Vol II Issue 1 / 2007

Charge

A Technical News Journal from Deki Electronics Ltd

June 2007

Editor's Desk

Dear Reader,

The year 2006-07 has been a year of major expansion in capacity for us at Deki. Our annual capacity in film/foil line is now 360 million, a 3-fold jump from the 120 million earlier. The plan is to now accelerate growth to over 30% annually.

Our business plan for 2007-08 reflects this ambition. We plan to achieve this by maintaining our leadership in the lighting and industrial segments and increasing our share in consumer electronics, telecom and auto.

Deki's fan regulator capacitors have set a benchmark in the industry for their reliability. The range has now been augmented with the introduction of the new, flame-proof Ultima line. This edition of *Charge* is, therefore, devoted to capacitors for fan regulators.

As usual, we look forward to your comments and suggestions.

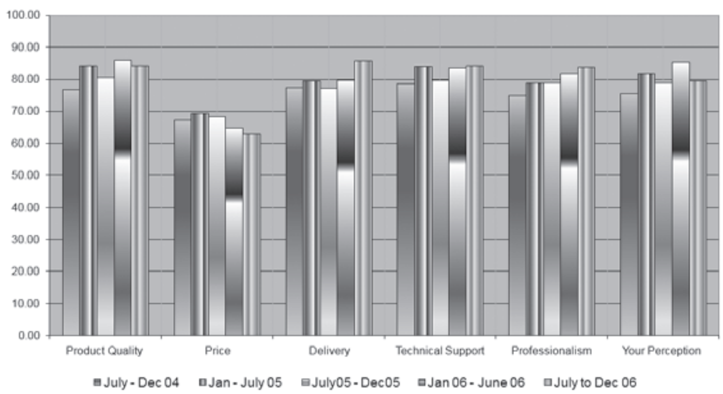
Anil Bali

External Customer Satisfaction Survey

As you may be aware, Deki conducts an external customer satisfaction survey every six months. The results of the last survey indicated a stable trend in the total score which was around 80%. The highlight this time was the improvement in the area of delivery.

The marketing team at Deki is committed to taking this score over 85% in the next six-monthly survey by:

i) frequent visits to customers to understand their needs,
ii) increased technical seminars to share expertise, and,
iii) regular publishing of "Charge" and other technical matters to disseminate information.



Employee Satisfaction Survey

Deki also conducts an employee satisfaction survey every six months in which employees provide feedback on:

i) their work environment,
ii) salaries,
iii) satisfaction levels,
iv) growth opportunities,
v) knowledge of targets, standard specifications, operating procedures, etc.

Responses, in terms of marks for specific questions, are consolidated and compared with the results of the previous survey. The consolidated report along with the action points for improvement are then discussed with all the employees in an Open House session by our Managing Director, Mr Vinod Sharma.

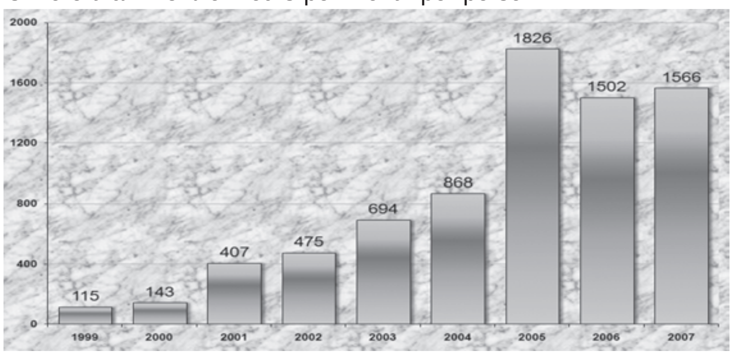
The February 2007 survey showed an improvement of 2% in the total score over the previous survey. The main areas of gain were:

i) knowledge of targets, standard specifications and operating procedures, *a direct result of the intensive in-house training programme,*
ii) salaries,
iii) work environment, *since temperature, noise and lux levels are monitored and recorded at most work places - including quarterly monitoring of PPM levels of VOCs like Styrene and Xylene - and appropriate action taken,*
iv) satisfaction levels

The main area of concern for employees was growth. To address this issue, key employees have been identified and allocated added responsibilities.

Training in Deki

Training in Deki has grown at a steady rate. However, training hours increased sharply in 2005 owing to additional recruitment in anticipation of the three-fold increase in capacity in 2006. From 2006 we are devoting over 1500 hours of training per month which is more than 2.5% of hours per month per person.



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Fan Regulators

A Fan Regulator, as the name suggests, regulates or controls the speed of the fan motor. Before dealing with the fan regulator, a brief discussion about the fan motor is necessary, as the main purpose of the regulator is to control the speed of the fan motor.

Fan Motor

The motor used in a household ceiling fan is a 1f squirrel cage type induction motor with the properties and specifications of a normal 1f motor.

Constructional Features

A 1f induction motor employs two windings for its operation as it is not a self-starting version of an induction motor (polyphase motor). The two windings are main/running winding and starting/auxiliary winding. The windings are placed on a stationary member called stator, that has stampings and slots to hold the windings.

