International Journal of Scientific & Engineering Research Volume 11, Issue 7, July-2020
ISSN 2229-5518

Oscillating fan system for electronic cooling applications

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Abstract—The cooling fans used in today's electronic devices are rotating fan type. This type of cooling device will not cool the centre portion of the heat sink. Usually heat sinks have linear air flow channel. Hence the air flow generated by rotary fans cannot cool the system effectively. To overcome the drawbacks of the existing rotating type fan, a prototype model of swinging fan cooling device is fabricated and its performance is studied.It operates quite differently from rotary fans as it generates air flow due to swinging action of blades.Oscillating action of the blades is obtained by using magnetic relay. The relay gets magnetized and demagnetized at specific time intervals with correspondence to the electric supply. The time interval is controlled by IC 555 timer circuit. Due to this, blades attached with the relay swings up and down which causes air flow. Thus, the heat sink which is mounted on the heat source gets cooled by the flow of air. The performance is studied at different blade orientations. Also, the power consumption, operating frequency and vibration amplitudes are also discussed subsequently.

Index Terms – Electronic cooling system, oscillation, frequency, vibration and amplitude.

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1 Introduction

WITH an increasing boom in the IT industry owing to the advent of the internet, the necessity to process more data in a short processing time becomes a bare necessity. To meet this requirement, high performance devices like central processor unit (CPU), graphic processors etc. are built to enhance the performance of personal computers. Incorporating such highly capable devices eventually increase heat dissipation thereby causing temperature rise in the CPU. This spike in heat generation despite decreasing the life of the processor also induces malfunction and premature failure of the entire system. Hence alternative methods to achieve effective CPU cooling turns out to be an acute necessity in today's rapidly changing world.The computer performance depends mostly on the processor unit. Usually the processor's die surface has a maximum operating temperature ranging from 75°C to 85°C. But the optimum condition for the better performance would range between 50°C and 60°C. At present, it is cooled by employing natural convection from a heat sink placed directly on the processor and the processor cooling fan is used with heat sinks.

Though, conventional designs work to achieve a moderate level of output there still exists some inconvenience like noise produced by the cooling fan, additional power consumption due to the presence of a number of fans. These inconveniences instigate the need to design a more efficient cooler with a better design. To meet this requirement an innovative cooler design that works based on the principle of electromagnetismis discussed in our work. It generates air flow by vibrating cantilevers instead of spinning the blades.

[1] designed a technique to achieve cooling by using a closed end oscillating heat pipe (COEHP) where massive quantities of heat could be mobilized through a small area. This model attained reasonable performance, obviously comparable to the performance of conventional heat sink cooler. [2]enlisted innovative ideas that could be utilized for cooling higher end power processors.This work provided an insight on ways and means to empower the air-cooling capability and methodologies to enhance their performance.[3] concluded that by replacing conventional cooling fans and aluminium heat sinks with miniature heat pipes resulted in efficient cooling of the entire desktop processor. Also,additional use of a fan at the condenser section of the MHPS further reduced the surface temperature of the CPU.[4] discussed the advent of active cooling mechanisms for central processing units (CPU) of desktop computers on the basis of copper–water loop heat pipes (LHP). They finally concluded that the loop heat pipes made it possible to create on their base compact active coolers with good mass-and-size characteristics and maximum heat-transfer capacities were scaled up to 500–600W.

2 Prototype Modelling

The rough modelling setup is shown in Fig. 3. The prototypeconsists of the following important parts mounted on to the base as shown in Fig. 4. They are:

2.1 Magnetic Relay

Swinging action of the blades is achieved by using magnetic relay. A simple electromagnetic relay consists of a coil of wire wrapped around a soft iron core. Moveable contacts are hinged to the relay and blades are attached with the contacts. Input circuit controls on/off time intervals of the contacts. When current is passed through the coil, a magnetic field is

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generated that activates blade to move down. When the current flowing through the coil is cut, de-magnetization happens forcing the blades to move up.

