Ceramica Introduction

Creating a New Concept

In 1990, **Ceramica** was brought forth by a simple idea - ***Creating a better more affordable fan.*** Over the years we continued to adhere to this customer oriented approach and built our expertise in the field of thermal management.

Today, **Ceramica** has grown into an international organization of ***cooling solution research and development, design, manufacture, and marketing conglomerates.***

We are ***the proud inventor and sole maker of the most reliable fan*** ***"The Ceramic Bearing Fan"***

Ceramica is the premier expert in production and distribution of a wide range of:

- Cooling fans
- Cooling components
- Thermal management solutions

Our motto

Ceramica is dedicated to provide our customers with

- High Quality products at competitive prices.
- Excellent service
- Good delivery time frame

At Ceramica we strive to be the leaders in our field, and hope that by the turn of century, we have evolved into one of the leading companies in fan cooling. Ceramica continues to uphold the proud traditions that lead to today's success.

Ceramic Bearing System

A New Era for Cooling Fan

Retrospecting to the history we should be able to realize the amazing impact of new materials in various fields of applications. The discovery of semiconductor brought forth the era of electronic industry, and led the change of our life style. The development of heat resistant materials like engineering ceramics broke the power and life limits of traditional engines for jets and autos. Today, through our R&D efforts, Ceramica proudly announces the successful development of ceramic bearing system for mini cooling fan applications, a breakthrough for fans and a new thoughts for the fan industry.

Having Problems With Noise and Life Span? This is the Fan You Need!

Noise and life span have been two major issues when using fans as your cooling solution.
Because noise, especially abnormal noise, can be annoying and fidgety; and the life span can be a direct problem with the performance and reliability of your system. The major reason being its bearing. However Ceramica have solved this problem with their new Ceramic bearing system.

New Industry Demands

We always try to satisfy our customers demands. We have been striving to solve the noise and life problems of conventional cooling fans. The development of Ceramica fans is your solution! Patented technology utilizes the improved ZrO2 engineering ceramics for the bearing system. ZrO2 engineering ceramics has the advantages of wear, heat and chemical resistant. It can be shaped and machined precisely and easily. Owing to its superior material characteristics, this type of bearing system has passed CSIST's rigorous test, which showed extended life compared to existing fans. Ceramica fans have been well accepted by our customers since their introduction at the end of 2001. The application of new technology changes your thoughts, and it is the future in fan application.

Switching to Ceramics

Five years ago, Ceramica realized that the IT industry was posing new demands on fan
Makers, and the company began to develop its own technology, taking advantage of the properties of ceramic materials.

After years of research and development, Ceramica launched its first generation of ceramic bearing systems, featuring a ceramic shaft and a high-precision alloy sleeve bearing. This arrangement proved to offer much better quality than a copper sleeve bearing. The ceramic shaft is very precisely machined, with a very fine surface texture, well in advance of the traditional steel shaft.

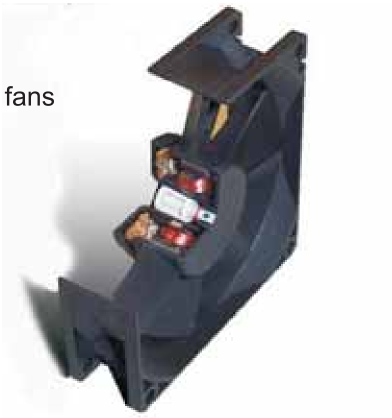
Ceramica launched it's A series fans late in 2001, and this year the company plans to launch its C series, which feature a combination of ceramic shaft and ceramic sleeve. This combination offers very durable and smooth operation, at the same or slightly less cost than a two-bearing system,
while keeping its noise level to a minimum.

For Ceramica, the ceramic design approach has been a success, with a very positive market response, and increase in sales turnover. More design companies are turning to this ceramic technology as ceramic materials offer many advantages, some of which include being durable and resistant to heat and humidity."

Why Ceramic Bearing

Ceramica R&D believes ball bearing type fans are no longer the best fan solution.
Through years of research and development, we have found the following advantages of the ceramic bearing type over the current two ball bearing type fan:

- Reduced complexity of fan assembly compared to traditional fans
- Improved fan structure to reduce noise from bearing system
- Provides alternative to traditional bearing system
- Provides equivalent or better life expectancy
- Provides equivalent or better reliability
- Provides Cost effective solution
- Increase the yield rate of fan production



The Advantages of Zirconia Based Ceramics

Zirconia based ceramics have evolved to the stage where diversified design of microstructures and attributes are within the power of engineer and designers. Varying its control of composition, fabrication route, thermal treatment and final machining, Zirconia has provided hundreds of successful cases in replacing traditional materials as robust and cost effective solutions.

- High hardness
- Greater wear resistance
- Low thermal expansion
- Low conductivity
- Chemical Inertness
- Good for precision machining

Ceramica Improved Ceramics

Ceramica is always seeking for better ways to develop its materials. The processes developed from raw material, molding,

ZrO_2	Conventional Properties	Ceramica Properties
Bonding Form	Ionic and Covalent	Ionic and Covalent
Density (g/cm3)	5.5~5.7	> 6.0
Hardness (Hv)	1000 1100	>1300
Sintering Temp. (℃)	> 1500	< 1400
Thermal Expansion Coefficient (10-6/℃)	8~11	~8
Fracture Toughness K_{IC} (MPa • $m^{1/2}$)	4~6	> 8
Flexural Strength (MPa)	400~600	~800
Friction Coefficient	>0.2	~0.15

Sintering to final machining have gone through a trial and error period until the final ceramic bearing was perfected. This process was as follows:

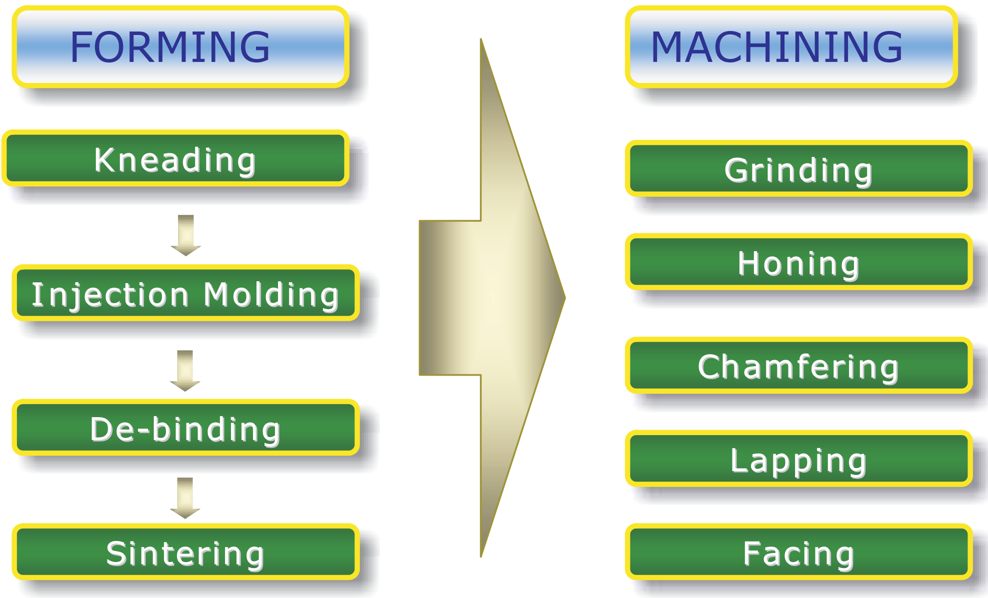
- Employing the state-of-the-art nano technology
- Partially Stabilized Zirconia (PSZ), which well disperses the tetragonal preci-pitates within cubic morphology
- The transformation toughened zirconia is characterized by high strength and fracture toughness Precision injection molding for forming
- Good for creating finely polished surfaces