The rotor is the rotating member, of a squirrel cage type, on which the fan blades are mounted.

Note: It also incorporates a capacitor in series with a starting winding.

Principle of Operation

A ceiling fan motor is based on Faraday's Law of Electro-magnetic Induction according to which whenever a conductor is placed in a rotating magnetic field, an electromagnetic force (emf) is induced. The frequency of the induced emf is the same as the supply frequency and its magnitude is proportional to the relative motion between the flux and the conductor. The direction of the induced emf is given by Fleming's Right Hand Rule.

Working

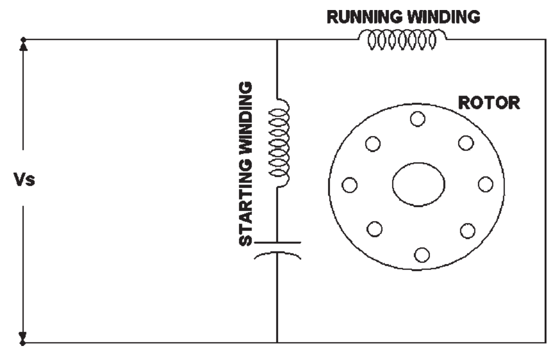


Fig: Capacitor Run Fan Motor

In order to make a ceiling fan self-starting, a starting or auxiliary winding is used, placed electrically 90° apart from the main winding, with a running capacitor in series with the starting winding. Both the windings are connected in parallel to each other. Winding supply across the terminal as shown in the figure.

Purpose of Running Capacitor

A capacitor is incorporated in circuit so that I_S and I_M are 90° apart in phase from each other (ideal case) so that a revolving or rotating magnetizing flux can be set up.

Starting of Fan

When the supply is given a rotating flux is set up in the stator which is revolving with synchronous speed N_S.

$$N_s = (120*f) / p$$

f = supply frequency

p = number of poles

This flux induces a voltage in the rotor due to electromagnetic induction. As this rotor is initially stationary, torque is developed which rotates the rotor and rotor speed starts to build up. The direction of rotation is the same as that of the rotating flux. The torque developed is given by

$$T \propto S V^2$$

S = slip speed

Now, this torque is proportional to square of voltage.

$$\text{Speed} \propto \text{Torque} \propto V^2$$

Hence, by controlling the voltage supply across the fan its speed can be varied.

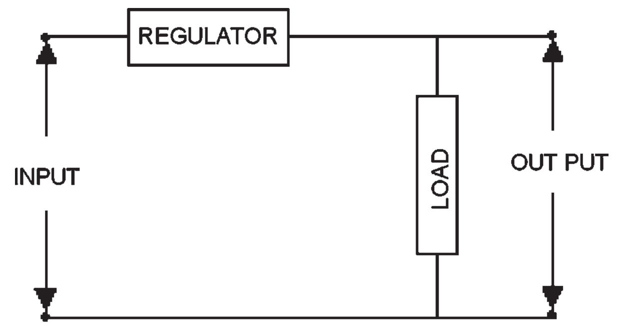
Types of Fan Regulators

Currently Fan Regulators are of these four types:

- Resistive regulator
- Phase angle controlled regulator
- Inductive regulator
- Capacitive regulator (latest)

Resistive Regulator

This is the most common type in household ceiling fans. It works by providing different taps on a wire wound resistor connected in series with the fan.



Advantages

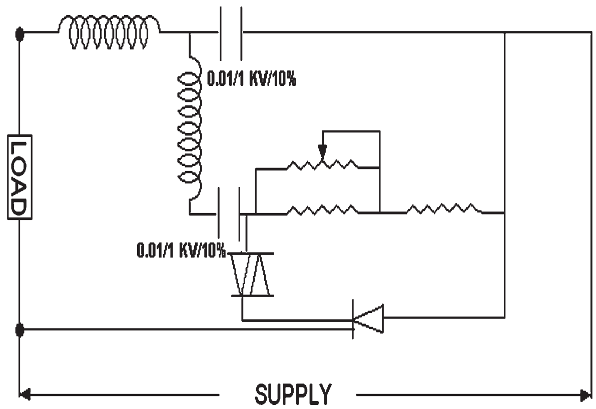
- Cost-effective.

Disadvantages

- Considerable power loss as heat, especially at lower speeds, making it inefficient.
- Bulky, lack of aesthetic appeal.
- Very high energy consumption.

Phase Angle Controlled Regulator

Phase angle controlled regulators employ active devices such as DIAC and TRIAC. The basic principle is to change the firing angle of the TRIAC in order to change the voltage across the fan.



Advantages

- Continuous speed control.
- Low power consumption as compared to resistive type regulators.