2.2 Blade

Blades made of thin metal sheets are attached to the relay contacts. Air flow is generated due to vertical to and fro motion of the blades during on/off of the relay. It is designed in such a way that the front portion of the blade is heavier than rear portion. As a result, the free end develops more deflection due to minimal deflection at the rear end. The overall geometry of the blade is similar to that of a cantilever beam.

2.3 Heat sink

A heat sink is designed to increase the surface area in contact with the cooling medium surrounding it, in our case the air. The primary function of heat sink is to absorb heat energy generated by the component mounted to its surface and then successfully dissipate to the surroundings. In computers, heat sinks are used to cool central processing units or graphics processors. The most common heat sink materials are aluminum alloys (6061 and 6063) due to favorable properties such as mechanically softness and minimal weight.

2.4 Heating element

In our work,the processing unit stands as the heating element. By supplying electrical energy to the element, the temperature gets increased to the processor temperature and stands maintained. Thus, the heat accumulated is transferred to the surrounding through the heat sink mounted on the element.

2.5 Input circuit

Circuit consists of following main components like transformer, diode, 555 IC transistor, and relay. This input circuit regulates on/off interval of the relay through 555 timer IC. The flow of input supply is done as shown in Fig. 1. Fig. 2 schematically demarcates the parts of the cooling arrangement.

