online). The Arduino board can know what to do by a set of instructions sent from the user to the microcontroller on the Arduino board. To do so, the users use the Arduino programming language (based on Wiring) and the Arduino Software (IDE) based on Processing. [38]

In this project, we have used the UNO type of Arduino that can be supplied with 5V to 12V. Our Arduino is programmed in a way that where it can capture the change in the potentiometer value than transform that value to PWM

signals used for the stepper motor's control, this process is to make the turbine's rotor towards the wind.
the used program is included in the annex

Figure 38: Arduino UNO

III.2.1.6. Potentiometer: Wind direction measurement:

To find out the wind direction, we have used a system that contains a vane and a potentiometer. We connected the rotating shaft of the potentiometer to the vane, so when the vane moves, it changes the potentiometer's value.
One pin of the potentiometer is connected to the ground. The other to 5V (this voltage can be provided directly by the Arduino), the potentiometer's output voltage is then sent on one analogic pin of the Arduino.
The resulting voltage on the analog input, give in the form of a number between 0 and 1023, then it will be used as a command for the stepper motor using the program in it and thus optimize the performance of our wind turbine, which will always be positioned to optimize the energy gained from the wind.

III.2.1.7. LCD:

The LCD in our project was meant to display the energy produced by the wind turbine and all the information regarding wind direction, wind speed, and magnitude of the current generation.
The output voltage of the motor can reach 30V at high values of wind speed speeds, but it must be reduced in order to accurately read this value on one

of the analog pins of the Arduino. Indeed, the real value between 0 and 1023 is proportional to a default voltage of 5V, which is the Arduino pins' voltage. To bring the output voltage within this range of values, a voltage divider bridge is used:

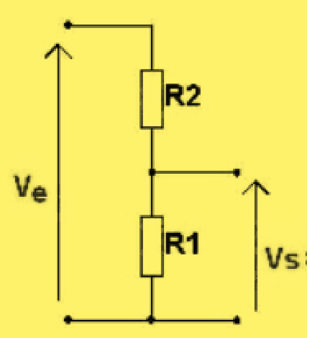


Figure 39: Circuit diagram of Voltage

With: $Vs = \frac{R1}{R1+R2} \cdot Ve$

Using two resistors: $R1 = 33k\Omega$ and $R2 = 148k\Omega$, a voltage $Vs = 5V$ correspond to a motor's output voltage Ve equal to $5xKp$ (about $27.4V$) with $Kp = R1/(R1 + R2)$. With Arduino software, the function" map" enable from the read analogic value to get the corresponding voltage between 0 and $5V$. By multiplying this value by Kp, we obtain the motor's output voltage.

Documentation of the LCD used specifies than a negative supply voltage is necessary for the functioning. To get it from the +5 V voltage generated by the microcontroller, a switch capacitor voltage converter is used: this component makes it possible to obtain an output voltage of-5V from an input voltage of 5V. The LCD can be used without this negative voltage but the contrast may be lower. These two potentials are then connected to pins of a potentiometer. Its output voltage is connected to pin V0 of LCD and enable to optimize the display resolution.

III.2.2. Mechanical components:

III.2.2.1. Blades and hub:

For the blades, we have chosen and produced PVC blades using a PVC pipe (the cutting steps are shown in fig.41 and we have reinforced them with metal to increase its hardness, the length of the blades is R = 60cm.

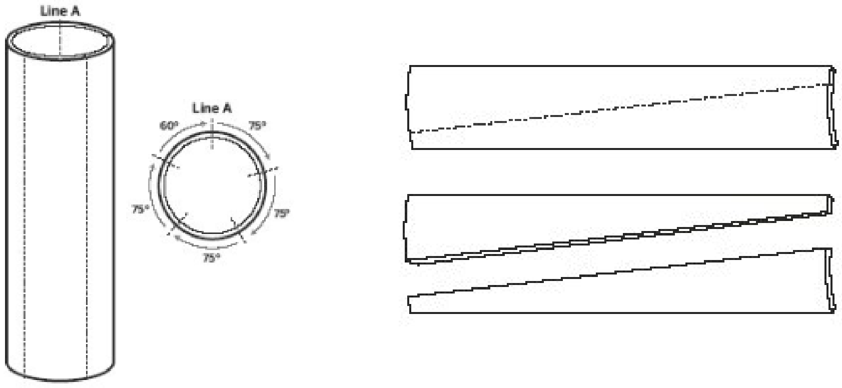


Figure 40: Cutting the Blades

we sand the blades to achieve the desired airfoil. This will increase the efficiency of the blades, as well as making them quieter.

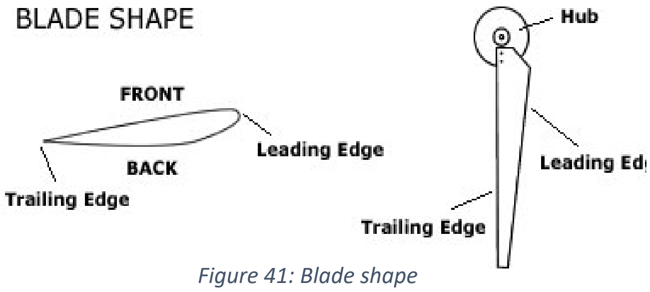


Figure 41: Blade shape

Figure 42: The Blades

For the hub we made holes in it for the blade's fixation. Fig.43

Figure 43: the hub

Figure 44: the rotor

III.2.2.2. Tower and yaw mechanism:

The rotor axis of a wind turbine rotor is usually not aligned with the wind since the wind is continuously changing its direction.

To solve this problem the wind turbines, have a system called yaw mechanism this mechanism uses electric motors and gearboxes to keep the turbine yawed against the wind.

For our system, we used a yaw mechanism contains a stepper motor controlled by Arduino and mounted conical bearing and gear on the tower so it helps the upper frame to be rotated by the motor to be against the wind.

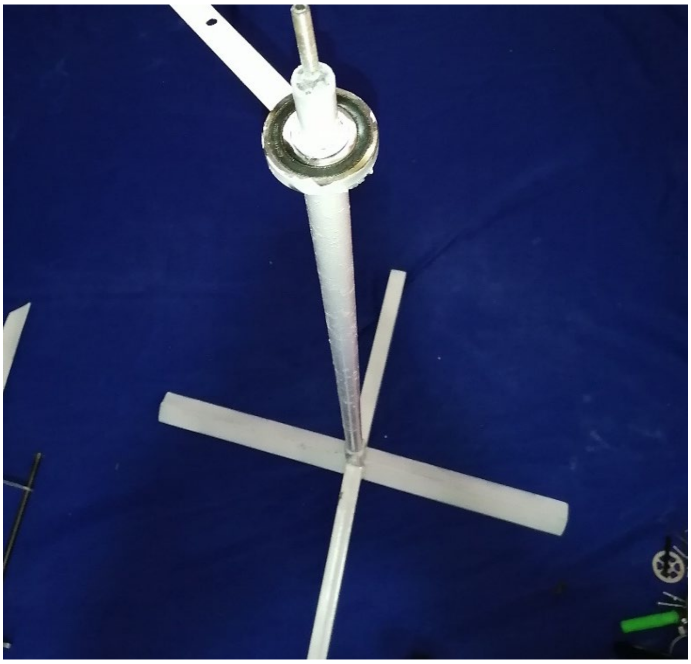


Figure 45:Tower and mounted conical bearing

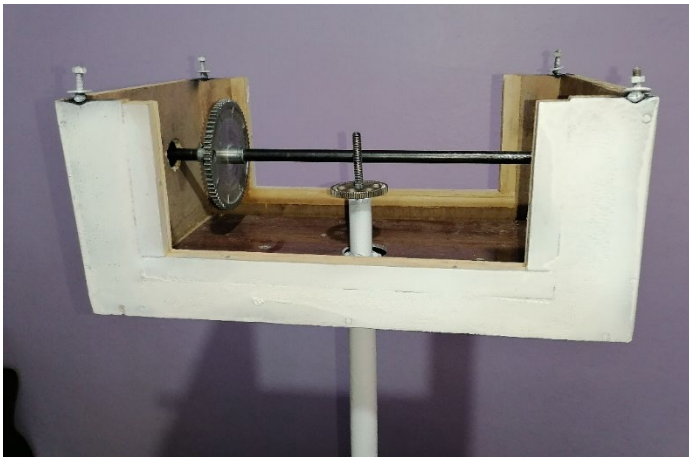


Figure 46: Yaw mechanism without stepper motor

III.2.2.3. The upper frame (nacelle):

The nacelle is housing on top of the tower that accommodates all the components that need to be on a turbine top.

the nacelle is made of wood, its length is: 40 cm, the width is: 22 cm with 16 cm in Hight

We used glass on both sides of it, so when we close it, the inside components will be shown fig 47.

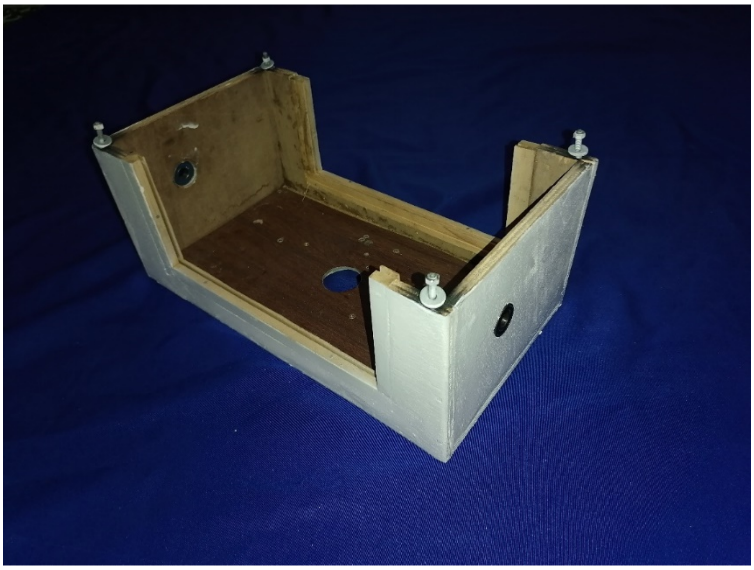


Figure 47: the upper frame (nacelle)

III.2.2.4. Gear train:

Gear train increases the main shaft speed to a speed suitable for the generator. fig 48.

The used gear system increases the rotation speed of the shaft by $I = 5.83$ (gear ratio), so the increased speed will be the rotation speed of the generator.

The gear ratio is calculated by dividing the output speed by the input speed ($i = Ws/We$) or by dividing the number of teeth of the driving gear by the number of teeth of the driven gear ($i = Ze/Zs$).

In our gear system, the number of teeth of the driving gear (the gear mounted on the shaft) is = 70, and the number of teeth in the driven gear (the gear on the motor) is= 12. so, $I = 70/12 = 5.83$

Figure 48: Gear train mounted on the shaft mating with generator

III.2.2.5. Tale vane mechanism:

The wind vane is responsible for finding the wind direction.

In our system, we connected the rotating shaft of the potentiometer to the vane, so every position of the vane gives a particular value of the potentiometer; this value goes to the Arduino, and based on the software on, it converts it to an order for the yaw mechanism to move the turbine to wind direction.