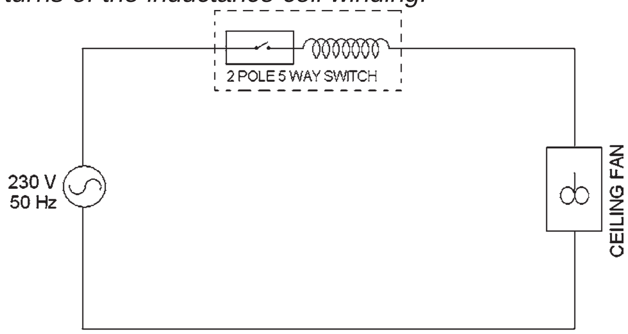
Disadvantages

- Speed control not linear.
- Expensive as compared to resistive fan regulators.
- Produces humming sound that is disturbing.
- Higher failure rate as active devices are susceptible to power supply transients and interference.
- Causes EMI/RFI interference creating disturbances in TV and radio sets.

Inductive Type Fan Regulator

An inductive type fan regulator has a tapping on the winding of the transformer and the inductive reactance is varied to achieve variation in speed.

NOTE: Speed decreases with the increase in the number of turns of the inductance coil winding.



Advantages

- Low heat power dissipation.

Disadvantages

- Low power factor.
- Quite costly.
- Heavy and bulky.

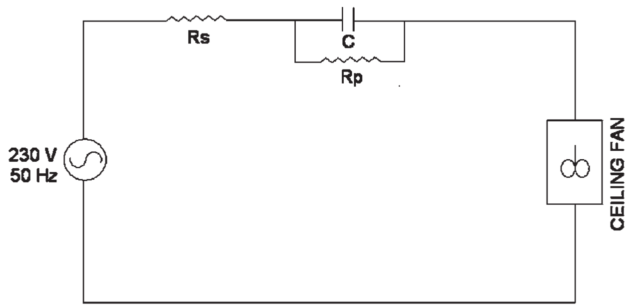
Capacitative Type Fan Regulator

Basic Principle

The main purpose here is to control the voltage across the fan. As we know, the voltage across the capacitor is given by the formula $V_c = Q/C$ where Q is the charge across the capacitor and C is the capacitance.

According to the preceding formula, $C \propto 1/V_C$.

As C increases V_C decreases. Thus, the voltage across the fan increases. Therefore, the speed increases. So, by increasing the value of capacitor, the speed of the fan can



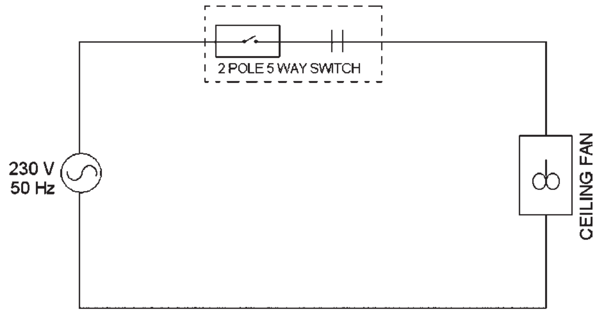
be increased. Thus, by employing suitable combinations of capacitors a fan's speed can be regulated.

Purpose of R_S and R_P

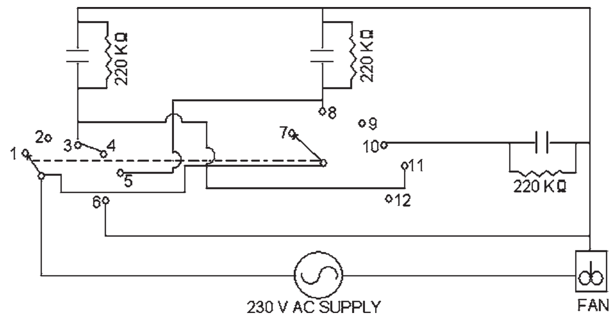
R_S is a series resistance which is used in series with the capacitor in order to limit the current flowing to the capacitor to a safe value.

R_P is a parallel resistance which serves as a discharging path for the capacitor for each supply cycle.

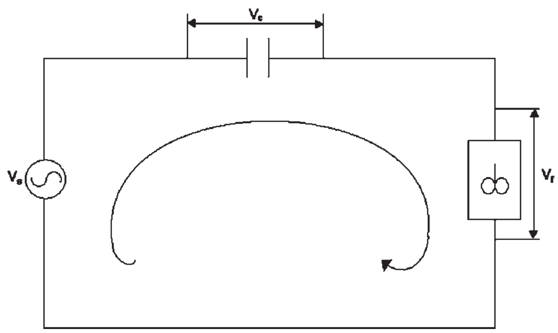
Capacitive Fan Regulator - Block Diagram



Capacitive Fan Regulator - Circuit Diagram



How to calculate the value of the capacitors



Applying KVL (Kirchof's voltage law), the calculated value of X_C is given by

$$(V_S \times Z_F - V_F \times Z_F) / V_F = X_C$$

where, V_S= supply voltage
V_F= voltage across the fan
Z_F= impedance of the fan,

and, the value of capacitance can be calculated by

$$C = 1 / (2 \times \pi \times f \times X_C)$$

where, f is the supply frequency

Advantages

» Energy efficient
» No humming sound during operations
» Speed is linear
» High reliability as compared to electronic type regulator.

Disadvantages

» Because of size only marginal design is possible for film capacitor
» Fire hazard is, hence, the only failure mode.