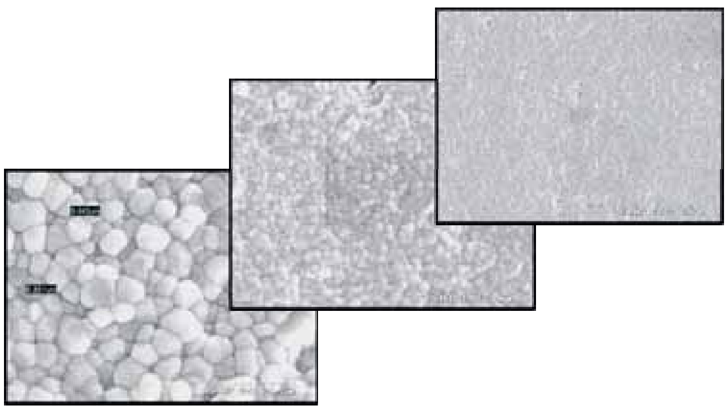
Ceramica's Manufacturing Processes

Ceramica has its full capability from forming to final machining. The raw material is made by deliberately mixing all the necessary ingredients with ceramic powder of less than 300 nano for molding. Precision injection molding process is developed to make ceramic shafts and bearing of various shapes and dimensions. The debinding and sintering processes are then followed to make the final shape and the characteristics needed. The two processes are finely controlled such that all the binders are removed with great precession while microstructure and the grain size can be produced and Maintained for best strength and hardness. In addition, the perfect combination of molding and sintering processes makes the need of machining to a minimum. This is achieved by the "near-net-shape" technology such that there is no excess ceramic material to be machined and therefore the post machining process can be conducted in a very productive way.

Upon the completion of the pre-forming process, the shaft and bearing are moved forward for post machining process. Various machining processes are employed depending on the functional need of each part designed. Either the need to make the dimension, the geometry or the required surface texture can be achieved.

Ceramica Ceramic Manufacturing Processes

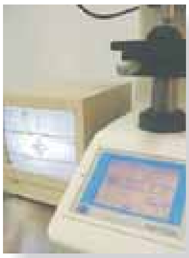




The Microstructure of Ceramica Ceramic Material with Magnification
Of x 15000, x 5000 and x 1000

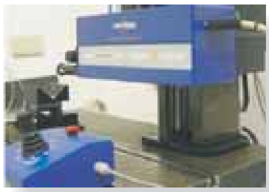
Ceramica's Ceramics Research and Inspection

Ceramica ceramic products have gone thorough investigation from different perspectives.
The ceramic laboratory and quality control are equipped with necessary high precision instruments for verifying the properties and characteristics of the material made and parts produced.
These high precision instruments are capable of checking and reflecting the quality of the products from material and machining aspects, such as the microstructure, strength, hardness, roundness, roughness, etc.







The most important factors and parameters to be examined are listed in the table for your reference.

	Kneading	Injection Molding	De - binding	Sintering	Post Machining
Ingredient	●				
Appearance		●	●	●	●
Dimension		●			●
Weight Ratio		●	●		
Contraction Ratio				●	
Strength				●	
Density				●	
Hardness					●
Roughness					●
Roundness					●

Ceramica A Series

The “A” series fans were introduced a few years ago. Its bearing system features a well machined and polished ceramic shaft along with a fine alloy sleeve. The ceramic shaft possesses adequate hardness that results in very high wear resistance. The surface of the shaft is machined and polished **(Figure 1)**, Reflecting a smooth and shiny texture that conventional SUS shaft can not match **(Figure 2)**. Not only can this hard and fine surface preserve its original quality for an Extreme long period of time of operation, it also comes with the run-in polishing effect on the alloy sleeve.

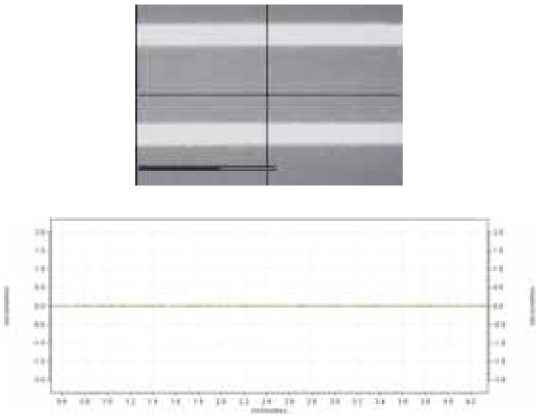


Figure 1 Shows the fine surface of the ceramic shaft as well as the measured surface roughness.

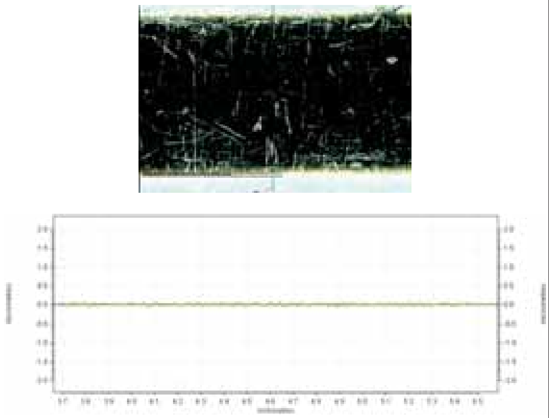


Figure 2 Shows the surface of the SUS steel shaft as well as the measured surface roughness

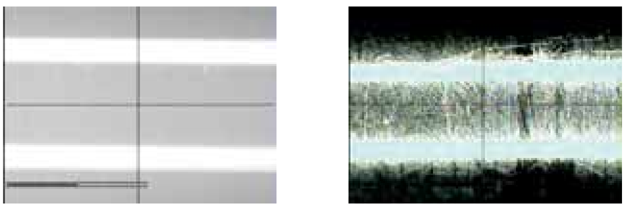


Figure 3 The ceramic shaft after 8,000 hours of operation in 70°C test environment, compared to the traditional steel shaft after 1500 hours of operation under the same condition

Figure 3 and 4 (next page) shows the surface of the ceramic shaft before any operation, and the surface of the ceramic shaft after an extended period of operation under high temperature (acceleration test). It can easily be seen how durable the ceramic shaft is, by its low ware characteristics after a long operational period.

Figure 4. Roughness measurement of ceramic shaft after 8,000 hours of operation in 70°C test environment versus the traditional steel shaft after 1500 hours of operation under the same condition

(Figure 5) The comparison roughness measurement of a ceramic shaft versus a traditional steel shaft. **(Figure 6)** Shows the ware factor of the sleeve between the ceramic shaft versus the metal type. The perfect match of the ceramic shaft and the alloy sleeve results in a very smooth and quite operation, with exceptionally long service life expectancy. Ceramica A series is, in its essence, different from traditional bearing systems in many perspectives, from material characteristics, processes to precision. A complete comparison can be found on table “A”. Currently the Ceramica “A” series fan ranges from 25 mm to 120 mm, both in axial and centrifugal. It has been applied to different fields of market segments, such as IT, telecom, industry, auto, and home appliances, etc.