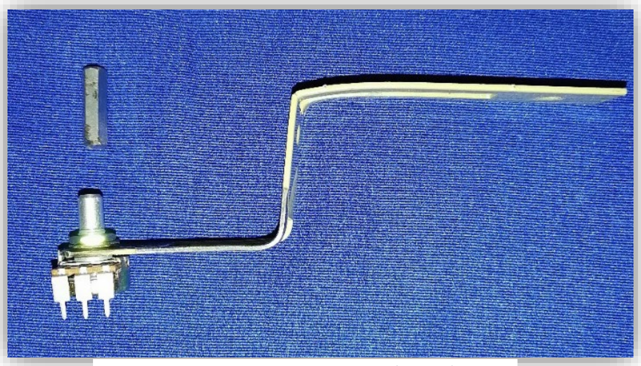


Figure 50: potentiometer attaching design

Figure 49: Components of tail vane

Figure 51: Tail vain attached

II.2. Conclusion:

In this chapter, we presented our horizontal wind turbine, its parts, and all the steps we followed to make it. This turbine has a similar idea to the one on the large wind turbines used nowadays around the world, which is directing itself to the wind direction; this makes it more effective because being always against the wind always gives the maximum amount of the produced energy.

General conclusion

General conclusion:

This work's primary goal is to design an intelligent wind turbine for an efficient generation of current. The structure consists of two parts, i.e., tower with foundation and wooden frame. The tower is made from a cylindrical steel tube welded with a base foundation made up of sheet metal and plywood. The upper end of the tower is connected with the frame, and the rotation of the frame is feasible concerning the tower due to the roller bearing connection. Most of the electronics, as well as mechanical components, are placed at the frame.

The efficiency increment of the current generation in wind turbines is a tough job. This project was intended to enhance the efficiency of the wind turbines, so this wind turbine is based on Horizontal-axis wind turbines (HAWT) and its design on the Yaw mechanism where the Arduino Uno is used as a micro-controller for controlling the wind turbine, with the potentiometer detecting the intensity and direction of the wind and forwards the data to the controller. Based on received data about wind direction and intensity, the microcontroller commands the stepper motor to align the frame with the wind direction.

Due to time limitations, we could not test the turbine with every component installed, but short tests were executed without the generator, and the rotor turned relatively fast. With the generator installed, rotation torque demand increases, so the speed becomes lower.

The wind direction detector works as it was planned. We tried that by changing the value of the potentiometer, so the stepper turns to the corresponding degree; it means when the tail vain moves to the wind direction, changing the potentiometer's value, the stepper will move the rotor to be against the wind.

During the design process, estimation of blades efficiency, start-up rotation speed, and standard operational rotation speed were extremely difficult.

The main gear ratio design was done based on information gained from the rotation speed diagrams of other small wind turbines. Because of uncertainties back to lack of equipment, the rotor does not rotate in the small wind speeds, so no voltage is given where the voltage produced by the generator is relative to the rotation speed of the rotor, but that is the case with every wind turbine.

As a step forward in continuing this project, we can work on several points that improve this project consisting of changing the low range of output voltage to higher ranges, get a proper and efficiency blade, because making them was one of the hardest parts, adding a developed gearbox to get maximum of speed on the generator shaft, adding pitch control to the rotor and a system that sends information to the phone or an external device, adding an Anemometer and other sensors as a temperature sensor that can help with studies of the relation between the heat and the wind, a light sensor to for the statistics of wind energy between day and night and other sensors as the pressure sensor.

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Annexes:

Abstract:

The main objective of this project is to design and build an intelligent wind turbine. After presenting state of the art about the wind energy in the world and in Algeria, and discussed wind turbines different structures and types, the advantages and disadvantages, and the various structures of the used generators in the first chapters, we posed the steps we followed to make our wind turbine starting with the blades then the other parts. To ensure that the turbine is always against the wind to get the maximum of the produced power, we added a yaw mechanism controlled with Arduino Uno.

Keywords:

wind, wind turbine, generator, Arduino.

Résume :

L'objectif principal de ce projet est de concevoir et de construire une éolienne intelligente. Après une brève présentation de l'état de l'art sur l'énergie éolienne dans le monde et dans l'Algérie, et discuté les différentes structures et types d'éoliennes, les avantages et inconvénients, et les différentes structures des générateurs utilisés dans les premières parties dès ce travaille, nous avons posé les étapes que nous avons suivies pour fabriquer notre éolienne en commençant par les pales puis les autres pièces. Pour s'assurer que la turbine est toujours contre le vent pour obtenir le maximum de puissance produite, nous avons ajouté un système d'orientation contrôlé avec Arduino Uno.

Mots clés :

Vent, éolienne, générateur, Arduino.

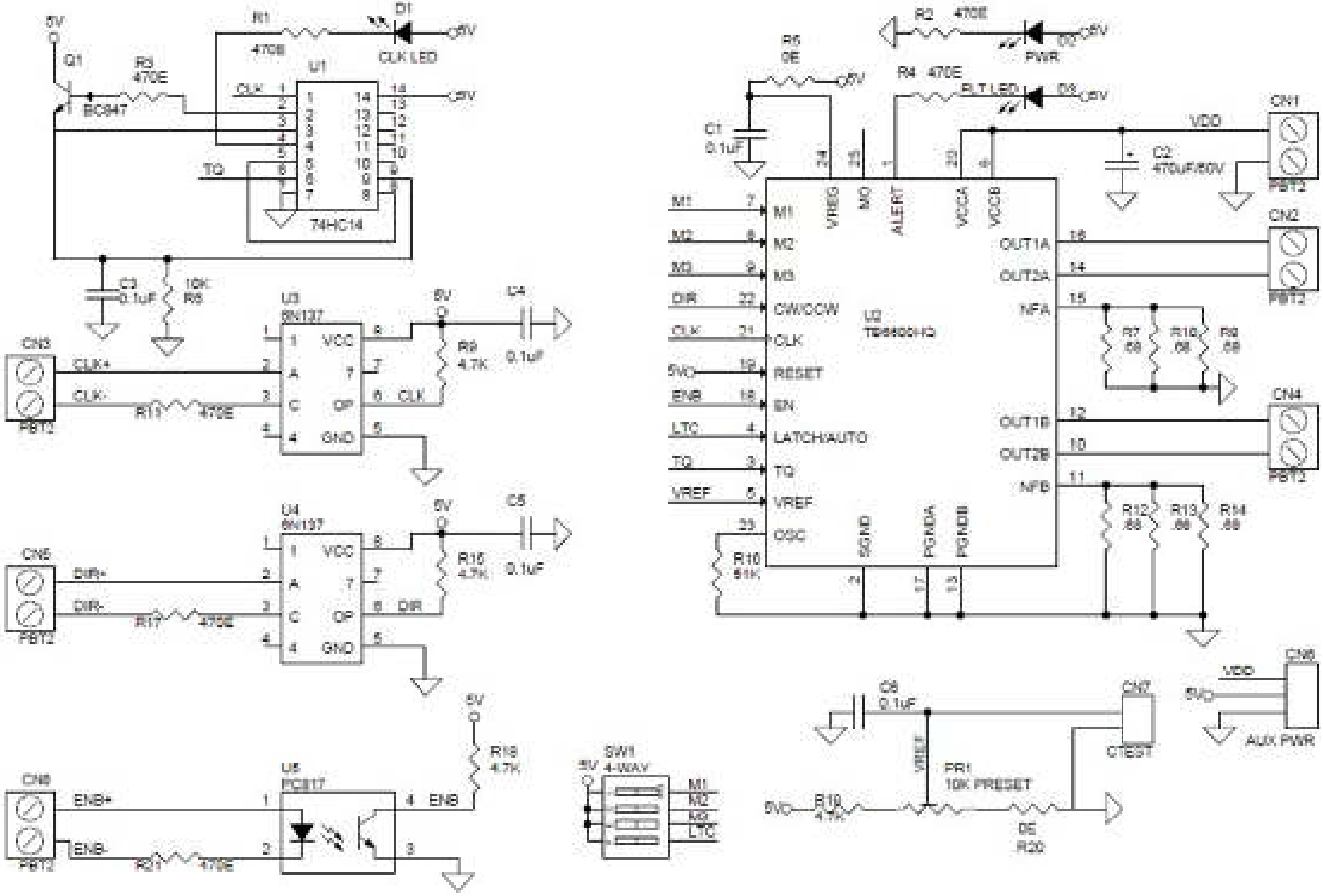
الملخص:

الهدف الرئيسي لهذا المشروع هو تصميم وبناء توربين رياح ذكي. بعد عرض موجز لأحدث ما توصلت إليه تكنولوجيا طاقة الرياح في العالم والجزائر، وناقشنا الهياكل والأنواع المختلفة لتوربينات الرياح، مزاياها وعيوبها، والهياكل المختلفة للمولدات المستخدمة في القسمين الاولين. استعرضنا الخطوات التي اتبعناها لبناء توربين الرياح الخاص بنا، بدءًا من الشفرات الى الأجزاء الأخرى. للتأكد من أن التوربين دائمًا موجه ضد الرياح من اجل لحصول على أقصى طاقة منتجة، أضفنا نظام توجيه يتم التحكم فيه بواسطة الاردوينو.

الكلمات الدالة:

الرياح، توربينات الرياح، مولد، اردوينو.

4.5Amps Bipolar Stepper Motor driver Based On TB6600



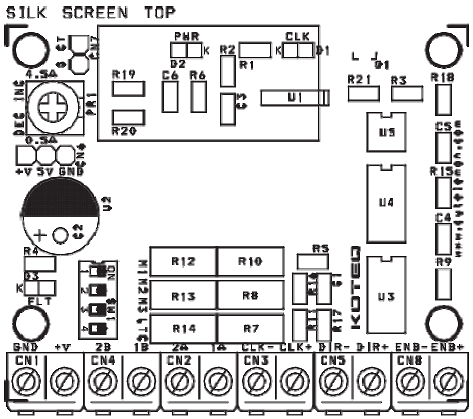
www.twovolt.com

www.youtube.com/thetwovolt

Author Rajkumar Sharma

4.5Amps Bipolar Stepper Motor driver Based On TB6600

SILK SCREEN TOP



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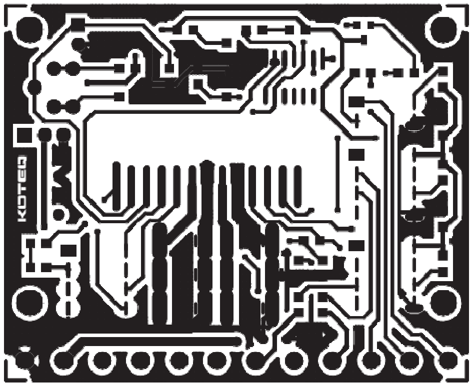
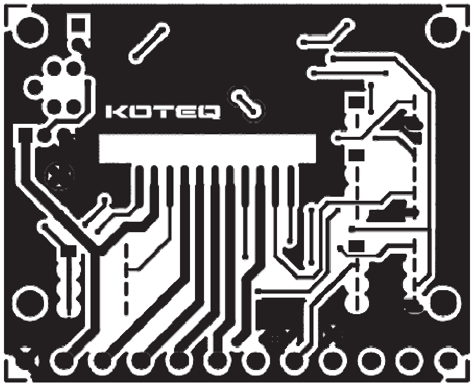
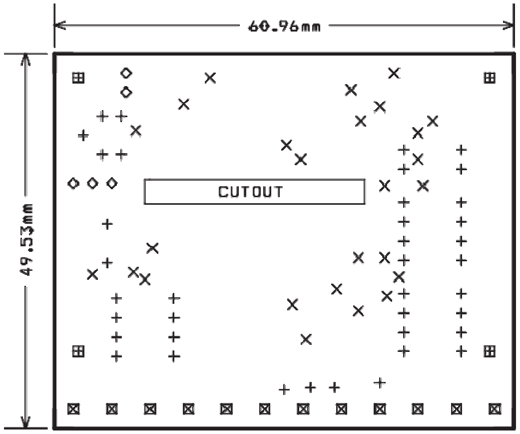