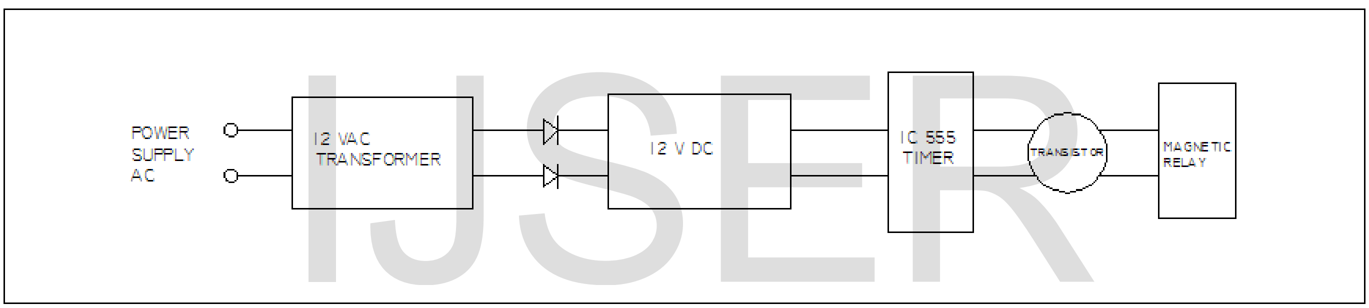

Fig 1. Schematic circuit diagram

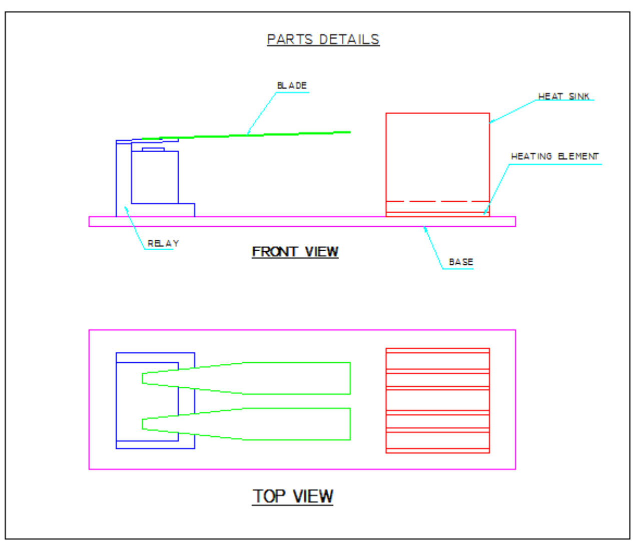

Fig 2. Schematic representation of parts

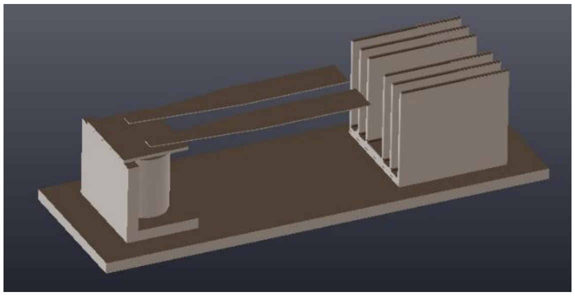

Fig 3. Modelling representation of setup

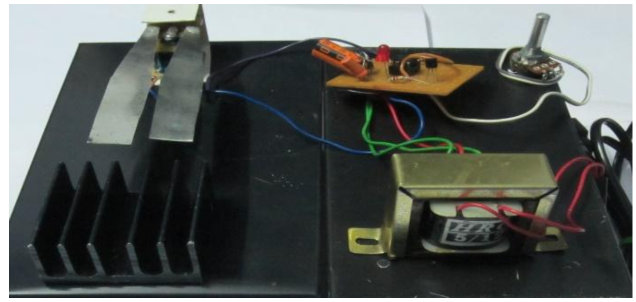

Fig 4. Prototype model

3 Working Principle

- 12V DC input is supplied to the relay in the form of square pulse through astable circuit. Due to magnetic force the relay contacts move down when supply is passing through coil. When there is no supply in the coil, relay contacts move up.
- Thus, the relay gets magnetized and de-magnetized at specific time intervals, due to frequent on/off of the relay contacts eventually swinging the blades up and down. It causes air flow at tip of the blades.
- On /off time is controlled by IC 555 timer circuit.
- Due to blade design, the front portion of the blade swings with high vibration amplitude. It generates air flow.
- Thus, the generated air flow is directed to the heat sink and the optimum temperature range is maintained.

4 Results And Discussion

4.1 Vibration Amplitude Measurement

The main purpose of this test is to find out the blade amplitude at different of frequency rates. The designed circuit shows minimum frequency of 5Hz and maximum frequency of 12.5Hz. The blade tip vibrates at different amplitude for each frequency rate.With the help of this measurement, the maximum tip displacement for various frequencies can be surmised.

The frequency of the circuit can be controlled by varying the resistance of the circuit as a result of which various frequency ranges can be achieved. CRO is employed to measure the frequency rate. Using CRO, the cycle time is determinedusing the formula

$$Frequency = 1/Time \qquad \text{-------}(1)$$

The effect of electrical input frequency on fan amplitude is tabulatedas shown in Table 1. Also, a graph drawn is drawn between frequency and vibration amplitude as shown in Fig.5. A maximum vibration amplitude is seen at a frequency of 7Hz.

TABLE 1
Vibration Amplitude Measurement

S. No	Cycle time (T) in (mill sec)	Frequency(1/T) in (Hz)	Vibration amplitude in (mm)
1	200	5	30
2	165	6	35
3	132	7.5	45
4	100	10	42
5	80	12.5	40

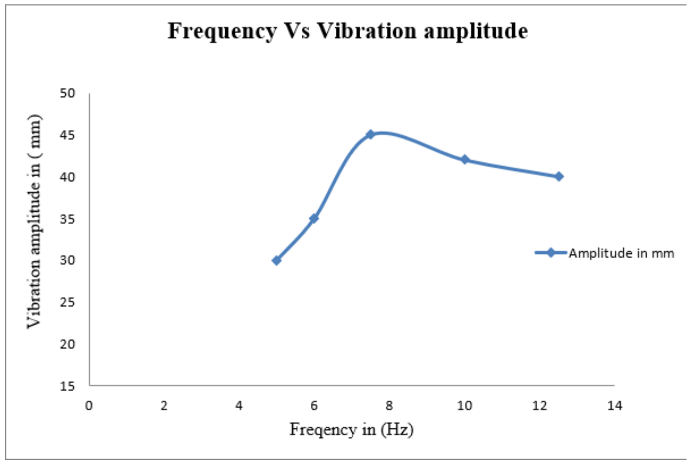

Fig 5. Plot between vibration amplitude and frequency

4.2 Performance Evaluation

The cooling rate is studied at different possible orientations of fan. They are,

- Horizontal orientation
- Vertical orientation

4.2.1 Horizontal orientation

During horizontal orientation the blade stroke will be up and down as demonstrated in Fig. 6. The heat sink is heated up to 80°C and maintained during the test. This orientation enjoys perks due to the natural phenomenon of gravity as a consequence of it the blade swings at a faster rate. The cooling performance of the fan is tested for three types of vibration amplitude like low, medium, high. Table 2 shows the cooling rate for different vibration amplitude.