Figure 5 the roundness measurement of ceramic shaft after 8,000 hours of operation in 70°C test environment and the traditional steel shaft after 1500 hours of operation under the same condition

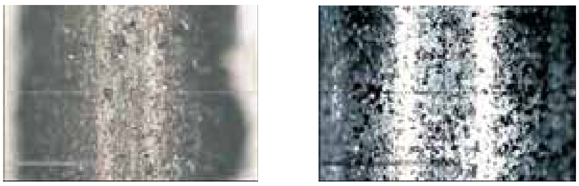


Figure 6 The inner surface of the alloy sleeve before operation and the inner surface of the alloy sleeve after 8,000 hours of operation in 70°C test environment, showing a run-in polishing effect by ceramic shaft

Ceramica C Series

After further research and development, Ceramica launches C fan series in year 2004, featuring a precisely machined ceramic shaft and ceramic bearing. By best using the advantages of the ceramic material and well defined tolerance and precision, Ceramica C series out performs most of the current existing bearing systems in many aspects such as in operation stability, noise, service life, etc. **Figure 7** shows the surface characteristics of the shaft before and after 12000 hours of high temperature operation test. Note that the shaft is the same as what is used for A Series. **Figure 8 and 9** show the surface characteristics and the roundness of the ceramic bearing under the same test condition as the shaft. Due to the precision and the advantages of the material, Ceramica C series results in an even more reliable performance. Furthermore, the patented design of the bearing makes this high-end application more cost effective.

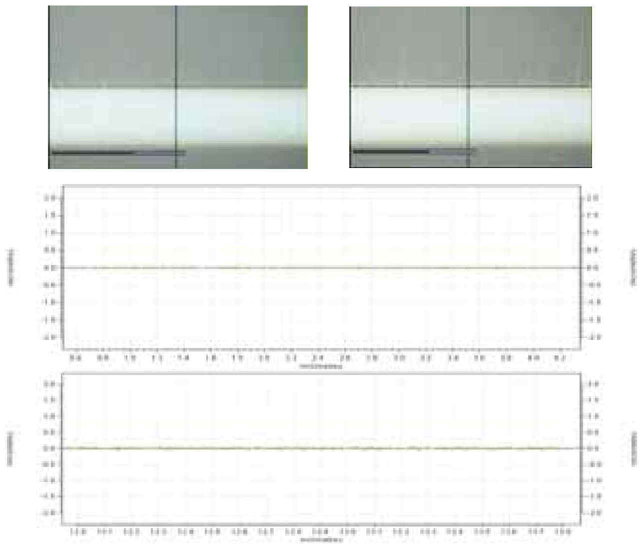


Figure 7 The surface of the ceramic shaft before and after 12,000 hours of operation at 70°C test environment

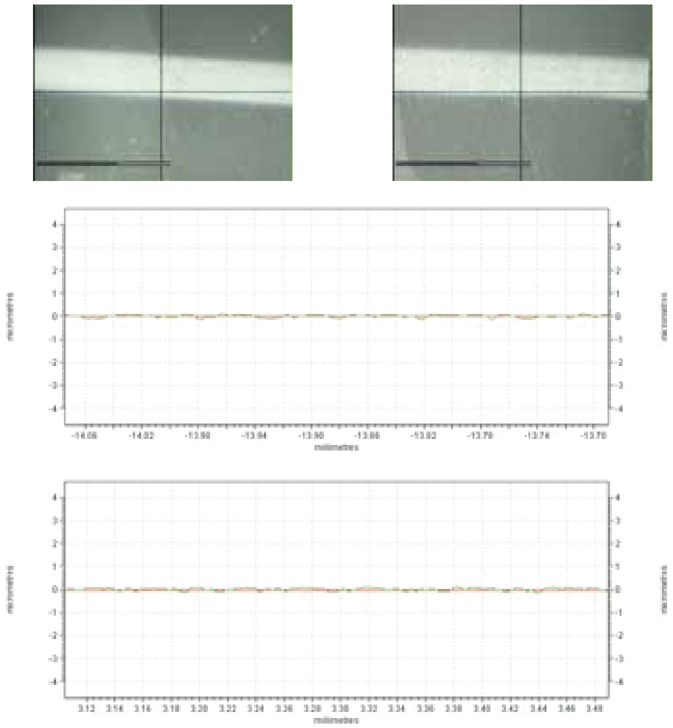


Figure 8 The surface and the roughness measurement of the ceramic bearing before and after 12,000 hours of operation at 70°C test environment

Figure 9 The roundness measurement of the ceramic bearing before and after 12,000 hours of operation at 70°C test environment

Table A - The Comparison of Traditional Bearing Systems with Ceramica Bearing System

Bearing System	① Dual Ball	② One Ball-One Sleeve	③Sleeve	④ Ceramica A-Series	⑤ Ceramica C-Series
Shaft Material	SUS	SUS	SUS	Toughened ZrO_2	Toughened ZrO_2
	*	*	*	High hardness, wear resistance, chemical inertness	High hardness, wear resistance, chemical inertness
Bearing	Two ball	Ball+Sleeve	Sleeve	Alloy Sleeve	Ceramic Sleeve
Material	Bearing steel	Bearing steel Copper	Copper	BCF	Toughened ZrO_2
Motion Characteristics	Rolling	Rolling + Sliding	Sliding	Sliding	Sliding
Precision	☆☆☆☆	☆☆☆	☆☆	☆☆☆☆	☆☆☆☆☆
Stability	☆☆☆☆	☆☆☆	☆☆	☆☆☆☆	☆☆☆☆☆
Noise	Early period ☆☆☆ Late period ☆☆	Early period ☆☆☆ Late period ☆	Early period ☆☆☆☆ Late period ☆	Early period ☆☆☆☆☆ Late period ☆☆☆☆	Early period ☆☆☆☆☆ Late period ☆☆☆☆☆
Bearing Structure	Complex	Complex	Simple	Simple	Simple
Durability	Durable under normal operating condition. Good for high speed operation. Easy to be damaged due to external impact. Sensitive to environment.	Between ① and ③	Not durable due to low wear resistance and low precision.	Durable. Can be comparable to ①.	Very durable due to superior material properties and the precision of machining. Good for high temperature applications
Assembly	Ball bearing is fragile, easy to be damaged during assembly	Ball bearing is fragile, easy to be damaged during assembly.	Simple	Simple	Simple
Price	High	Between ① and ③	Low	Between ① and ③	High

Engineering Information

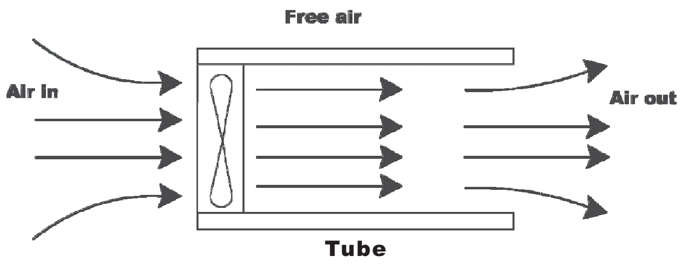
Understanding a Fan and Its Performance

1. P - the static pressure

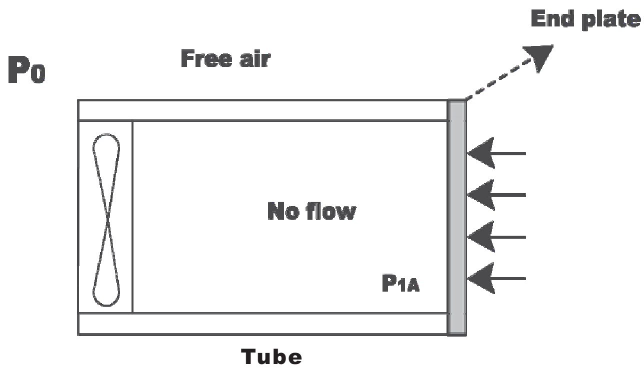
The fan static pressure is one of the key specifications required to calculate its airflow performance. Regardless how it is measured it can be explained in the following simplified manner. Imagine that a fan is installed at one end of an open tube in a way that the fan is drawing air from out side of the tube (the free air) and sending the air flow into the tube **(Figure 10)**. Now, let's take a plate and cover the other end of the tube, which will have the following results:

A. Zero air flow if we completely seal the other end of the tube with the plate **(Figure 11A)**.
B. We will get a little flow if we leave a small gap by slightly moving the plate **(Figure 11B)**.
C. We will get more flow if we leave a larger opening **(Figure 11C)**.
D. Maximum Air flow if we completely move the plate away from the tube **(Figure 11D)**..