MOTTOB





BOM			
SR.	***QNTY.***	***REF.***	***DESC.***
1	6	CN1,CN2,CN3,CN4,CN5,CN8	2 PIN SCREW TERMINAL
2	1	CN6	3 PIN HEADER CONNECTOR
3	1	CN7	2 PIN HEADER CONNECTOR
4	5	C1,C3,C4,C5,C6	0.1uF SMD 0805
5	1	C2	470uF/50V
6	1	D1	RED LED SMD 0805
7	1	D2	RED LED SMD 0805
8	1	D3	RED LED SMD 0805
9	1	PR1	10K PRESET
10	1	Q1	BC847 SMD
11	7	R1,R2,R3,R4,R11,R17,R21	470E SMD 0805
12	2	R5,R20	0E SMD 0805
13	1	R6	10K SMD 0805
14	6	R7,R8,R10,R12,R13,R14	0.68 SMD 2512
15	4	R9,R15,R18,R19	4.7K SMD 0805
16	1	R16	51K SMD 0805
17	1	SW1	4-WAY DIP SWITCH
18	1	U1	74HC14 SMD SO14
19	1	U2	TB6600HQ
20	2	U3,U4	6N137 DIP 8
21	1	U5	PC817 DIP 4

4.5Amps Bipolar Stepper Motor driver Based On TB6600

Bipolar stepper drive board described here has been designed around TB6600HG IC. The TB6600HG is PWM chopper type single chip bipolar sinusoidal micro-step stepping driver.

Features

- Based on Single chip
- Suitable for Nema17, Nema23, Nema34 bipolar stepper motors
- Suitable for 4Wires, 6 wires and 8 wires stepper motor.
- Forward and reverse rotations available
- Selectable Phase (Micro-step) drives 1/1, 1/2, 1/4, 1/8, and 1/16
- Maximum Input supply 42V DC Minimum Input supply 10V DC
- Output current 4.5Amps
- Output Fault Monitor LED indicator
- On Board Power LED indicator
- On Board step pulse input LED indicator
- Standby auto half current reduction circuitry onboard
- Built in Thermal shutdown (IC)
- Built in under voltage lock out (UVLO) circuit (IC)
- Built in over current detection (ISD) circuit (IC)
- Large capacitor to handle inrush current

Applications

- Robotics
- Large format Size Printers
- CNC
- Routers
- 3D Printers
- Machine Automations
- Camera Pan Tilt Heads
- Slot Machines
- Vending Machines

4 X DIP SWITCH SETTINGS

LATCH : ON=Automatic Return if Thermal Shutdown Or Over Current Detection,

LATCH : OFF Its return to normal operation on power on

Micro-Stepping (Excitations Settings)			
M1	M2	M3	**Operations**
OFF	OFF	ON	**Full step 1/1**
OFF	ON	OFF	**1/2A type (1-2 phase excitation A type)** **0% - 71% - 100%**
OFF	ON	ON	**1/2B type (1-2 phase excitation B type)** **0% - 100%**
ON	OFF	OFF	**1/4 Step**
ON	OFF	ON	**1/8Step**
ON	ON	OFF	**1/16Step**
ON	ON	ON	**Standby (Operation of the internal circuit almost turned off**
OFF	OFF	OFF	**Standby (Operation of the internal circuit almost turned off**

07005

Heat-sink and Thermal Shutdown

The board has sense resistors and these resistors has been set as per maximum load current 4.5A, If you use lower current motor, please set the PR1-Preset (Potentiometer) to the required level for the motor. At maximum current load TB6600 IC will overheat in some time and a RED LED turns on. This LED goes off once the temperature falls to a safe operating level.
For maximum load current Drive required a forced air cooling, better to have fan and large heat-sink other than the provided heat sink

Micro Stepping

A 4way DIP switch is used to set the micro step modes (Full, Half, Eight, Sixteenth), please see the table for Micro step settings. DIP Switch settings should be changed when power is off so the correct selection is active at power up.

Step Pulse

Minimum positive duty cycle of the input step pulse should be 2.2us and required 5V (TTL) signal. A positive going pulse on the step input activates a step operation.

Current Settings

Average drive current can be set using a Preset (On Board PR1 Potentiometer). CN7 (CT) onboard connector is provided to measure the voltage to set the motor current (torque). Voltage range to set the torque 0.3V to 3.5V

Cautions

- Never connect or remove supply wires, motor wires, or input interface when power is on, this can cause damage to drive.
- Never set the dip switch when power is on.
- Before using this drive, please have proper information about stepper motors, Motor impedance, Inductance and other specs.

Inputs

All Inputs are optically isolated to prevent the device for any kind of noise, short circuits.

- Enable: Required 5V DC input, Set high Input disabled the drive, Set low input Enable the drive
- Dir.: Required 5V DC input, Set high Input CW Rotation, Set low input CCW Rotation, Direction of the motor depends how stepper motor has been wired.
- CLK: Step Pulse required 5V DC TTL pulse

Outputs

4 Wires, 6 Wires, 8 Wires Motors can be used with this drive in bipolar mode.
On board LED for Alert

Data Sheet

Please read the Data sheet of Tb6600 for more information.

Clock Indicator

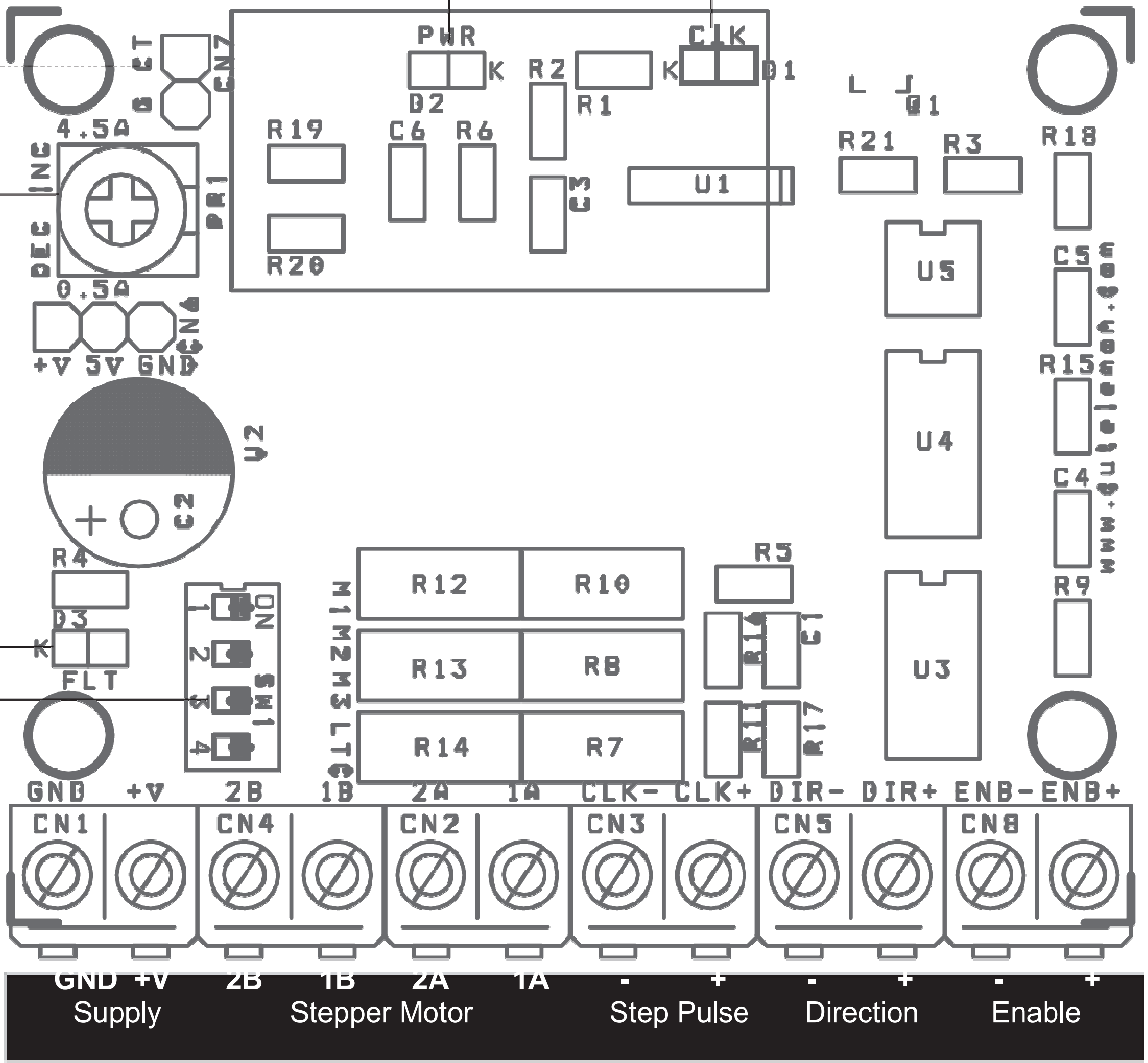
Power Indicator

Current Set Test Point
Test point (Voltage)

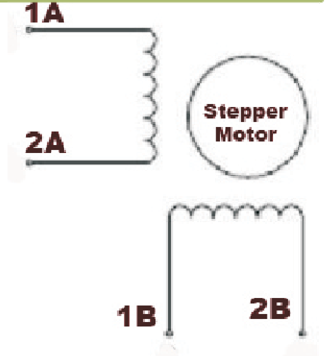
Motor Current Adjust

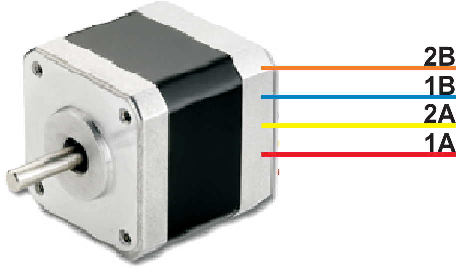
Fault Indicator LED

Micro-Step Setting Switch
1 M1
2 M2
3 M3
4 Latch (Auto Fault)



- **Motor Supply 24V DC Advisable (10V to 42V DC input possible)**
- **Step Pulse , Dir Pulse , Enable inputs required (5V TTL) please don't apply 24V**





www.twovolt.com www.youtube.com/thetwovolt Author Rajkumar Sharma

EN - For pricing and availability in your local country please visit one of the below links:

DE - Informationen zu Preisen und Verfügbarkeit in Ihrem Land erhalten Sie über die unten aufgeführten Links:

FR - Pour connaître les tarifs et la disponibilité dans votre pays, cliquez sur l'un des liens suivants:

LM317LBDG	LM317LBDG.	LM317LBDR2G	LM317LBZG	LM317LBZG.
LM317LDG	LM317LDR2G	LM317LZG	LM317LZG.	