Let us examine the **ISI standards for fan regulators as per IS:374-1979:**

- Regulators including electronic type of speed regulators shall be capable of reducing the speed of the fan at least 50 per cent of the full speed at the test voltage.
- Fans shall be capable of running on all the running positions of the regulator at the rated voltage or within the whole rated voltage range.
- Shall have an 'OFF' position preferably next to the lowest speed contact.
- Shall be provided with not less than five running positions except in case of continuously variable speed regulators.
- The speed difference at any running position shall not deviate by more than +/- 50 % from the ideal speed difference calculated on the basis of maximum and minimum speeds divided by the number of steps.
  Max speed of the fan: 400 rpm
  Min speed of the fan: 200 rpm
  Regulator steps: 5
  Ideal speed difference = 200/5 = 40 rpm
- Speed difference between any two running positions should be between 20 and 60 rpm.
- Electronic type regulators shall be provided with radio and television interference suppressing devices.
- The voltage drop across the electronic type regulators at the maximum speed position shall not exceed 2% of the rated voltage of the fan.

Experimental Study

Fans from different manufacturers are tested on a standard regulator with combinations of 2.2, 1.0 and 3.1 μfd.

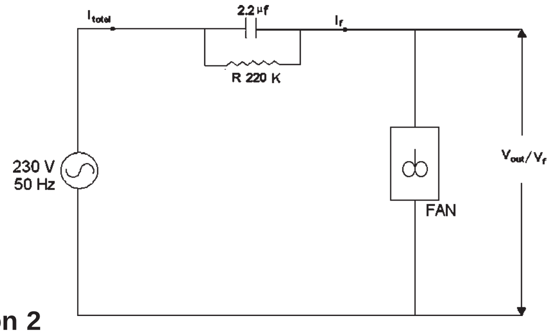
Now,
At speed 1 = 2.2 μfd
At speed 2 = 3.1 μfd
At speed 3 = 4.1 μfd
At speed 4 = 5.3 μfd
At speed 5 = no capacitor

For,
Fan A, maximum RPM = 320
Fan B, maximum RPM = 422
Fan C, maximum RPM = 380

Configurations at various switch positions

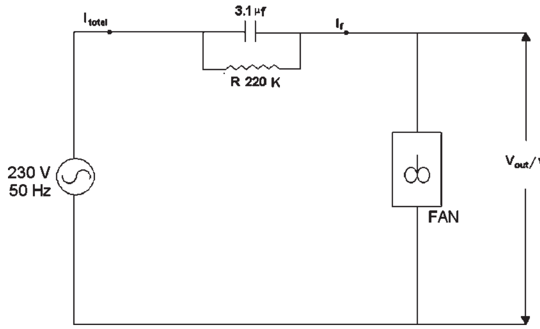
Position 1

At this position, capacitor in the circuit = 2.2 μfd.



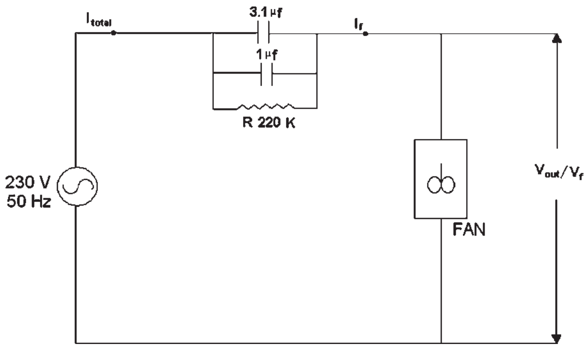
Position 2

At this position, capacitor in the circuit = 3.1 μfd.



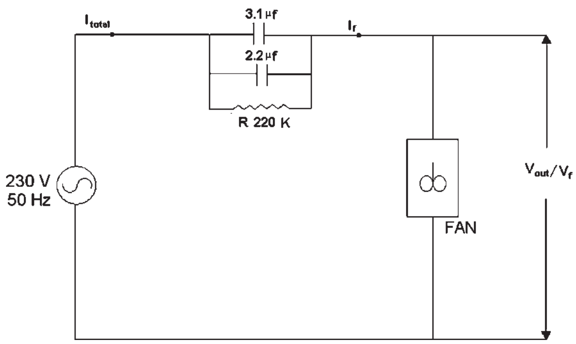
Position 3

At this position, capacitor in the circuit = 3.1 + 1 = 4.1 μfd.



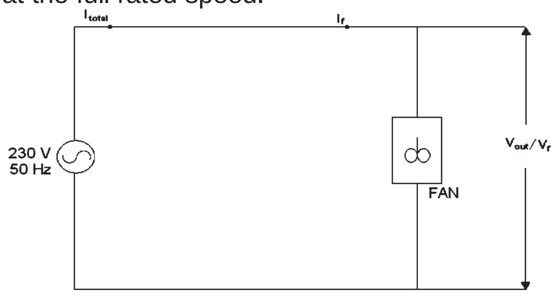
Position 4

At this position, capacitor in the circuit 3.1 + 2.2 = 5.3 μfd.