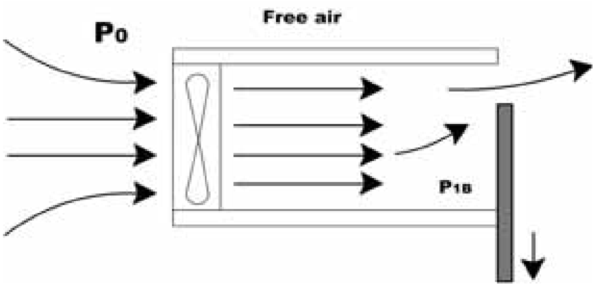
In **Figure 11A** there is no air flow as the tube is pressurized such that the fan driving force can not overcome the tube pressure. When the tube has a slight leak (Figure 11B) the pressure inside the tube is lower than that of **Figure 11A** and the fan is able to expel air out of the tube. As the end plate is moved to allow a larger opening to the other end of the tube, the lower the resistance and the easier it is for the Fan to push the air through the tube.



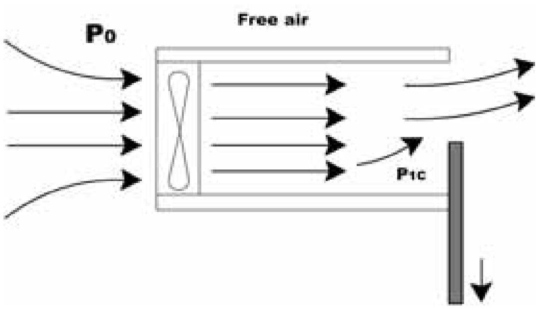
(Figure 10) Free air is drawn through the tube by the fan



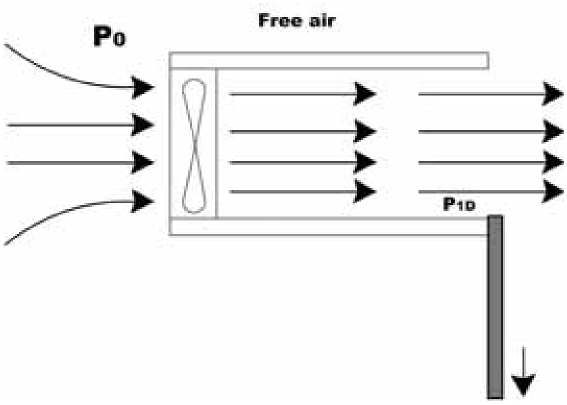
(Figure 11A) End plate seals the tube, no air flow.



(Figure 11B) A small opening will only allow a small amount of air flow.



(Figure 11C) As the opening becomes larger, the airflow is increased while the internal resistance of the tube decreases.



(Figure 11D) Maximum airflow is achieved when the end plate is fully removed.

P1A > P1B > P1C > P1D
P0 is the ambient pressure

As the end plate is fully removed, the tube pressure becomes minimum, and no resistance within the tube. (assuming Non-viscous flow, no friction and no boundary layer closed to the wall).

Normally we use the term “static pressure” to evaluate the performance of the fan or the amount of power to overcome the resistance given by the working environment. Maximum static pressure is the maximum power a fan can generate. Air flow will commence when the pressure (or, the resistance) of the working environment is lower than the fan maximum static pressure. The higher this number is, the more capable the fan is to overcome resistance.

2. Q- the air flow rate

The air flow rate is the volume of air flow delivered by the fan per unit time. Following the scenario described in previous section, we get the maximum air flow rate in **Figure 11D.** In other words maximum airflow because there is no “resistance” in the tube. When the end of the tube is blocked, the internal resistance will increase, causing a pressure difference between both ends of the tube. This can be called a “Back Thrust”, causing the fan to work harder. No airflow will be produced when the back thrust is equal to the fan maximum pressure.

3. The meaning of P-Q curve

In **Figure 12** below, the ordinate is the static pressure and the abscissa is the flow rate. The most commonly used units for flow rate is the CFM (cubic foot per minute) and CMM (cubic meter per minute). The counter part units for pressure are inch-H_2O and mmH_2O. From time to time you may use units other than the said ones. **Table 1 and 2** is a cross reference between different units. A P-Q curve shows, when a fan is selected and used, the maximum flow the fan can deliver (of course, under zero static pressure situation); the maximum pressure the fan can generate to overcome the system resistance (under zero flow rate situation); and all the possible flow rate the fan can produce between these two extremes. Your next question is how do you know the exact fan operating point when a fan is installed on your system? This is, in fact, a question that needs more knowledge and is not easily answered (it will be explained in later section). Owning to this reason, most of the time engineers select fans based on two extremes without involving themselves too much further. people are selecting fans based on the two extremes without involving themselves too much further. It is suggested that you try to get several fans with similar performance and make your own experiment and select the best one based on which fan gives you the best operating point (max airflow within the system).

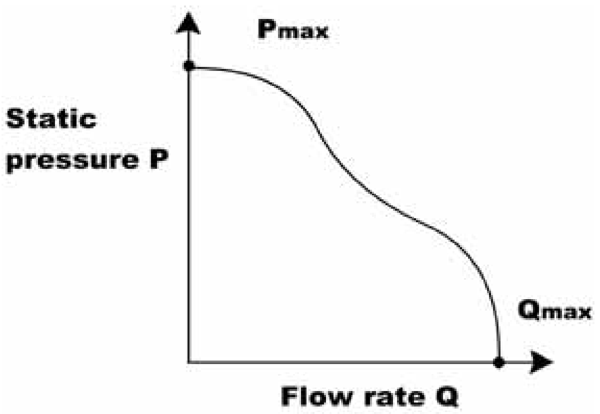


Figure 12 An example of a P-Q curve

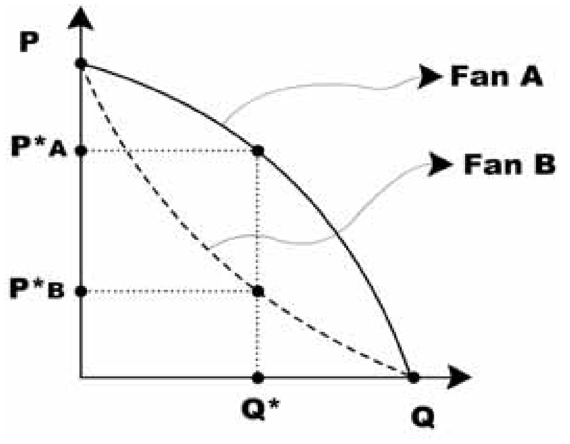


Table 1 Conversion table of static pressure

mmH_2O	inH_2O	Pa (N/m^2)	Bar
1	3.939×10^{-2}	9.807	9.807×10^{-5}
25.4	1	2.49×10^{2}	2.49×10^{-3}
1.02×10^{-1}	4.017×10^{-3}	1	1×10^{-5}
1.02×10^{4}	4.017×10^{2}	1×10^{5}	1

Table 2 Conversion table of air flow rate

CMM	CFM	L/sec	L/min
1	3.532×10	1.666×10	1×10^{3}
2.831×10^{-2}	1	4.72×10^{-1}	2.831×10
6×10^{-2}	2.118	1	6×10
1×10^{-3}	3.532×10^{-2}	1.666×10^{2}	1

In general terms the greater the convex, the better. For example, in **Figure 13A,** curves A and B have the same maximum flow rate (at zero pressure) and maximum pressure (at zero flow rate). However, the fan representing curve A is much better than the fan in curve B. As the static pressure level is much higher under the same air flow conditions Q*. Therefore Fan “A” has a higher airflow than Fan “B” (See **Figure13B**). But in reality, these curves are not as simple as our illustrated waveforms. A typical fan curve can have a curve which concaves somewhere in the middle, other times the P-Q curve can be complex to understand and it requires good knowledge in aerodynamics. Generally the greater the convex curve the better the performance of the fan.