EN This Datasheet is presented by the manufacturer	**DE** Dieses Datenblatt wird vom Hersteller bereitgestellt	**FR** Cette fiche technique est présentée par le fabricant

LM317L, NCV317L

100 mA Adjustable Output, Positive Voltage Regulator

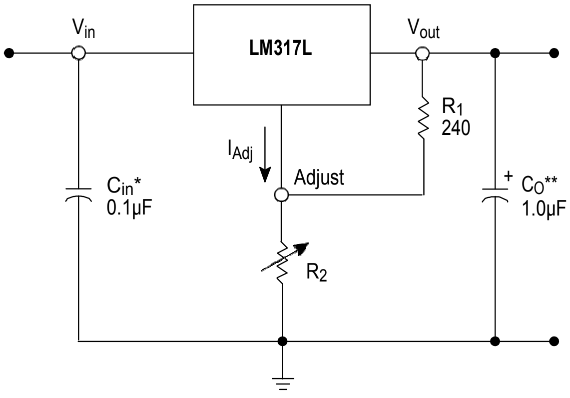
The LM317L is an adjustable 3−terminal positive voltage regulator capable of supplying in excess of 100 mA over an output voltage range of 1.2 V to 37 V. This voltage regulator is exceptionally easy to use and requires only two external resistors to set the output voltage. Further, it employs internal current limiting, thermal shutdown and safe area compensation, making them essentially blow−out proof.

The LM317L serves a wide variety of applications including local, on card regulation. This device can also be used to make a programmable output regulator, or by connecting a fixed resistor between the adjustment and output, the LM317L can be used as a precision current regulator.

Features

- Output Current in Excess of 100 mA
- Output Adjustable Between 1.2 V and 37 V
- Internal Thermal Overload Protection
- Internal Short Circuit Current Limiting
- Output Transistor Safe−Area Compensation
- Floating Operation for High Voltage Applications
- Standard 3−Lead Transistor Package
- Eliminates Stocking Many Fixed Voltages
- NCV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC−Q100 Qualified and PPAP Capable
- These are Pb−Free Devices

Simplified Application



* C_{in} is required if regulator is located an appreciable distance from power supply filter.
** C_O is not needed for stability, however, it does improve transient response.

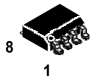
$$V_{out} = 1.25\ V\left(1 + \frac{R_2}{R_1}\right) + I_{Adj}\ R_2$$

Since I_{Adj} is controlled to less than 100 µA, the error associated with this term is negligible in most applications.

ON Semiconductor®

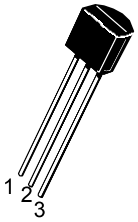
www.onsemi.com

LOW CURRENT THREE−TERMINAL ADJUSTABLE POSITIVE VOLTAGE REGULATOR

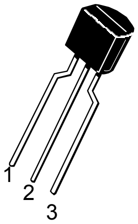


SOIC−8
D SUFFIX
CASE 751

Pin 1. V_{in}
2. V_{out}
3. V_{out}
4. Adjust
5. N.C.
6. V_{out}
7. V_{out}
8. N.C.



STRAIGHT LEAD
BULK PACK



BENT LEAD
TAPE & REEL
AMMO PACK

TO−92
Z SUFFIX
CASE 29

Pin 1. Adjust
2. V_{out}
3. V_{in}

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 9 of this data sheet.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Input−Output Voltage Differential	V_I−V_O	40	Vdc
Power Dissipation Case 29 (TO−92) T_A = 25°C Thermal Resistance, Junction−to−Ambient Thermal Resistance, Junction−to−Case	 P_D $R_{\theta JA}$ $R_{\theta JC}$	 Internally Limited 160 83	 W °C/W °C/W
Case 751 (SOIC−8) (Note 1) T_A = 25°C Thermal Resistance, Junction−to−Ambient Thermal Resistance, Junction−to−Case	 P_D $R_{\theta JA}$ $R_{\theta JC}$	 Internally Limited 180 45	 W °C/W °C/W
Maximum Junction Temperature	T_{JMAX}	+150	°C
Storage Temperature Range	T_{stg}	−65 to +150	°C

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. SOIC−8 Junction−to−Ambient Thermal Resistance is for minimum recommended pad size. Refer to Figure 24 for Thermal Resistance variation versus pad size.
2. This device series contains ESD protection and exceeds the following tests:
   Human Body Model, 2000 V per MIL STD 883, Method 3015.
   Machine Model Method, 200 V.

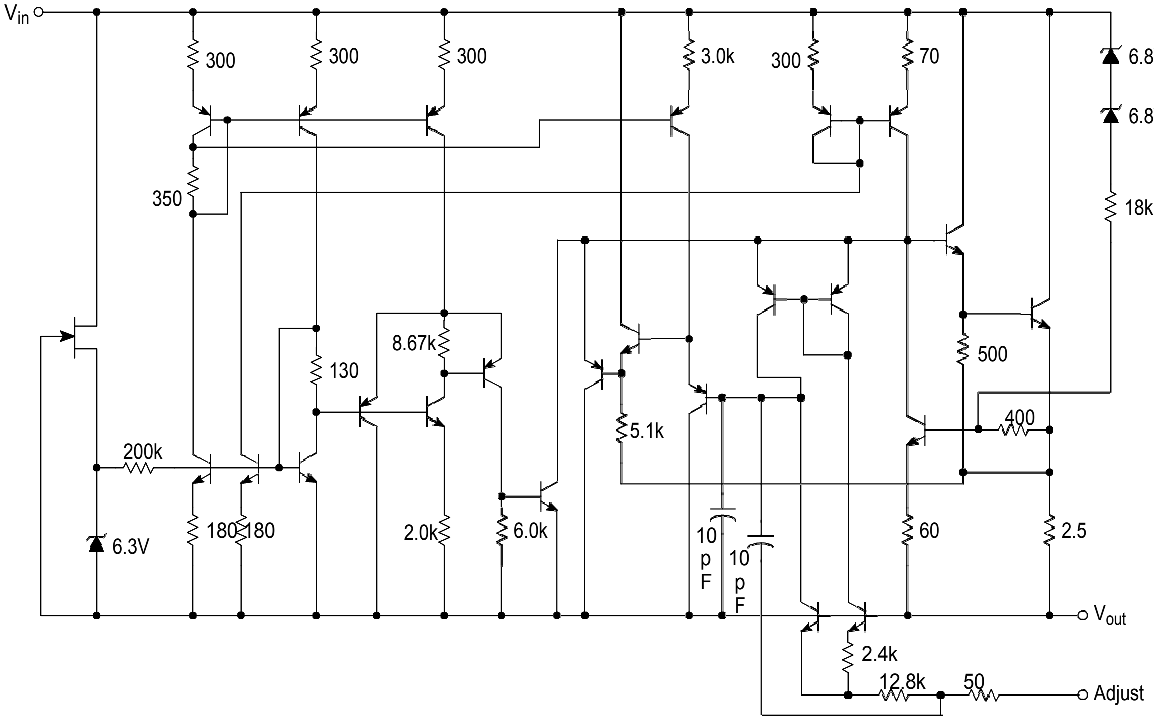


Figure 1. Representative Schematic Diagram

ELECTRICAL CHARACTERISTICS

(V_I−V_O = 5.0 V; I_O = 40 mA; T_J = T_{low} to T_{high} (Note 3); I_{max} and P_{max} (Note 4); unless otherwise noted.)

Characteristics	Figure	Symbol	LM317L, LB, NCV317LB			Unit
			Min	Typ	Max	
Line Regulation (Note 5) T_A = 25°C, 3.0 V ≤ V_I − V_O ≤ 40 V	1	Reg_{line}	−	0.01	0.04	%/V
Load Regulation (Note 5), T_A = 25°C 10 mA ≤ I_O ≤ I_{max} − LM317L V_O ≤ 5.0 V V_O ≥ 5.0 V	2	Reg_{load}	 − −	 5.0 0.1	 25 0.5	 mV % V_O
Adjustment Pin Current	3	I_{Adj}	−	50	100	μA
Adjustment Pin Current Change 2.5 V ≤ V_I − V_O ≤ 40 V, P_D ≤ P_{max} 10 mA ≤ I_O ≤ I_{max} − LM317L	1, 2	ΔI_{Adj}	−	0.2	5.0	μA
Reference Voltage 3.0 V ≤ V_I − V_O ≤ 40 V, P_D ≤ P_{max} 10 mA ≤ I_O ≤ I_{max} − LM317L	3	V_{ref}	1.20	1.25	1.30	V
Line Regulation (Note 5), 3.0 V ≤ V_I − V_O ≤ 40 V	1	Reg_{line}	−	0.02	0.07	%/V
Load Regulation (Note 5) 10 mA ≤ I_O ≤ I_{max} − LM317L V_O ≤ 5.0 V V_O ≥ 5.0 V	2	Reg_{load}	 − −	 20 0.3	 70 1.5	 mV % V_O
Temperature Stability (T_{low} ≤ T_J ≤ T_{high})	3	T_S	−	0.7	−	% V_O
Minimum Load Current to Maintain Regulation (V_I − V_O = 40 V)	3	I_{Lmin}	−	3.5	10	mA
Maximum Output Current V_I − V_O ≤ 6.25 V, P_D ≤ P_{max}, Z Package V_I − V_O ≤ 40 V, P_D ≤ P_{max}, T_A = 25°C, Z Package	3	I_{max}	 100 −	 200 20	 − −	mA
RMS Noise, % of V_O T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz	−	N	−	0.003	−	% V_O
Ripple Rejection (Note 6) V_O = 1.2 V, f = 120 Hz C_{Adj} = 10 μF, V_O = 10.0 V	4	RR	 60 −	 80 80	 − −	dB
Thermal Shutdown (Note 7)	−	−	−	180	−	°C
Long Term Stability, T_J = T_{high} (Note 8) T_A = 25°C for Endpoint Measurements	3	S	−	0.3	1.0	%/1.0 k Hrs.

3. T_{low} to T_{high} = 0° to +125°C for LM317L −40° to +125°C for LM317LB, NCV317LB
4. I_{max} = 100 mA P_{max} = 625 mW
5. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.
6. C_{Adj}, when used, is connected between the adjustment pin and ground.
7. Thermal characteristics are not subject to production test.
8. Since Long−Term Stability cannot be measured on each device before shipment, this specification is an engineering estimate of average stability from lot to lot.