Position 5

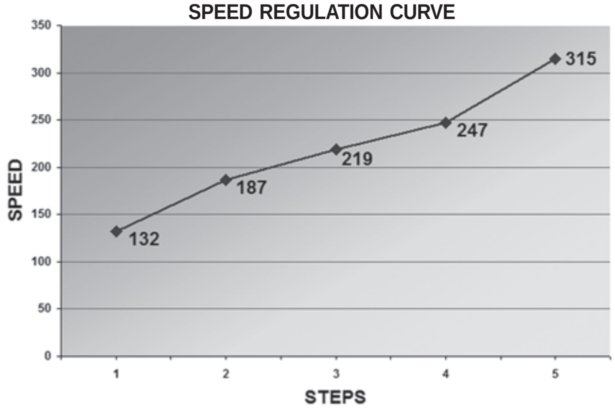
At this position there is no capacitor in the circuit and the fan moves at the full rated speed.



DATA SHEETS

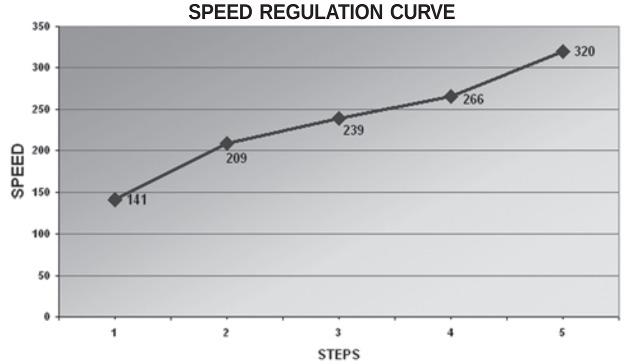
Type A fan tested on a standard regulator
Case 1: Supply voltage = 220V

Regulator Number	Voltage V_f Volts	Current Amps	Power Watts	Voltage V_c Volts	Speed RPM
1	81	0.100	0.81	200.000	132
2	112	0.150	16.80	181.000	187
3	131	0.180	23.58	164.000	219
4	150	0.210	31.50	143.000	247
5	220	0.250	55.00	0.044	315



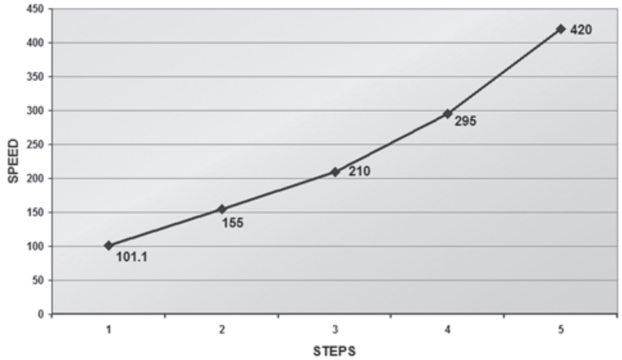
Type A fan tested on a standard regulator
Case 1: Supply voltage = 240V

Regulator Number	Voltage V_f Volts	Current Amps	Power Watts	Voltage V_c Volts	Speed RPM
1	89	0.120	10.68	225.000	141
2	121	0.170	20.57	202.600	209
3	142	0.200	28.40	176.000	239
4	162	0.220	35.64	155.000	266
5	240	0.270	64.80	0.043	320



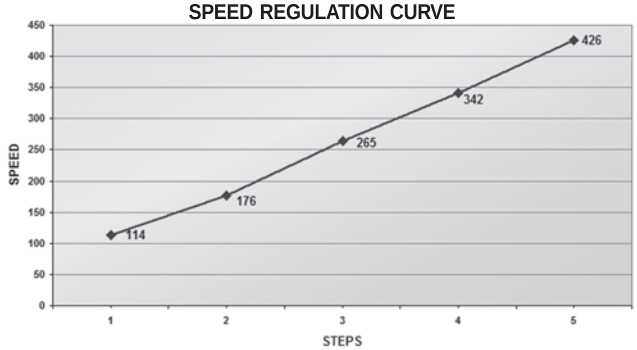
Type B fan tested on a standard regulator
Case 1: Supply voltage = 220V

Regulator Number	Voltage V_f Volts	Current Amps	Power Watts	Voltage V_c Volts	Speed RPM
1	76	0.110	8.36	219.40	101.1
2	111	0.170	18.87	201.40	155.0
3	134	0.210	28.14	187.40	210.0
4	154	0.240	36.96	163.90	295.0
5	219	0.290	63.51	0.06	420.0



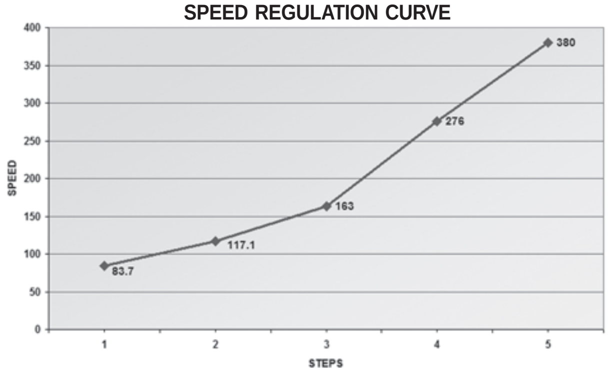
Type B fan tested on a standard regulator
Case 1: Supply voltage = 240V