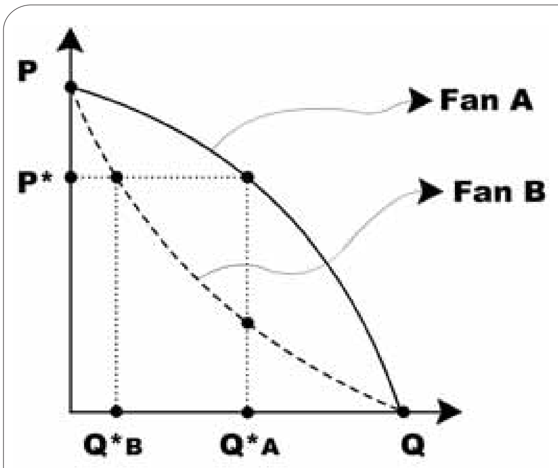


Figure 13B Fan A has more flow than Fan B at P*

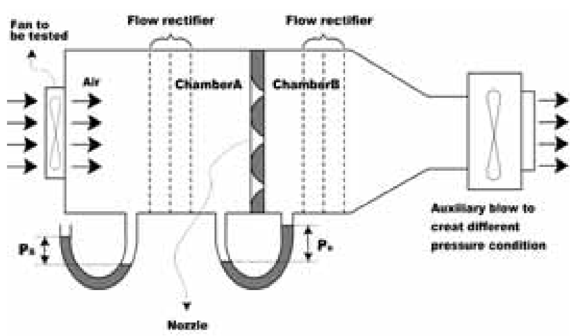


Figure 14 Double chamber wind tunnel

4. Measuring method and standard

The performance of a fan is reflected by the performance curve, or the so-called P-Q curve, which is obtained by measuring the flow rate and the corresponding pressure. The measurement is done using the double chamber method, based on AMCA standard 210 (85). This method employs a wind tunnel with two chambers **(Figure 14)** to create an environment with dissimilar pressure difference, such that the airflow rate can be obtained under each pressure condition. During the measurement, the volume of air flow is obtained by measuring the pressure difference (Pn) between the two sides of the nozzle. The static pressure (Ps) generated by the fan can be measured at the same time. The auxiliary blower is the key to create the intended pressure differences from zero to the highest static pressure a fan can perform.

Basically, the pressure, or the pressure difference is measured by using pitot venturi. But the air flow rate is obtained by calculation based on the following:

Q = 60 AV

where

Q = the air flow rate (m3/min)

A = the cross section area of the nozzle = π D2/4 (m2)

D = the diameter of the nozzle

V = the average flow speed at the nozzle

The average flow speed at the nozzle is calculated as:

$V = (2g\ Pn / \gamma)^{0.5}$ (m/sec)

Where

γ Is the specific weight of the air in kg/m^3 (e.g., γ=1.20 at 20°C, 1 atmospheric pressure) and g is the acceleration of gravity with the value of 9.8 m/sec^2. Pn is the pressure difference in mmH_2O.

5. Parallel and series operation

Parallel operation is a situation were two or more fans are set up side by side. **Figure 15** shows the comparison of P-Q curves of a single fan and of two fans in parallel. It can be seen the air flow rate is increased when using two fans in parallel and the flow is doubled when there is no resistance in the system. However, it can also be noticed that the static pressure of the fan set is not changed.
This Method should only be used when the system resistance is low.

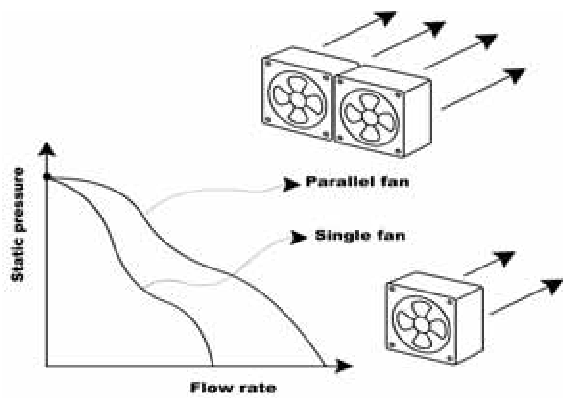


Figure 15 The comparison between single fan operation and parallel fan operation

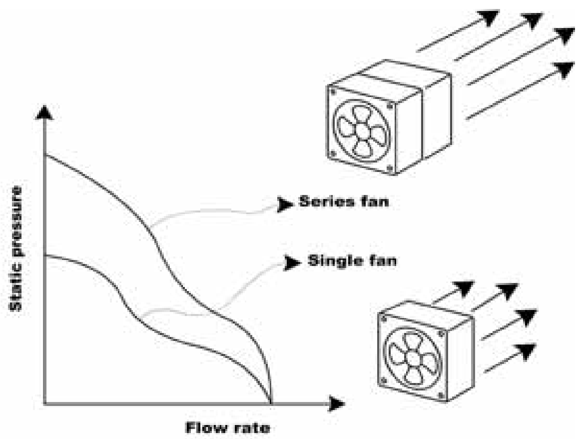


Figure 16 The comparison between single fan operation and series fan operation

Another multiple fan operation is series operation. In this case, you use two or more fans in series. Figure 16 is a comparison of the performance curve of a single fan with that of two fans in series. We can see that the static pressure of the fan series is almost doubled. However, the maximum flow rate is not increased. Series operation can be considered when the resistance of the system is high. Because single fan operation is not able to deliver adequate air flow for cooling. Higher static pressure is needed to overcome the resistance of the system. Series operation is one of the options when high static pressure is required.

Steps to Select Your Ideal Fan

Why do you need a fan? It is because you need some extra air flow to cool your system down? Do you have still air conditions when the system is hot? No. Air is actually moving slowly due to density difference. We call it natural convection. When the temperature of the system or key component exceeds its limit, we need extra air flow. When this extra air flow is produced by using a fan, we call it active cooling (achieved by forced convection). Air is a material with mass. Anything with mass can absorb heat. As a result, the fan that can drive the amount of volume of air to prevent the temperature of the system from reaching it limit is the bottom line choice. Any fan that can not cool your system down enough will be ruled out for further evaluation. So the first thing you want to do is to figure out how much air flow you need to remove the heat generated by your system.

1. How much Air flow is required?

Heat is transferred only when there is a temperature difference between the heat source (your system) and the environment. When air flow rate is high, the temperature difference will be low, as the air removes the heat very fast not allowing the heat to accumulate (when heat accumulates, the temperature rises). When the air flow rate is low, the heat accumulates until it creates a temperature difference that is adequate for another equilibrium (i.e., more "load" on the air passed by). Therefore, in order to know the volume of air flow needed, the following points must be known:

A. The amount of heat generated in your system
B. The temperature limit of your system and the surrounding temperature.
C. Calculate the minimum air volume required.
D. Estimate the system impedance (resistance, in terms of air flow) of your system.
E. Match the above estimate with the performance curve of the selected fan.

Air Volume Calculation

Figure 17 is a schematic expression of a system with a heat source inside. This system is to be cooled down by using a fan. Assume the ambient temperature is T_{amb} and the ceiling temperature of the system is T_c. The minimum heat to be removed in order to keep the system temperature less than Tc is calculated as:

$H = Cp \times M \times \Delta T$ where

C_p is the specific air heat, M is the air mass and ΔT is the temperature difference between Tc and T_{amb}. The air mass is the flow rate Q times the density (ρ) of the air.