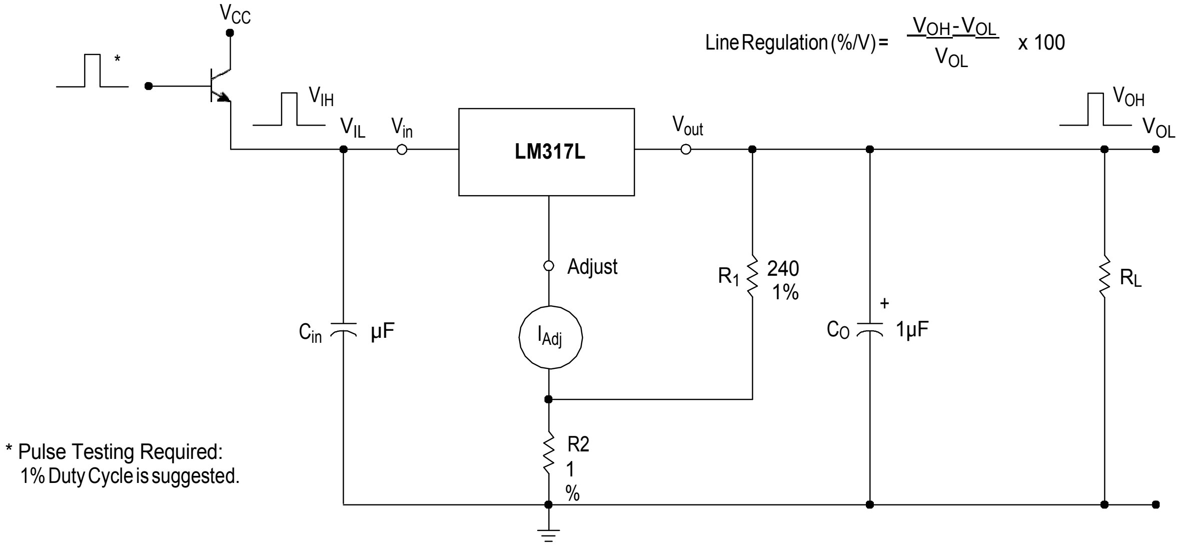


Figure 2. Line Regulation and □I_{Adj}/Line Test Circuit

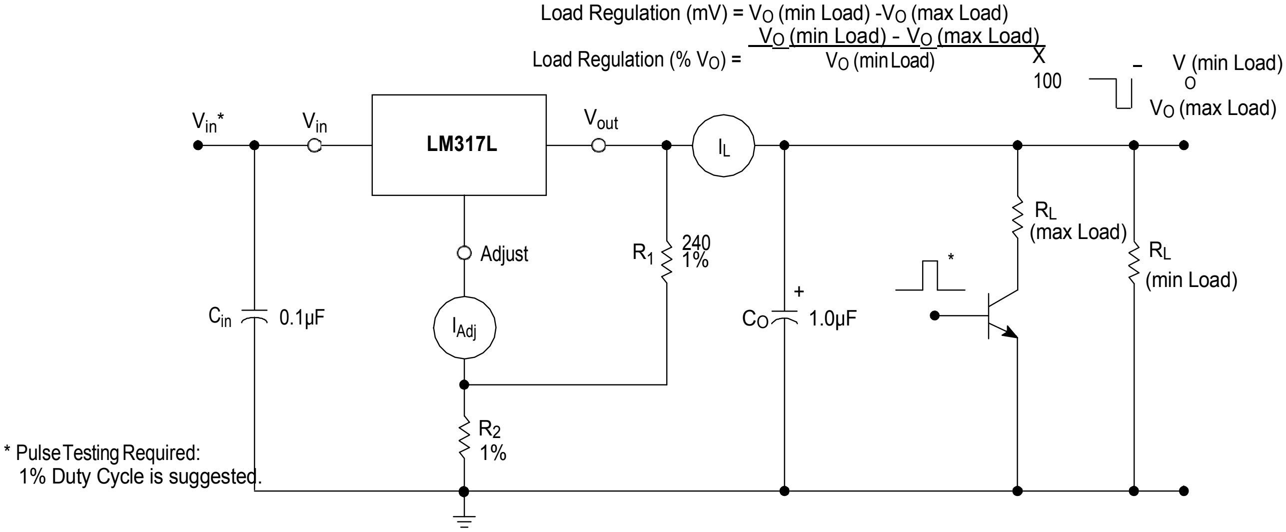


Figure 3. Load Regulation and □I_{Adj}/Load Test Circuit

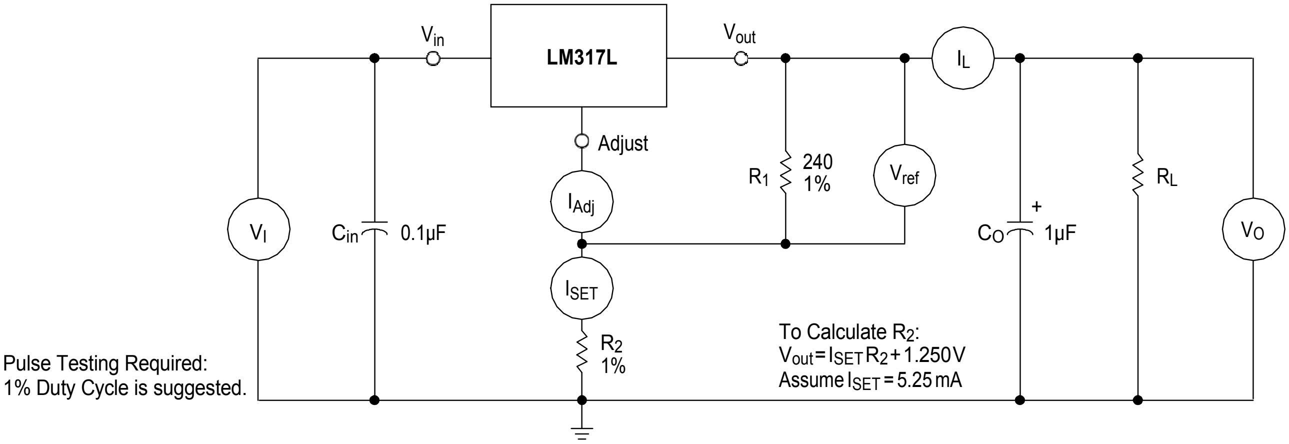
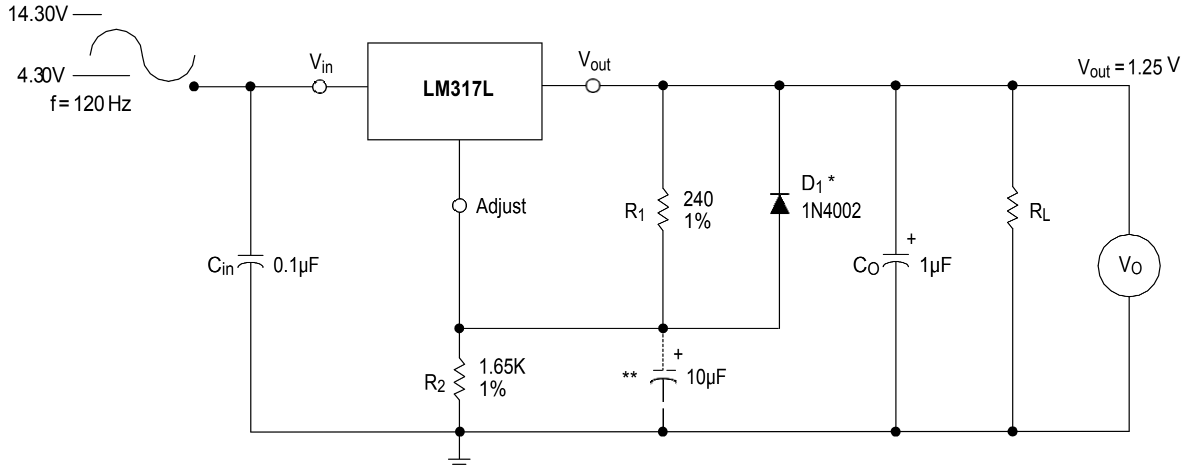


Figure 4. Standard Test Circuit



* D_1 Discharges C_{Adj} if Output is Shorted to Ground.