Also, a graph is drawn for the tabulated values with time in the X axis and temperature in the Y axis. Figure 7 shows cooling rate at different time intervals.

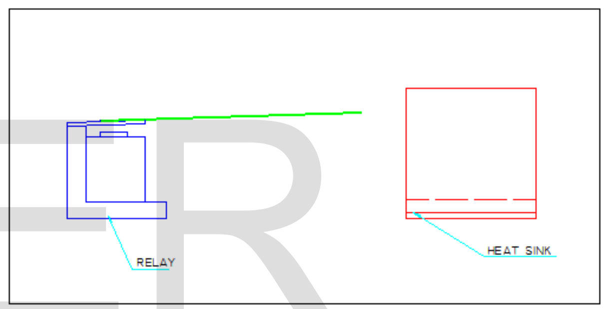

Fig 6. Horizontal orientation

TABLE 2
COOLING RATE FOR DIFFERENT VIBRATION AMPLITUDE OF BLADES – HORIZONTAL ORIENTATION

S. No	Time In sec	Temperature in ^0C		
		30 mm vibration amplitude	45 mm vibration amplitude	40 mm vibration amplitude
1	0	80	80	80
2	30	78.5	72	73
3	60	76	68	68
4	90	75	64	65
5	120	70.5	63	60
6	150	68	60	58
7	180	66	59	57
8	210	64	58	56
9	240	62.5	58	54.5
10	270	61	56	53
11	300	60	55	52.5

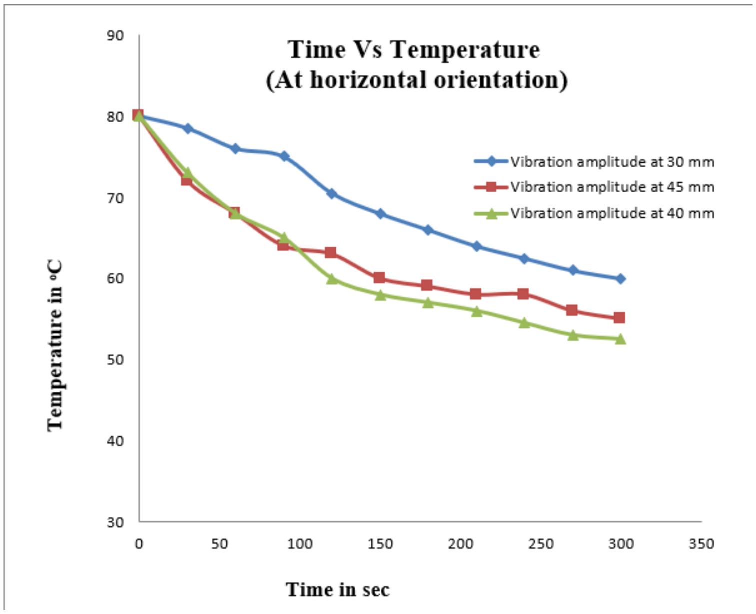

Fig 7. Plot between temperature and time – horizontal orientation

4.2.2 Vertical orientation

During vertical orientation as depicted in Fig. 8, the blade strokes will occur in a linear fashion. The heat sink is heated up to 80°C and maintained during the test. This position advantageously covers almost the entire width of the heat sink. This may drastically reduce the number of blades. The cooling performance of the fan is tested for three types of vibration amplitude like low, medium, high. Table shows the cooling rate for different vibration amplitude.