Regulator Number	Voltage V_f Volts	Current Amps	Power Watts	Voltage V_c Volts	Speed RPM
1	83	0.130	10.79	235.000	114
2	121	0.190	22.99	218.700	176
3	144	0.230	33.12	198.700	265
4	166	0.250	41.50	170.300	342
5	238	0.310	73.78	0.068	426



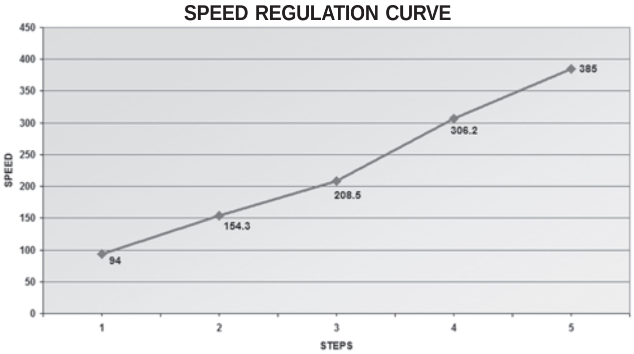
Type C fan tested on a standard regulator
Case 1: Supply voltage = 220V

Regulator Number	Voltage V_f Volts	Current Amps	Power Watts	Voltage V_c Volts	Speed RPM
1	82	0.120	9.84	221.300	83.7
2	109	0.160	17.44	194.500	117.1
3	131	0.200	26.20	179.600	163.0
4	149	0.220	32.78	155.800	276.0
5	219	0.270	59.13	0.056	380.0



Type C fan tested on a standard regulator
Case 3: Supply voltage = 240V

Regulator Number	Voltage V_f Volts	Current Amps	Power Watts	Voltage V_c Volts	Speed RPM
1	84	0.120	10.080	225.900	94.0
2	115	0.170	19.55	210.400	154.3
3	140	0.210	29.40	191.700	208.5
4	156	0.220	34.32	154.300	306.2
5	240	0.300	72.00	0.068	385.0



Analysis and Conclusion

Why cannot a common or general fan regulator be designed?

Different types of fans have been tested using a general regulator. After analysing all data it is observed that with one standard fan regulator we can achieve speed regulation approximating a linearity pattern but cannot satisfy the ISI standards for different fans.

Full rated RPMs of different fans are different due to electrical parameters such as number of turns in the winding, number of poles, impedance, air gap between stator and rotor, etc., that vary from one manufacturer to the other. Therefore, a common, general fan regulator is unable to regulate the speed within the ISI limits.

Selection of Capacitor for a Good Fan Regulator

In a capacitive type fan regulator, the capacitor is the vital element. In order to design a reliable, accurate, durable and effective fan regulator, all the electrical parameters of the capacitor must be selected properly.

Basically, a fan regulator is a low power AC application for which the following parameters of the capacitor determine its working life:

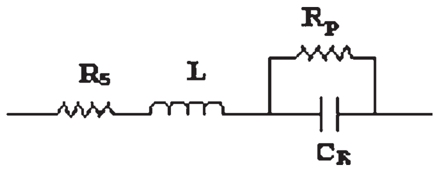
1) Tan δ at working frequency.
2) Power handling capability.

Tan δ (Tangent of Loss Angle): The dissipation factor or tangent of loss angle is the power loss of the capacitor divided by the reactive power of the capacitor at a sinusoidal voltage of specified frequency.

Equivalent circuit of capacitor

$\tan\delta = \omega CR = 2 \times P \times f \times C \times R_S$

where, R_S = series resistance, f = supply frequency, and C = capacitance



NOTE: The measuring method shall be such that the error does not exceed 10% of the specified value or 0.0001, whichever is higher.

Equivalent Series Resistance (ESR)

The ESR is the resistive part of the equivalent series circuit and is temperature and frequency dependent. The ESR can be calculated from the dissipation factor (tan d) as follows:

$ESR = \tan\delta / \omega C$

Power Dissipation

The power dissipated by a capacitor is a function of the voltage across or the current (I) flowing through the equivalent series resistance ESR.

$P = \omega \times C \times \tan\delta \times U^2$
$P = 2 \times P \times f \times C \times \tan\delta \times U^2$
where f = frequency,
tan δ = maximum value specified, and,
U = rated voltage.

Breakdown Voltage

The breakdown voltage is the minimum voltage required for dielectric breakdown. It follows that the operating voltage must be less than the breakdown voltage.

Calculation of Power Dissipation

When a capacitor is used in AC applications at high frequency, internal heating of the capacitor may follow with a possible risk of smoke or fire. This is caused by the heating effect of the current flowing through the internal resistance of the capacitor.