**C_{Adj} provides an AC ground to the adjust pin.

Figure 5. Ripple Rejection Test Circuit

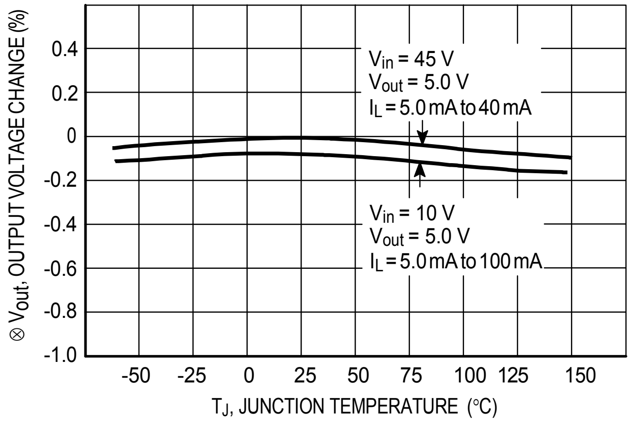


Figure 6. Load Regulation

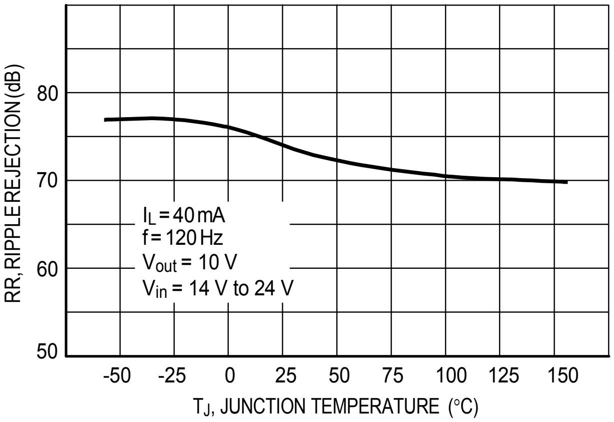


Figure 7. Ripple Rejection

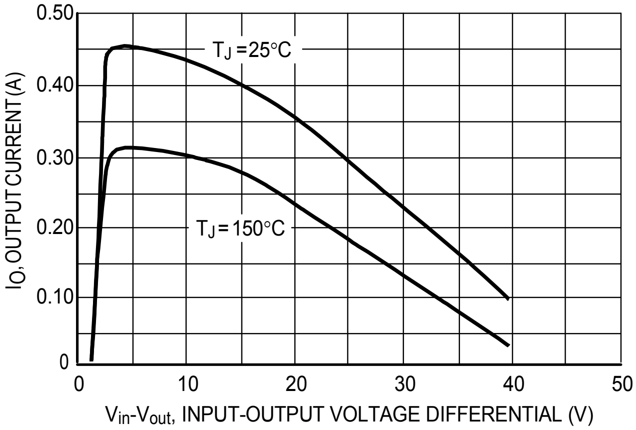


Figure 8. Current Limit

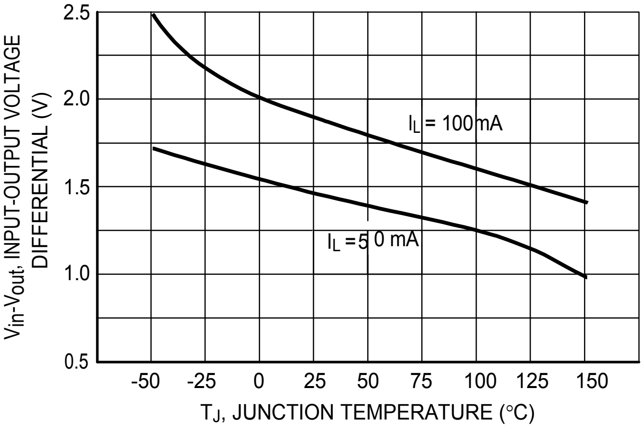


Figure 9. Dropout Voltage

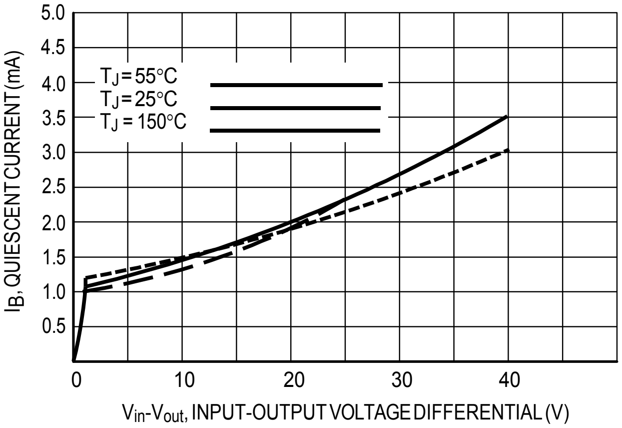


Figure 10. Minimum Operating Current

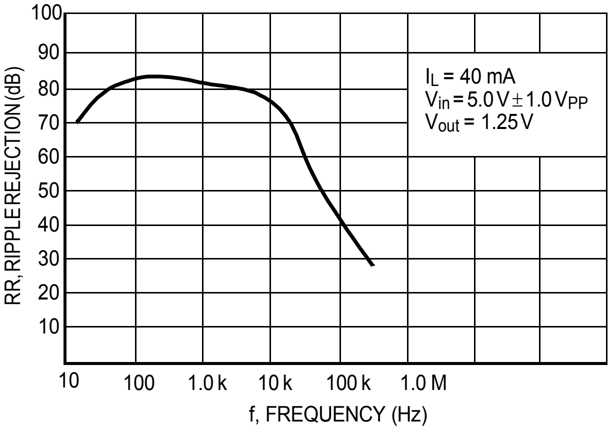


Figure 11. Ripple Rejection versus Frequency

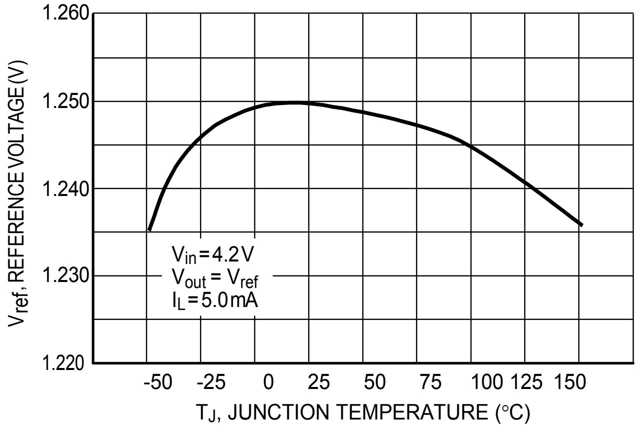


Figure 12. Temperature Stability

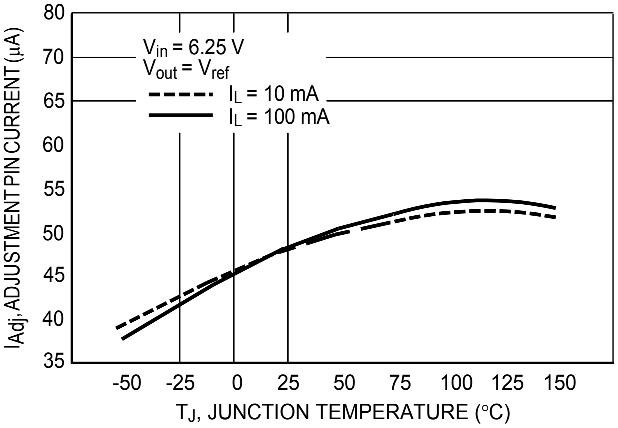


Figure 13. Adjustment Pin Current

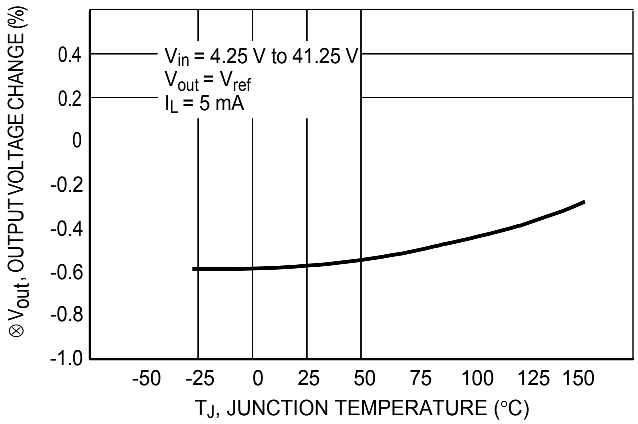


Figure 14. Line Regulation

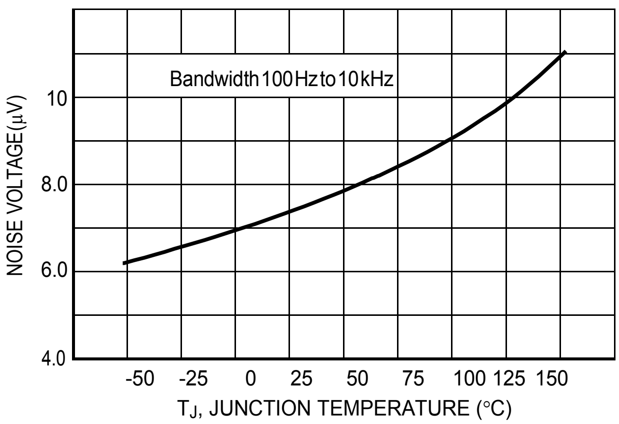


Figure 15. Output Noise

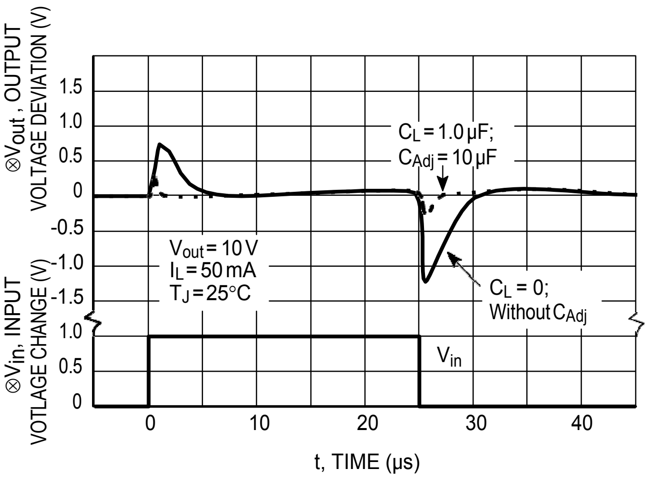


Figure 16. Line Transient Response

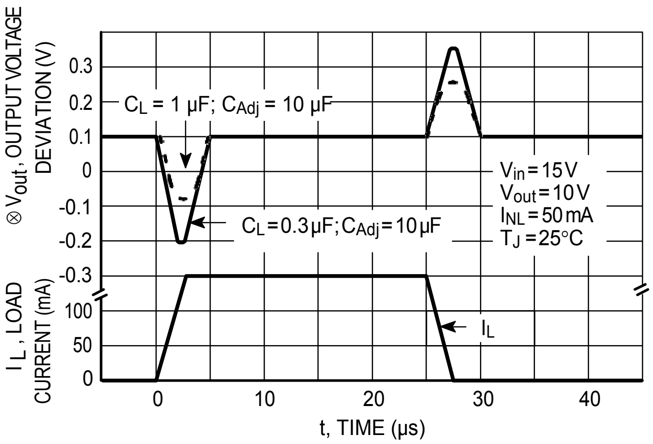


Figure 17. Load Transient Response

APPLICATIONS INFORMATION

Basic Circuit Operation

The LM317L is a 3−terminal floating regulator. In operation, the LM317L develops and maintains a nominal 1.25 V reference (V_{ref}) between its output and adjustment terminals. This reference voltage is converted to a programming current (I_{PROG}) by R_1 (see Figure 13), and this constant current flows through R_2 to ground. The regulated output voltage is given by:

$$V_{out} = V_{ref}\left(1 + \frac{R_2}{R_1}\right) + I_{Adj} R_2$$

Since the current from the adjustment terminal (I_{Adj}) represents an error term in the equation, the LM317L was designed to control I_{Adj} to less than 100 µA and keep it constant. To do this, all quiescent operating current is returned to the output terminal. This imposes the requirement for a minimum load current. If the load current is less than this minimum, the output voltage will rise.

Since the LM317L is a floating regulator, it is only the voltage differential across the circuit which is important to performance, and operation at high voltages with respect to ground is possible.

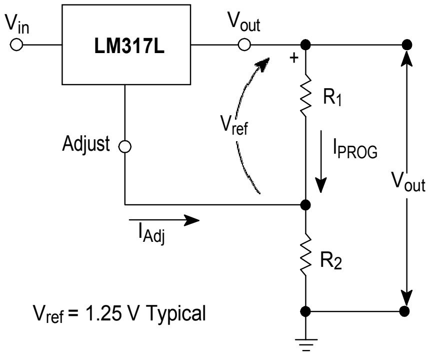


Figure 18. Basic Circuit Configuration

Load Regulation

The LM317L is capable of providing extremely good load regulation, but a few precautions are needed to obtain maximum performance. For best performance, the programming resistor (R1) should be connected as close to the regulator as possible to minimize line drops which effectively appear in series with the reference, thereby degrading regulation. The ground end of R2 can be returned near the load ground to provide remote ground sensing and improve load regulation.

External Capacitors

A 0.1 µF disc or 1.0 µF tantalum input bypass capacitor (C_{in}) is recommended to reduce the sensitivity to input line impedance.

The adjustment terminal may be bypassed to ground to improve ripple rejection. This capacitor (C_{Adj}) prevents ripple from being amplified as the output voltage is increased. A 10 µF capacitor should improve ripple rejection about 15 dB at 120 Hz in a 10 V application.

Although the LM317L is stable with no output capacitance, like any feedback circuit, certain values of external capacitance can cause excessive ringing. An output capacitance (C_O) in the form of a 1.0 µF tantalum or 25 µF aluminum electrolytic capacitor on the output swamps this effect and insures stability.

Protection Diodes

When external capacitors are used with any IC regulator it is sometimes necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator.

Figure 14 shows the LM317L with the recommended protection diodes for output voltages in excess of 25 V or high capacitance values ($C_O > 10$ µF, $C_{Adj} > 5.0$ µF). Diode D_1 prevents C_O from discharging thru the IC during an input short circuit. Diode D_2 protects against capacitor C_{Adj} discharging through the IC during an output short circuit. The combination of diodes D_1 and D_2 prevents C_{Adj} from discharging through the IC during an input shortcircuit.