If we rearrange the above equation we will have:

$Q = H / (Cp \times \rho \times \triangle T)$

Where

$Cp \fallingdotseq 1005$ J/Kg°C and $\rho \fallingdotseq 1.18$ Kg/m3

Example. For a given heat source of 200 watts with a system enviroment that cant exceed 80°C. If air with ambient temperature of 25°C is drawn from outside of the system, the air flow rate Q can be calculated.

Before the calculation. Check Table 2 for help.

Q = 200 watts/ (1005 x 1.18 x 55) = 0.00307 (m3/s) = 0.184 CMM = 6.5 CFM

To help you further, you may use

$Q \fallingdotseq H / (20 \times \triangle T)$ for CMM (H in watt and $\triangle T$ in °C) or

$Q \fallingdotseq 1.79 \times H / \triangle T$ for CFM (H in watt and $\triangle T$ in °C)

Table 3 is an easy guide table for your reference.

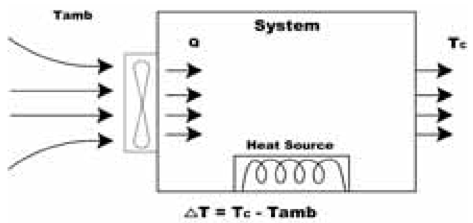


Figure 17 A schematic cooling model

Table 3 A look-up reference for flow rate estimation

ΔT (°C)	Q \ H	10	20	40	60	80	100	120
80	144	0.22	0.45	0.90	1.34	1.79	2.24	2.69
70	126	0.26	0.51	1.02	1.53	2.05	2.56	3.07
60	108	0.30	0.60	1.19	1.79	2.39	2.98	3.58
50	90	0.36	0.72	1.43	2.15	2.86	3.58	4.30
40	72	0.45	0.90	1.79	2.69	3.58	4.48	5.37
30	54	0.60	1.19	2.39	3.58	4.77	5.97	7.16
20	36	0.90	1.79	3.58	5.37	7.16	8.95	10.74
10	18	1.79	3.58	7.16	10.74	14.32	17.90	21.48
℃	F	H (watt); Q (CFM)						

System Impedance Estimation

Now we have to get some idea about how to estimate the system impedance. It should be noted that it is not an easy task to estimate the system impedance without extra measuring equipment. However, basic theory will still be explained for your reference.

When air is introduced into a system, it will encounter resistance due to the layout of the system. It is the pressure drop that causes the resistance. The pressure drop (or, the resistance) goes higher when more airflow passes through the system. As a result, we may envision that there is another P-Q like curve, which is commonly called the system characteristic curve. These curves show the relation between the system impedance and airflow rate. A widely used empirical relation between the two is:

$\triangle P = KQ^n$

Where $\triangle P$ is the system impedance, Q is the airflow rate, K is the system's characteristic constant and n is the flow factor with value between 1 and 2. For laminar flow, n=1
For turbulent flow, n =2

Figure 18 shows the relationship between fan performance curve and a typical system characteristic curves with similar flow factor but different Ks. In this figure we can see that curve A reflects a system with higher system impedance than that of curve B and thus curve C. In other words, you may need to use a fan with higher static pressure for system A in order to get the same flow rate as that of using a lower static pressure fan in system C. The intersection of fan performance curve versus the system impedance curve is called "operating point". The same fan installed in systems with different system impedance results in different air flow delivery, due to the fan operating at different
P-Q points.

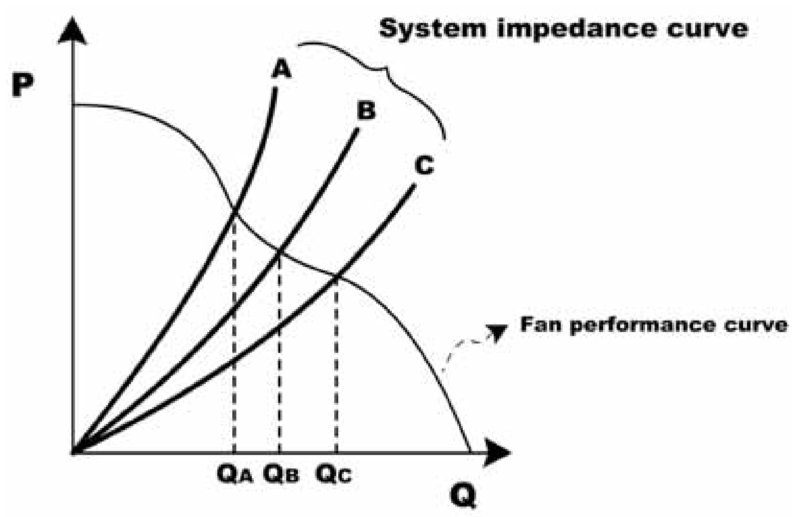


Figure 18 System impedance curve vs. fan performance curve

Matching System Characteristic Curve with P-Q curve

When you match the system characteristic curve with the P-Q curve of a fan, there can be an intersection point. This point is called “operating point”. That is, the fan is actually operated at the static pressure of that point and delivering the corresponding flow, not the maximum flow rate. This tells you that it is not recommended to select a fan by only compare the extreme values of fans at hand. You should select fans with similar numbers on the data sheet and compare their P-Q curves and examine the operating point of each fan. This can then be confirmed by testing the fan on the system. Figure 19 shows several situations that tell you the extreme values on the data sheets are just approximate figures. As Fan 2 and Fan 1 may perform the same in System A, though their extremes are very different. For a system with low impedance like in System B, the maximum static pressure of a fan may not be critical. But for a system with an impedance much higher than System A, Fan 3 may not be suitable, though its maximum airflow rate is far more than that in Fan 1. It is better to compare the fan performance curves of different fans with the concept of the system impedance in mind.

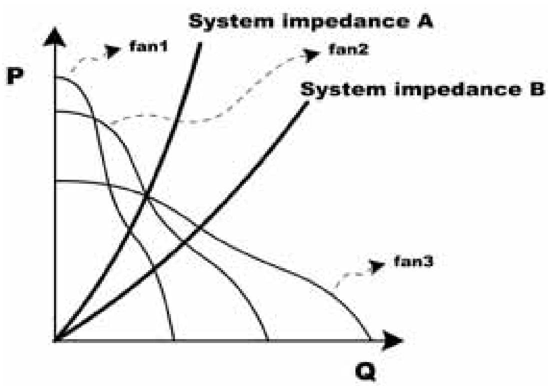


Figure 19 Fan operates in different systems results in different performance

2. What is the space allowed for installing the fan

The space available for the fan should be taken into consideration at an early stage of your calculations. Taking into consideration that the heat factor on the electronic circuit will increase with time, therefore the cooling process becomes very important. Do not consider your industrial, structural and functional design without considering the environment required for cooling your system. The smaller the space allowed, the higher the speed of the fan may be needed, and therefore, the higher the noise level produced.

How to specify a fan in terms of its dimension

The most common practice when specifying a fan in terms of its dimension is to identify the width (length) and height of the housing. For a fan of square or round shape, you can use its width (square) or diameter (round) along with its height. For example, a square fan of 60mm x 60mm with a height of 25mm can be named as “sixty by twenty five”. However, if the shape of the fan housing is not square for some reason, the only thing we can do is to specify all the dimensions.

3. Concerning the noise

The major sources of acoustic noise come from the airflow generated by impeller through its housing, bearing system and electro-magnetic switching. These are explained in detailed below:

A. Flow field generated by impeller

Generally, the noise level produced by your fan is produced by its airflow. When a fan is operating, the impeller is doing work, moving a mass of air from the intake side to the exhaust side. There are relative motions between air and blades, air and housing, air and the ribs that support the motor. These relative motions are usually not laminar flow (streamlined). That is, turbulence (or wind shear) are generated and vortices of different scales are formed. These vortices are shedding from the leading edges or the trailing edges of blades or ribs with dissimilar frequencies and energies. This is why you may feel differently when hearing the operation of fans of different design. You may correlate tone with frequency, and loudness with energy. If you have a fan with 7 blades when rotated at 4200 RPM, you may imagine a major frequency of noise at around 7 x 4200 60(sec)= 490 Hz. Other frequencies of noise depend on the design of the fan.