The following formula is used to calculate the maximum power dissipated by the capacitor:

$$P_{cmax} = \sum_{i=l}^{N} V^2_{rmsci} \times 2\pi f_i \times C \times \tan\delta_{max}(f_i) \qquad \text{— ①}$$

where, P_{cmax} = max dissipated power in watts,
V_{rmsci} = RMS voltage of the ith harmonic in volts,
I_{rmsci} = RMS current of the ith harmonic in amperes,

f_i = frequency of the ith harmonic in hertz,
C = capacitance in farads,
tan d_{max} (f_i) = maximum dissipation factor corresponding to the frequency of the ith harmonic, and,
N = number of significant harmonics.
In sinusoidal waveform we take N = 1
Now, DT_{lim} = allowed capacitor overtemperature in °C.
T_h = maximum ambient temperature surrounding the capacitor, or, hottest contact point (i.e., tracks), whichever is higher, in the worst operation conditions in °C.

For T_h < 40° C

DT_{lim} = 40° C for film-foil polypropylene capacitors (PP), polypropylene capacitors with double sided metallised film electrodes (MMPP), and metallised polyester film capacitors (MPET).

DT_{lim} = 20°C for polypropylene capacitors with single sided metallised film electrodes (MPP).

For 40° C < T_h < 100° C, DT_{lim} = 10° C

DT_{lim} = 40 [1-0.0166(T_h-40] for PP, MMPP and MPET—,
DT_{lim} = 20 [1-0.0166(T_h-40] for MPP — ③

For 100° C < T_h < 105° C

DT_{lim} = 0° C
The formula used to calculate the maximum power that may be dissipated by the capacitor is:

$P_{clim} = DT_{lim} / R_{th}$ — ④

where, P_{clim} = maximum power that may be dissipated by the capacitor in watts,
R_{th} = thermal resistance of the capacitor in °C / watts, and,
ΔT_{lim} = allowed capacitor overtemperature in °C.
It must be: $P_{cmax} < P_{clim}$

$\Delta T_{max} = (\Delta T_m / \tan \delta_m) \times \tan \delta_{max}$ — ⑤

where, ΔT_{max} = capacitor overtemperature calculated using the maximum tan δ value at the working frequency,
$\Delta T_m = T_1 - T_2$, tan δ_m = dissipation factor of the tested capacitor measured at the working frequency and at the temperature reached by the capacitor under test, and,
tan δ_{max} = maximum dissipation factor at the working frequency of the capacitor under test.

Calculation of Power Dissipation

For metallised polyester film capacitor
tan δ_{max} = 0.008 and tan δ_m = 0.003
According to equation 2,

ΔT_{lim} = 40 [1- 0.0166(33 – 40)]
= 40 (1 + 0.1162)
= 44.648°C

Putting the values in equation 4,
P_{clim} = 44.648 / 36 = 1.2402
Putting values of V_{rms}= 250V, f_i = 50Hz in equation 1
P_{cmax} = 0.3454
We see that $\mathbf{P_{cmax} < P_{clim}}$

Conclusion

Both metallised polyester and metallised polypropylene capacitors fulfil the requirements of our application.

However, metallised polyester capacitor scores over metallised polypropylene because its dielectric constant ε is 3.2 as compared to 2.2 for metallised polypropylene and better price.

So, for the same capacitance value MPET is smaller in area as compared to MPP because the capacitance value is given by the formula:

$$C= (\varepsilon \times A) / d$$

Though MPP has better dielectric strength, MPET is more popular in fan regulators because of smaller size and lower price.

However, if a bigger size can be accommodated then MPP is the ideal choice.

The Ultima Range of flame-proof fan regulator film capacitors

In spite of all the improvements that have been made in the manufacturing process and over all quality of the metallised film capacitor, the fan regulator capacitor can still fail during its operational life time. The failure can result in the capacitor catching fire (as in the case of dip type capacitors) or the box bursting and metallised film oozing out of the box (in box type capacitors).

While this type of failure is not at all acceptable, customers are still forced to use these capacitors as there is no alternative.

Deki has now developed the Ultima range of flame-proof fan regulator film capacitors that do not catch fire nor burst in the box in the event of failure. Capacitors in this new range fail in the open mode thus fulfilling a long standing requirement of customers.

The new Ultima Flame-proof film capacitor range is available in three metallised polyester series in both, dip and box:

- Economy type
- Switch type
- Socket type

It is also available in metallised polypropylene series in dip and box versions in the socket type.

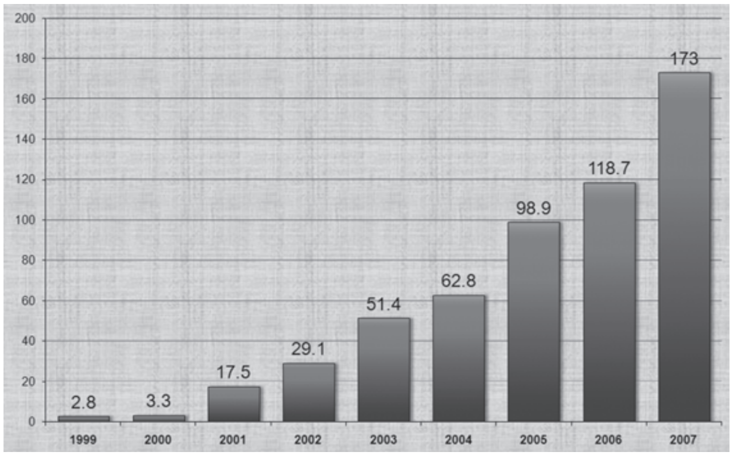
There is a marginal increase in size (suitable for accommodation in existing designs) and cost which is, however, far outweighed by the safety and peace of mind that the product offers.