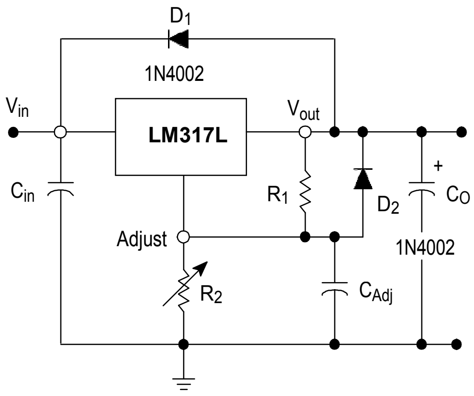
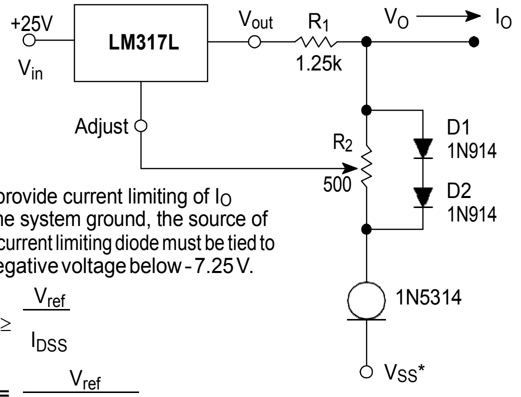


Figure 19. Voltage Regulator with Protection Diodes



* To provide current limiting of I_O to the system ground, the source of the current limiting diode must be tied to a negative voltage below -7.25 V.

$R_2 \geq \frac{V_{ref}}{I_{DSS}}$

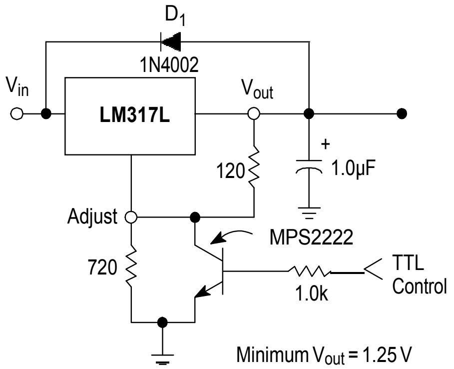
$R_1 = \frac{V_{ref}}{I_{Omax} + I_{DSS}}$

$V_O < P_{OV} + 1.25\,V + V_{SS}$

$I_{Lmin} - I_P < I_O < 100\,mA - I_P$

As shown O < I_O < 95 mA

Figure 20. Adjustable Current Limiter



Minimum V_{out} = 1.25 V

D_1 protects the device during an input short circuit.

Figure 21. 5.0 V Electronic Shutdown Regulator

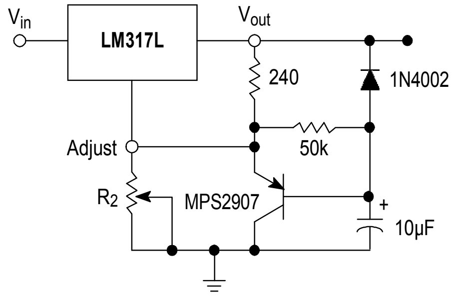
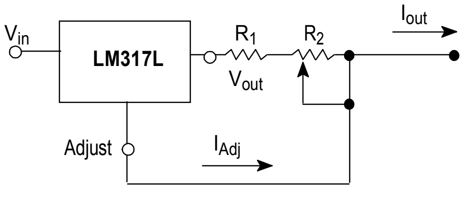


Figure 22. Slow Turn−On Regulator



$$I_{outmax} = \left(\frac{V_{ref}}{R_1}\right) + I_{Adj} = \frac{V}{R_1}$$

$$I_{outmax} = \left(\frac{V_{ref}}{R_1 + R_2}\right) + I_{Adj} = \frac{1.25\,V}{R_1 + R_2}$$

5.0 mA < I_{out} < 100 mA

Figure 23. Current Regulator

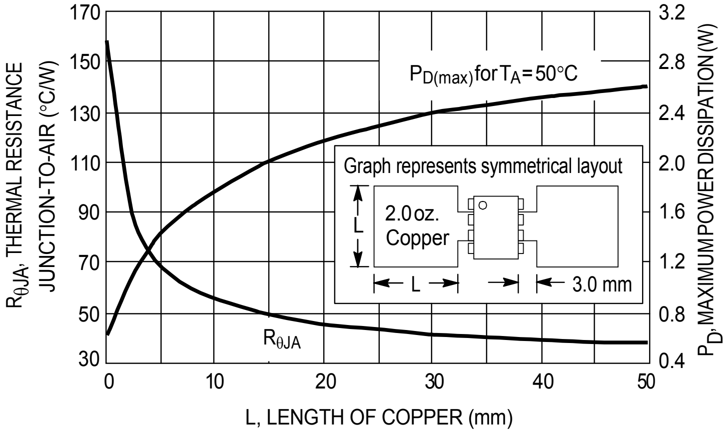


Figure 24. SOP−8 Thermal Resistance and Maximum Power Dissipation versus P.C.B. Copper Length

ORDERING INFORMATION

Device	Operating Temperature Range	Package	Shipping†
LM317LBDG	T_J = −40°C to +125°C	SOIC−8 (Pb−Free)	98 Units / Rail
LM317LBDR2G		SOIC−8 (Pb−Free)	2500/Tape & Reel
LM317LBZG		TO−92 (Pb−Free)	2000 Units / Bag
LM317LBZRAG		TO−92 (Pb−Free)	2000 Tape & Reel
LM317LBZRPG		TO−92 (Pb−Free)	2000 Ammo Pack
NCV317LBDG*		SOIC−8 (Pb−Free)	98 Units / Rail
NCV317LBDR2G*		SOIC−8 (Pb−Free)	2500/Tape & Reel
NCV317LBZG*		TO−92 (Pb−Free)	2000 Units / Bag
NCV317LBZRAG*		TO−92 (Pb−Free)	2000 Tape & Reel
LM317LDG	T_J = 0°C to +125°C	SOIC−8 (Pb−Free)	98 Units / Rail
LM317LDR2G		SOIC−8 (Pb−Free)	2500/Tape & Reel
LM317LZG		TO−92 (Pb−Free)	2000 Units / Bag
LM317LZRAG		TO−92 (Pb−Free)	2000 Tape & Reel
LM317LZREG		TO−92 (Pb−Free)	2000 Tape & Reel
LM317LZRMG		TO−92 (Pb−Free)	2000 Ammo Pack
LM317LZRPG		TO−92 (Pb−Free)	2000 Ammo Pack

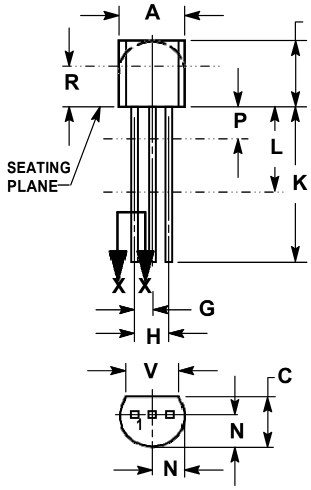
†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

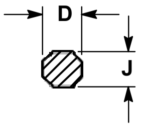
*NCV devices: T_{low} = −40°C, T_{high} = +125°C. Guaranteed by design. NCV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC−Q100 Qualified and PPAP Capable.

PACKAGE DIMENSIONS

TO−92 (TO−226)
Z SUFFIX
CASE 29−11
ISSUE AM

STRAIGHT LEAD
BULK PACK





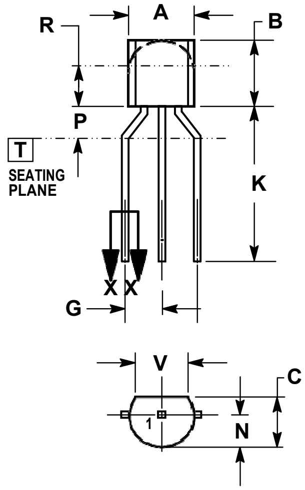
SECTION X−X

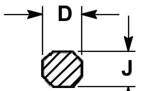
NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. CONTOUR OF PACKAGE BEYOND DIMENSION R IS UNCONTROLLED.
4. LEAD DIMENSION IS UNCONTROLLED IN P AND BEYOND DIMENSION K MINIMUM.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.175	0.205	4.45	5.20
B	0.170	0.210	4.32	5.33
C	0.125	0.165	3.18	4.19
D	0.016	0.021	0.407	0.533
G	0.045	0.055	1.15	1.39
H	0.095	0.105	2.42	2.66
J	0.015	0.020	0.39	0.50
K	0.500	---	12.70	---
L	0.250	---	6.35	---
N	0.080	0.105	2.04	2.66
P	---	0.100	---	2.54
R	0.115	---	2.93	---
V	0.135	---	3.43	---

BENT LEAD
TAPE & REEL
AMMO PACK





SECTION X−X

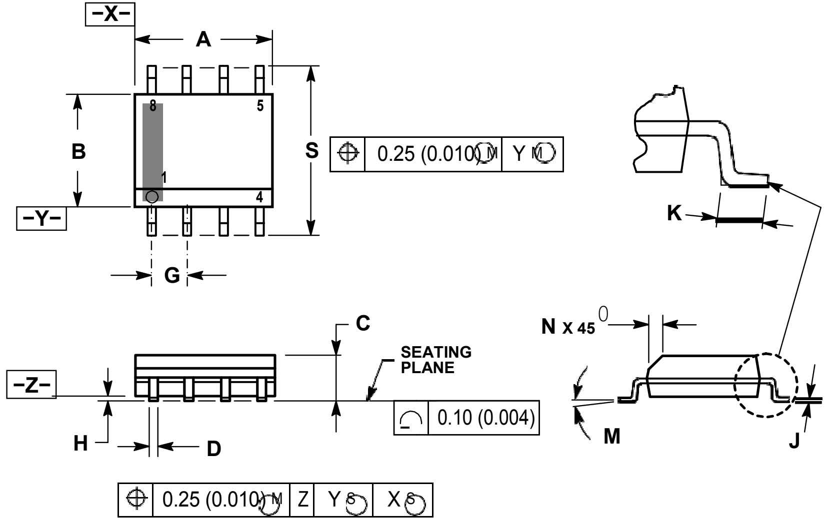
NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. CONTOUR OF PACKAGE BEYOND DIMENSION R IS UNCONTROLLED.
4. LEAD DIMENSION IS UNCONTROLLED IN P AND BEYOND DIMENSION K MINIMUM.