B. Bearing system

Bearing system is the mechanism that holds the rotor (or impeller) to create an axis of rotation. The noise comes from the sliding motion between shaft and sleeve type of bearing, or the rolling (driven by the shaft) motions between ball and bearing track of ball bearings. Normally, you should not be able to distinguish the bearing noise from the airflow (wind shear) noise.
However, if the bearing system is not of high standards, you may hear the bearing noise clearly when the fan is operated at low speed. It should be noted that, among the sources of noise, bearing noise is the only source that may change with time of operation, due to the ware & tare overtime. Therefore, the quality of bearing is very important.

C. Electro-magnetic switching

It is sometimes referred to as “buzzing”. The interaction between the magnet and motor core due to pole switching, and the internal switching of the induction IC are the two sources of buzzing sound.
It is not so susceptible as compared to the noise due to air flow. However, it does create certain high level of noise if the electro-magnetic design is not well design.

Another source of noise comes from the application, not the inherent by the fan. Remember that fan will be installed on a system. The layout of the system may cause airflow disturbances, and thus noise. The noise can be very sensitive to disturbances caused by card guides, brackets, capacitors, transformers, cables, finger guards, filter assemblies, walls or panels, inlet and outlet guards, etc, and the experience of the designer becomes very important to determine a low noise within the system.

It is therefore important to find a fan that results in the lowest noise level. Sometimes a larger fan with lower speed may be a good alternative for reducing the noise. If you have a problem finding a fan for low noise operation, probably you need to review the design (layout) of the system to avoid obstructions and compactness for a better aerodynamic air flow.

Cooling fan noise is expressed in decibels (dBA). The dBA rating is determined directly by a sound level meter (microphone) in an anechoic chamber, equipped with a filtering system which deemphasizes both the low and high frequency portions of the audible spectrum. This measurement is recorded at a distance of 1 meter from the intake side of the fan, which is running without resistance. **Figure 20** illustrates the setup.

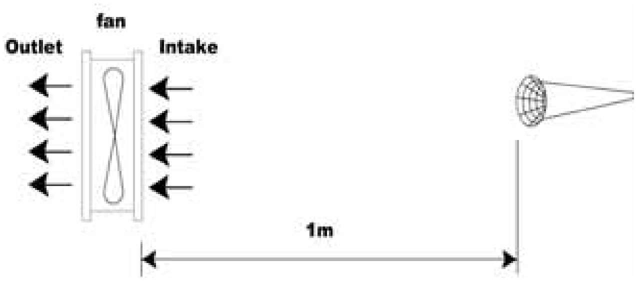


Figure 20 The measurement setup for determining the acoustic noise level

4. What is the power consumption allowed

You need to know the power consumption of your fan. What is the voltage, and the current allowed. The most common voltages in our Ceramica range of fans are 5V, 12V, 24V and 48V. The current depends on the size and the speed of the fan, basically. Multiplying the rated voltage and the rated current you can get the rated power. If you get a fan of similar performance, it is important to find a fan that consumes the least possible power. But sometimes you need to make trade-off between power consumption and performance. If all the fans in hand can meet the power consumption requirement, then you need to choose the one with the performance required.

5. What are the functional requirements needed? - Optional functions

There are certain functions that are required by customers from time to time. Most commonly asked functions are AR (auto restart), RD (rotation detection), FG (frequency generation), speed control, etc. Below you will find a brief summary of each function for your reference. For more information regarding detailed specification and applications, please contact Ceramica.

Auto Restart:

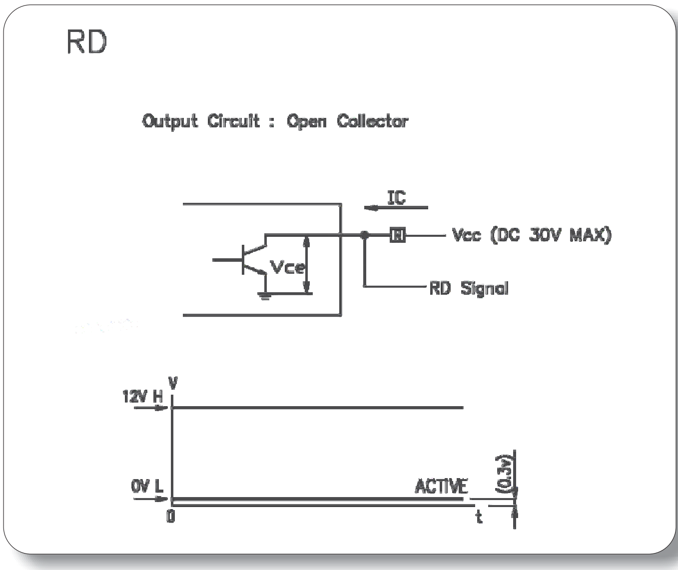
In the event that the fan (impeller) is blocked by expected or unexpected external means, a signal will be sent from the circuit IC, such that the power will be switched to stand by status. Meanwhile, a capacitor is charged as a reserved source of power for rebooting the fan. By applying this function, the temperature of the fan can be kept low while the fan is stopped, and power is still applied.

Alarm Signal:

Alarm signal is used to tell the status of operation. There are two kinds of alarm signals available.

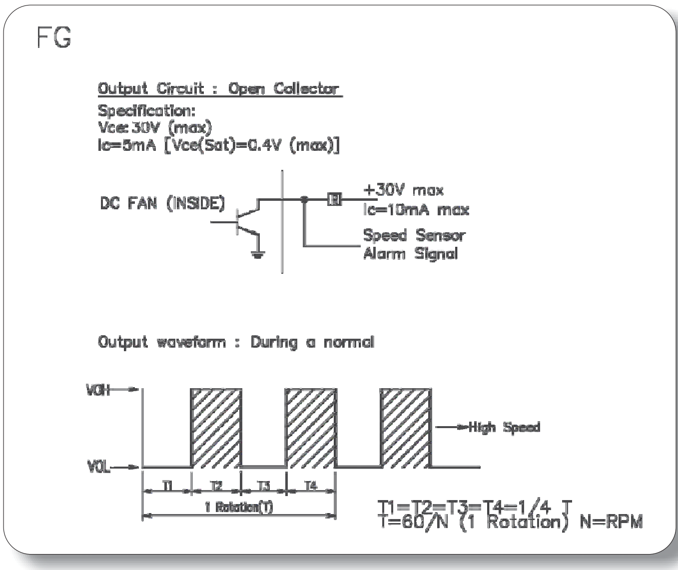
A. RD (Rotation Detection)

RD sensors are used to provide the signals of operating status of the fan motor via third wire. A DC level on the third wire will indicate the working status of the fan.



B. FG (Frequency Generation)

Signal is an open collector. This is also called tachometer signal, used to detect the speed of the fan. The two pulses per revolution comes with 50% duty cycle.



Speed Control:

A. Temperature Control

The thermal speed control option varies the speed without the need of any external input. This option uses an external thermistor to monitor the temperature and regulate the speed accordingly. The thermistor will change its resistance at different temperatures, thus creating a variable voltage divider circuit at the adjust leg of the voltage regulator. The fan will automatically adjust its speed to optimize the airflow to the surrounding temperature. The fan will operate at its maximum speed and minimum speed when detecting specific high (temperature) or specific low (temperature), respectively. Between the two temperature limits, the fan speed will vary almost linearly with temperature.