A graph plotted with respect to Table 3. X axis represents the time and y axis denotes the temperature. The following graph shows cooling rate at different time interval as shown in Fig. 9.

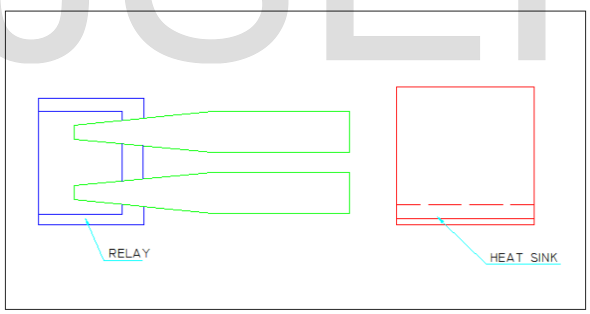

Fig 8. Vertical orientation

TABLE 3
COOLING RATE FOR DIFFERENT VIBRATION AMPLITUDE OF BLADES – VERTICAL ORIENTATION

S. No	Time In sec	Temperature in °C		
		30 mm vibration amplitude	45 mm vibration amplitude	40 mm vibration amplitude
1	0	80	80	80
2	30	79	74.5	77
3	60	77.5	72	73
4	90	76	70.5	70
5	120	73	68	69
6	150	71	66	68
7	180	69	63	65
8	210	67	62	63

9	240	65.5	61	66
10	270	63	60	60
11	300	62	59	58

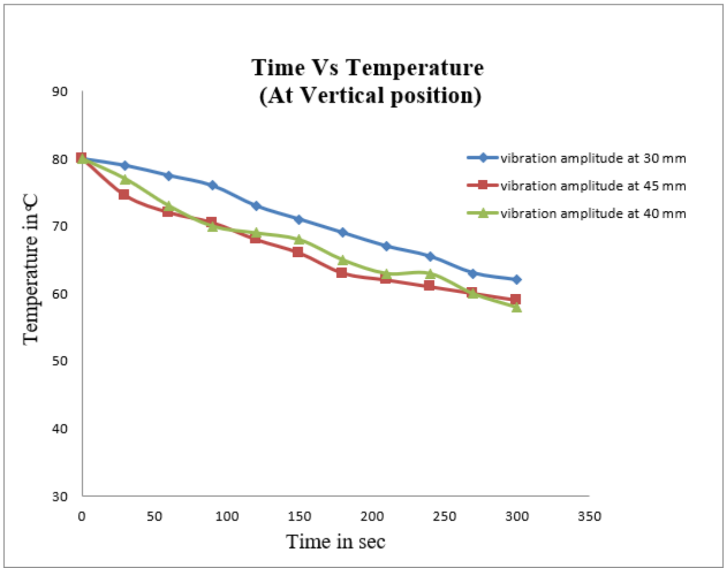

Fig 9. Plot between temperature and time - vertical orientation

4.3 Comparitive performance analysis with respect to orientation

The comparative study of temperature rise/fall with respect to increase in vibration amplitude is shown in Table 4. Also, a plot between temperature and time of the fan blades at different at different amplitudes is shown in Fig. 10, 11 and 12. From the graphs we can conclude that the horizontal orientation of fan blades aided is reducing the temperature more effectively than the vertical orientation of blades.

TABLE 4
COOLING RATE FOR DIFFERENT VIBRATION AMPLITUDE OF BLADES AT DIFFERENT ORIENTATION

Time in (Sec)	Temperature in °C (At 30 mm vibration amplitude)		Temperature in °C (At 40 mm vibration amplitude)		Temperature in °C (At 45 mm vibration amplitude)	
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0	80	80	80	80	80	80
30	78.5	79	73	77	78.5	79
60	76	77.5	68	73	76	77.5
90	75	76	65	70	75	76
120	70.5	73	60	69	70.5	73
150	68	71	58	68	68	71
180	66	69	57	65	66	69
210	64	67	56	63	64	67
240	62.5	65.5	54.5	62	62.5	65.5
270	61	63	53	60	61	63
300	60	62	52.5	58	60	62