The Deki range of fan regulator capacitors also includes:

- Metallised Polyester Film Capacitors — Switch and Socket type.
- Metallised Polypropylene Film Capacitors.

Employee Satisfaction Survey

The employee suggestion scheme at Deki has been growing year after year. We had nearly 120 suggestions implemented per month in 2006 which has gone up to 173 in the first three months of 2007.



The beauty of this scheme lies in its simplicity. An employee fills up a suggestion form mentioning:

1) the present process
2) the proposed process, and,
3) the savings/benefits accruing from the proposed process.

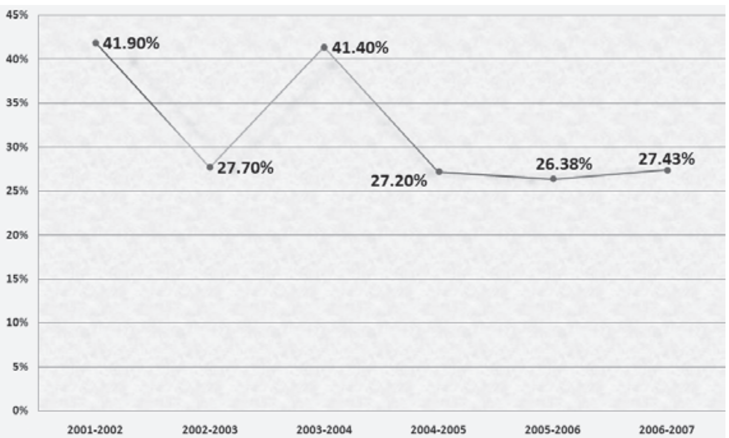
The form is handed over the line in-charge who adds his comments and forwards it to the suggestion committee.

The fifteen-member suggestion committee includes three executives and goes through each and every suggestion. Suggestions found practicable are approved for implementation and, once implemented, the employee giving the suggestion receives a monetary award.

Two employees with the maximum number of suggestions are given an additional award each month and the best two suggestions receive an additional award.

New Product Introduction

Deki's Technical Centre works continuously to introduce new products based on the market requirements. At Deki, *new product* means a product that is less than three years old. In 2006-2007 our turnover from new products was 27.4% of total sales against a target of 30%. The Technical Centre is now equipped with new customised test equipment, specially developed for Deki, and we should be seeing many more new products developed for the market and our customers.



Deki at Electronica in Munich

Deki participated in Electronica at Munich for the third time as a member of the CBI group, a Netherlands based organisation for the promotion of exports from developing countries.

Mr Bali, Vice-President with visitors at the Deki stall.

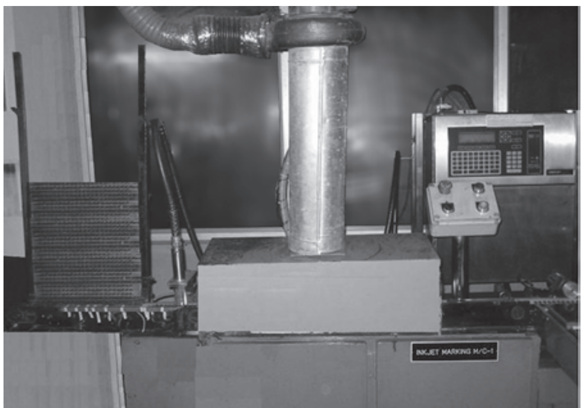
The exhibition held between November 12 and 14, 2006 is one of the world's biggest exhibitions catering to the electronics trade and industry. Deki had a very successful three days with the stall attracting a lot of interest as both Mr Shariq, Manager Marketing and Sales and Mr Bali, Vice-President were dressed as Indian jewellers. This was in consonance with the Deki theme of Jewels of India and product samples, kept in jewellery boxes, really looked like precious stones.

Deki Introduces Ink Jet Marking in Inductive Capacitors

Component markets have been flooded with green coloured, poor quality mylar capacitors originating mostly from China. Another disturbing trend that we have witnessed of late is the rise in spurious Deki inductive capacitors.

In order to address these issues and ensure that our customers continue to receive ever-reliable Deki capacitors, we have switched to brown epoxy from January 1, 2007.

In addition to the new epoxy colour, we have changed the marking to black inkjet from the earlier silver coloured UV curing type. This may well be the first known case in the world where a manufacturer is using expensive inkjet marking on inductive capacitors. However, in our quest for dependable quality, we feel that we owe this to our customers.



The inkjet marking machine at Deki.