B. PWM (Pulse Width Modulation)

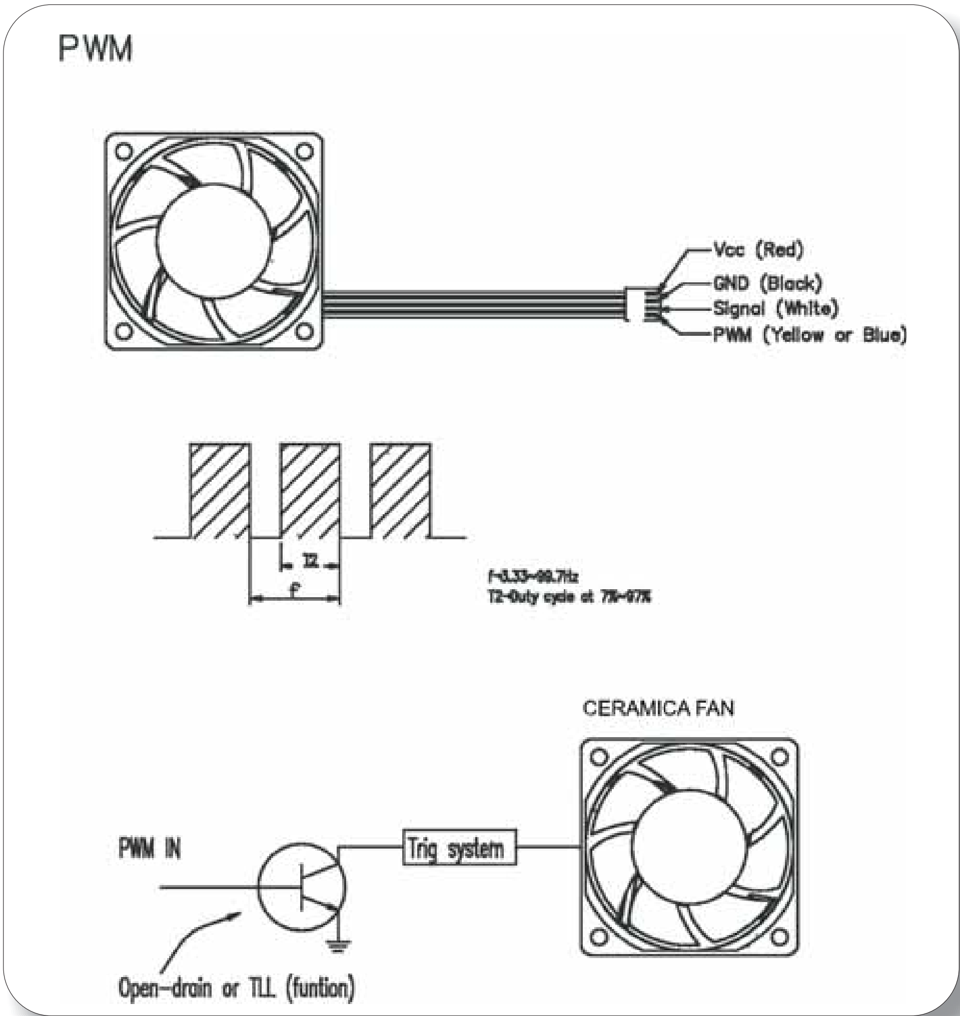
Pulse Width Modulation (PWM) s a technique for controlling analog circuit with a processor's digital output. In other words, PWM is a way of digitally encoding analog signal levels. The PWM fan speed control method adds an extra 4th wire to the connector. The 4th wire is a Pulse Width Modulation (PWM) input terminal that provides a duty cycle to the fan. For example a 60% PWM duty cycle is a perfect square wave where 60% of the signal is high and 40% of the signal is low. A 60% PWM duty cycle applied to the 4th wire of the fan will result in a fan speed of 60% the total maximum fan speed. That is, if the fan is rated for 5000 RPM max, a 60% PWM duty cycle will result in the fan running at 3000 RPM. An 80% PWM signal applied to the fan is a square wave were 80% of the signal is high and 20% is low resulting in a fan speed proportional to the duty cycle as referenced to the maximum speed of the fan.

(1) FPWM

By means of applying voltage on and off, the amplitude should be equal to the nominal voltage of the fan, the frequency should be held constant and the duty cycle allowed to vary between 0 and 100%.

(2) VPWM

By means of applying voltage on and off,



C. ST

This is a function that can produce a stand by state. The fan will stop its operation when getting the stand by signal. The fan will reboot when the system signals the need for cooling.

D. Others

Functions other than the above can be customized upon request. Please contact us if you have any special request.

6. Service life and reliability

Most frequently asked is the MTBF (mean time between failure) of the fan. Normally, the life of the fan is estimated by using the acceleration test. That is, install a specific number of fans (e.g., 50 pcs) in an oven with an elevated temperature (e.g., 70°C) to create a “quick aging” environment. The result will be analyzed and transformed in a way that can give a good indication of how long the fan can sustain your application. Whenever you choose a fan, you need to be sure that the fan and its specifications are based on the same condition. For example, some may guarantee a service life of 50000 hrs at 25°C and some may guarantee a service life of 25000 hrs, but at 50°C. You need to be careful that the former one may not be better than the latter. Why different specification? It is because the application varies. Some may need to use a fan mostly in a room temperature environment, but some may use the fan in a system that is always in an elevated temperature environment, e.g., 50°C. Fan manufacturers need to know what the application is in order to provide you the data you need.

7. Match cost with your application

Several aspects you have to consider concerning the cost. Some of the add-on functions will certainly increase your cost. As well as the bearing system is also directly related to the cost. For conventional bearing systems, there are sleeve, one-ball one sleeve (or, ball-sleeve), and two-ball bearing systems. Fans using sleeve bearing system is the cheapest option among the three. Two-ball bearing system is, on the other hand, the most expensive. You may directly link the bearing system with the service life of a fan. Generally, the life of two-ball bearing system is longer than ball-sleeve, and ball-sleeve is longer than sleeve.

The pioneer, Ceramic patented bearing system gives you different level of service, with lower noise levels and higher lifespand. Try Ceramica. If you are thinking for a replacement, it is time to switch to Ceramic.

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Comparisons between Ceramica Fans and Conventional Fans

Bearing System / Feature Comparison	Conventional Fans SUS420 Steel Shaft		Ceramica Fans ZrO_2 Ceramic Shaft
	Ball Bearing	**Cu Sintered Sleeve**	**Cu-Fe Alloyed Sleeve**
Contact Mode	Multi-Point Contact. Rolling Friction.	Line Contact. Sliding Friction.	Reduced Line Contact with Minimized Sliding Friction.
Noise Level	Steady noise level through life. Generally higher than sleeve bearing.	Lower noise level than ball bearing at early stage but gradually increases over life.	ZrO_2 shaft is fine polished to a mirror-like surface and thus substantially reduce noise level to lower than both ball and sleeve bearings.
Machining Precision	The characteristics of SUS420 present inherent limitation in machining precision to reach finite dimensional and geometrical tolerance.		Near-net-shape formed shaft needs minimal machining to achieve high level of precision.
Hardness	HRC = 50		HRC = 90
Durability	Good for high-speed operation at normal condition, but sensitive to changes in humidity and temperature.	Prone to be worn out of shape due to lower hardness or lack of fitting precision.	Stable operation throughout life as a result of superior material property that provides resistance to wearing, deformation, oxidation and corrosion.
Precision of Movement	Good level of precision but very fragile under external impact.	Low level of precision. Easily cause clogging or seizing.	High level of precision due to: 1. Machining and fitting 2. Lower thermal expansion coefficient, 3. Secondary polish effect between shaft and sleeve
Life Expectation	2-Ball system: 50,000~65,000 hrs avg. 1-Ball-1-Sleeve: 50,000 hrs avg.	30,000 hrs avg.	300,000 hrs avg. (from MTBF test by CSIST)
Cost	High	Low	Medium