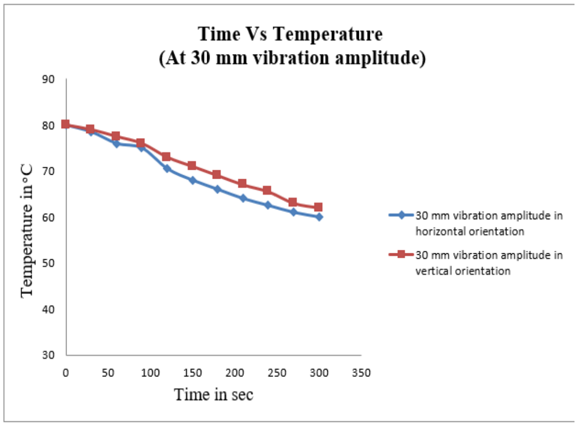

Fig 10. Plot between temperature and time (30mm amplitude)

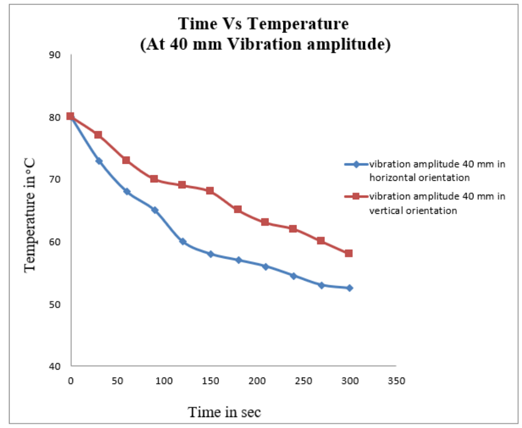

Fig 11. Plot between temperature and time (40mm amplitude)

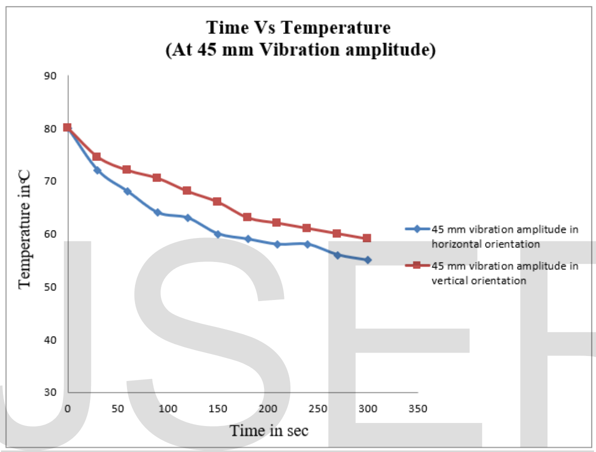

Fig 12. Plot between temperature and time (45mm amplitude)

4.4 Power consumption

Power consumption of swinging fan system is less when compared to other commercial heat sink cooling systems which approximately consume 1.5 to 3.5 Watts. The power consumption of our model is as follows.

Voltage = 12V DC
Current = 0.05 Amps

Power = VI
= 12x0.05
Consuming Power = 0.6 watts.

5 Conclusion

A prototype of electromagnet relay swinging fan model has been developed. The performance of swinging fan is studied at different orientations and their results are compared. The swinging fan operates with minimum power consumption (0.6 Watts) when compared with commercial cooling devices that consume 1.5 to 3.5 watts. The other advantage of the swinging fan cooling device lies in its simple construction, low cost and less noise. The performancedepended on both the vibration amplitude and frequency. The proposed swinging fan model is tested for the frequency ranging from 5-12.5Hz to produce vibration amplitude 30-45mm. It is found that the maximum cooling was obtained at 12.5Hz for 40mm vibration amplitude. Hence selection of proper frequency will give optimum vibration amplitude to give maximum air flow. Also, horizontal orientation of the blades more effectively contributed to reduce the temperature of the fan blades. In future improving heat sink designs by integrating the fan within the heat sink make the device compact and efficient.

Acknowledgment

The authors wish to Thiagarajar College of Engineering for the continuous support and motivation.

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