	MILLIMETERS	
DIM	MIN	MAX
A	4.45	5.20
B	4.32	5.33
C	3.18	4.19
D	0.40	0.54
G	2.40	2.80
J	0.39	0.50
K	12.70	---
N	2.04	2.66
P	1.50	4.00
R	2.93	---
V	3.43	---

PACKAGE DIMENSIONS

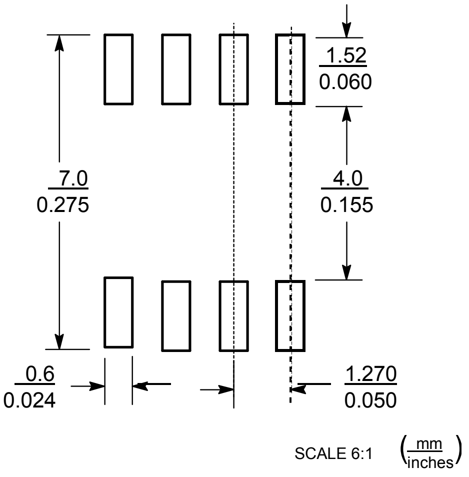
SOIC−8 NB
D SUFFIX
CASE 751−07
ISSUE AK



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. 751−01 THRU 751−06 ARE OBSOLETE. NEW STANDARD IS 751−07.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.197
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.053	0.069
D	0.33	0.51	0.013	0.020
G	1.27 BSC		0.050 BSC	
H	0.10	0.25	0.004	0.010
J				
M	0	8	0	8
N	0.25	0.50	0.010	0.020
S	5.80	6.20	0.228	0.244

SOLDERING FOOTPRINT*



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

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LM317LBDG.
LM317LBDR2G
LM317LBZG
LM317LBZG.
LM317LDG
LM317LDR2G
LM317LZG
LM317LZG.

EN
This Datasheet is presented by
the manufacturer

DE
Dieses Datenblatt wird vom
Hersteller bereitgestellt

FR
Cette fiche technique est
présentée par le fabricant

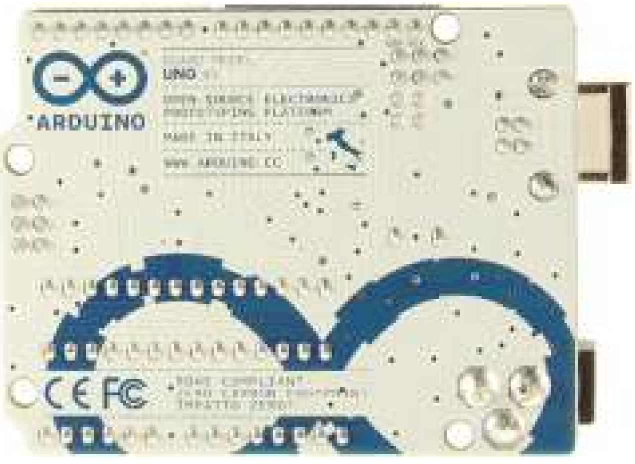
The Used Program:

```
const int stepPin = 9;
const int dirPin = 8;
const int enPin = 13;
void setup() {
pinMode(stepPin,OUTPUT);
pinMode(dirPin,OUTPUT);

pinMode(enPin,OUTPUT);
digitalWrite(enPin,LOW);

}
void loop() {

digitalWrite(dirPin,HIGH);     //  anticlockwise direction
for(int x = 0; x < 800; x++) {
digitalWrite(stepPin,HIGH);
delayMicroseconds(500);
digitalWrite(stepPin,LOW);
delayMicroseconds(500);
  }
delay(1000); // One second delay

digitalWrite(dirPin,LOW);    // clockwise driection
for(int x = 0; x < 800; x++) {
digitalWrite(stepPin,HIGH);
delayMicroseconds(500);
digitalWrite(stepPin,LOW);
delayMicroseconds(500);
  }
delay(1000);
```

```
}
```

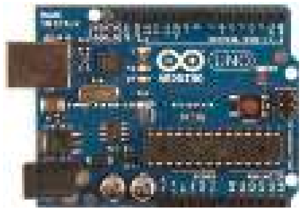
Arduino Uno

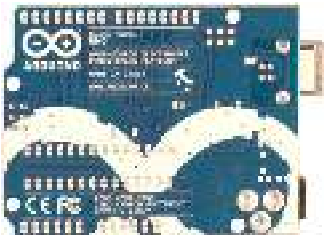

Arduino Uno R3 Front


Arduino Uno R3 Back


Arduino Uno R2 Front


Arduino Uno SMD


Arduino Uno Front


Arduino Uno Back

Overview

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.
The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.
Revision 2 of the Uno board has a resistor pulling the 8U2 HWB line to ground, making it easier to put into DFU mode.
Revision 3 of the board has the following new features:

- 1.0 pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible both with the board that use the AVR, which operate with 5V and with the Arduino Due that operate with 3.3V. The second one is a not connected pin, that is reserved for future purposes.
- Stronger RESET circuit.
- Atmega 16U2 replace the 8U2.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

Summary

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V

Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Schematic & Reference Design

EAGLE files: arduino-uno-Rev3-reference-design.zip (NOTE: works with Eagle 6.0 and newer)
Schematic: arduino-uno-Rev3-schematic.pdf
Note: The Arduino reference design can use an Atmega8, 168, or 328, Current models use an ATmega328, but an Atmega8 is shown in the schematic for reference. The pin configuration is identical on all three processors.

Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.
External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.
The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.
The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.**This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 14 digital pins on the Uno 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 ATmega8U2 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 using the SPI library.
- **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 Uno has 6 analog inputs, labeled A0 through A5, 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 AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

- **TWI: A4 or SDA pin and A5 or SCL pin.** Support TWI communication using the Wire library.

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 ATmega328 ports. The mapping for the Atmega8, 168, and 328 is identical.

Communication

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, a .inf file is required. 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 USB-to-serial 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 Uno's digital pins.
The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. For SPI communication, use the SPI library.

Programming

The Arduino Uno can be programmed with the Arduino software (download). Select "Arduino Uno from the **Tools > Board** menu (according to the microcontroller on your board). For details, see the reference and tutorials.
The ATmega328 on the Arduino Uno 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.
The ATmega16U2 (or 8U2 in the rev1 and rev2 boards) firmware source code is available . The ATmega16U2/8U2 is loaded with a DFU bootloader, which can be activated by:

- On Rev1 boards: connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2.
- On Rev2 or later boards: there is a resistor that pulling the 8U2/16U2 HWB line to ground, making it easier to put into DFU mode.

You can then use Atmel's FLIP software (Windows) or the DFU programmer (Mac OS X and Linux) to load a new firmware. Or you can use the ISP header with an external programmer (overwriting the DFU bootloader). See this user-contributed tutorial for more information.

Automatic (Software) Reset

Rather than requiring a physical press of the reset button before an upload, the Arduino Uno 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 ATmega8U2/16U2 is connected to the reset line of the 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 Uno 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 Uno. 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.
The Uno contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

USB Overcurrent Protection

The Arduino Uno has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics

The maximum length and width of the Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Four screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

N eıStepper M otor

Rev:
Date:

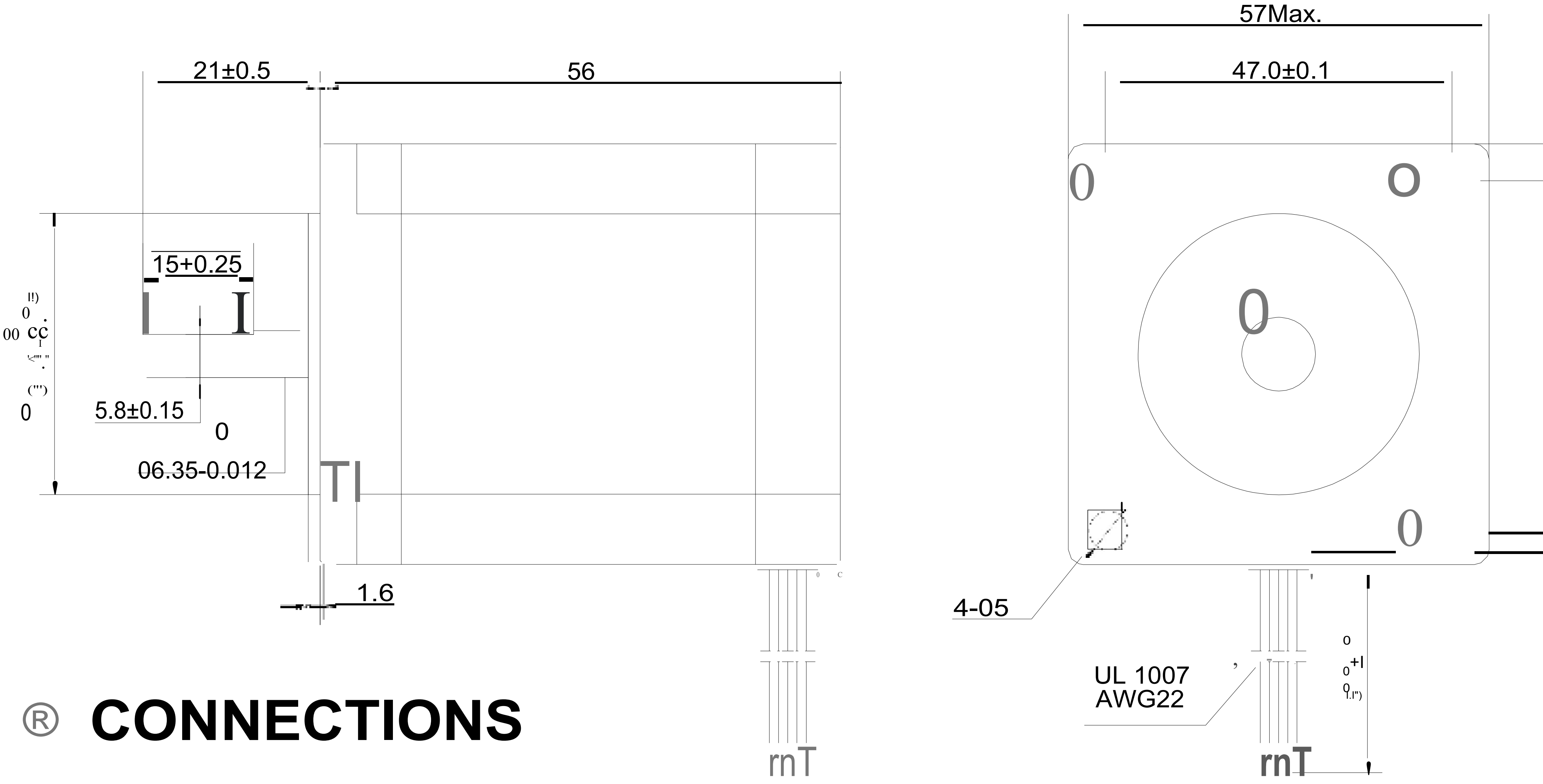
COMMON RATINGS

Step angle :	1.8°	Dielectric strength :	500VAC
Positional accuracy :	±5%	Insulation resistance :	100Mohm(500VD
Number of Phase :	2	Ambient Temperature:	-10°C-50°C
Temperature rise:	80°CMAX	Insulation class :	B
Rotor Inertia :	300gcm^2	Weight:	0.7Kg

SPECIFICATIONS

Holding Torque (2 phases on) Nm	Rated Current/Phase (Amps DC)	Phase Resistance (ohms) ±10%	Voltage Current/Phase (V DC)	Phase Inductar (mH)±20%(1K Typical
1.26	2.8	0.9	2.5	2.5

DIMENSIONS unit=mm



CONNECTIONS