Part F: Practical Applications

Indicative Contents

Fan-Cooled Enclosure of a PC System

Flow over a Heat Sink

28. Fan-Cooled Enclosure of a PC System

28.1 Objective

Design of airflow in PC systems is an important problem in electronics packaging. Flow Network Analysis using hand calculations or spreadsheets has been traditionally employed for the prediction of airflow distribution in computer systems. Such analyses are not general in nature and cannot be easily adapted for different types of systems. Ellison [1] has used the network modeling approach for the calculation of air flow in a fan cooled PC system. In the present study, we have repeated this analysis using MacroFlow to illustrate the ease with which the model can be constructed and the speed with which results are obtained. MacroFlow, with its easy-to-use graphical frame work and a generalized network solution methodology, enables use of Flow Network Modeling for expedited airflow design of computer systems.

28.2 Physical System

The physical system of interest is a fan-cooled enclosure containing a Printed Circuit Board (PCB) array and Power Supply. The system configuration represents a computer system package that is typical for personal computers and workstations. A schematic of the configuration is shown below.

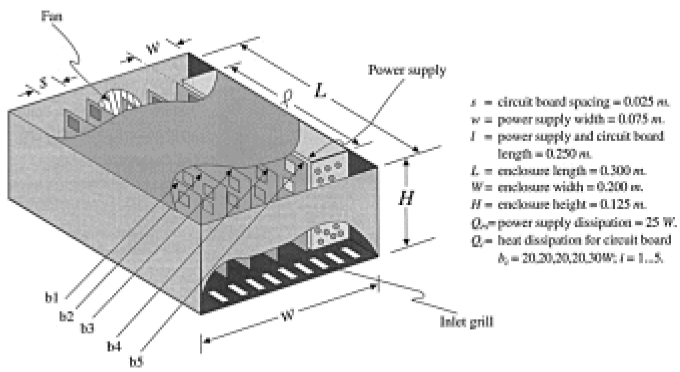

Figure 28.1 Fan-cooled enclosure containing a Printed Circuit Board array and Power Supply

The air flow is driven by an exhaust fan positioned at the back of the computer housing. Air at room temperature is drawn through an inlet screen on the bottom panel of the housing, turns 90 degrees, and spreads over the frontal area of the power supply and the PCB assembly. The PCB assembly contains five boards. In addition, the power supply has a screen at its entry and exit. Air moves over these heat dissipating components and then exits the housing through the exhaust fan.

28.3 Network Representation

The network representation of the flow system is constructed by representing the various paths that the air follows using the component and link library provided in MacroFlow. This representation of the fan-cooled enclosure is shown in Figure 28.2. Important features of the network are described below.

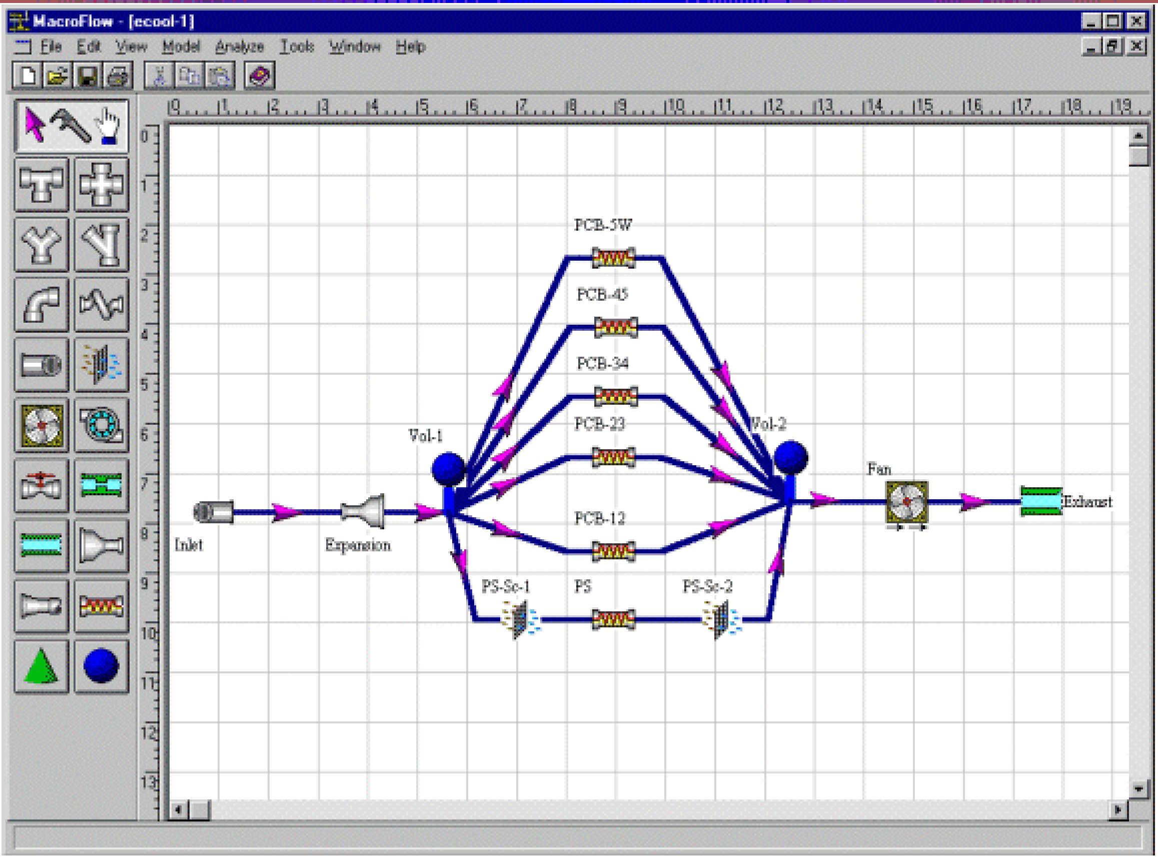

Figure 28.2 Flow network representation of the fan cooled enclosure

- The flow enters the enclosure through a slotted screen. It is represented by the Inlet/Exhaust component within the network.
- After entering the enclosure, the flow turns and faces the frontal area of the PCB array and the power supply. The network model represents the loss in total pressure and the static pressure recovery in this region using the area change component named "Expansion". The corresponding plenum upstream of the PCB and the power supply is represented by "Vol-1".
- The flow then splits into multiple streams corresponding to the passages between the cards of the PCB and the power supply. The five passages in the PCB are represented by the resistances PCB-12, PCB-23, PCB-34, PCB-45, and PCB-5W. (The resistance PCB-34 denotes the flow impedance for the passage formed by the 3rd and the 4th PCB in the array.) The power supply is embedded in a box with screens in the front and the back. These screens are represented by PS-Sc-1 and PS-Sc-2 while the power supply itself is represented by the resistance PS.
- The air streams exiting from the PCB passages and the power supply meet in the plenum named "Vol-2" upstream of the fan Ex-fan.
- The characteristics of the Ex-fan are represented using the piecewise-linear option. The fan provides a maximum head of 0.22 in of water, a maximum flow rate of 34 CFM, and follows a linear fan curve.
- The flow exits the box through the straight Inlet/Exhaust component exit.
- Each of the links connecting successive components serve to direct the flow and do not offer any resistance to flow. Therefore, all the links are zero resistance links.

28.4 Flow Impedance Characteristics

Flow resistance or impedance characteristics of various components need to be specified to complete the network specification. The flow characteristics of the PCB array and the power supply are known from empirical measurements and are expressed in the following form.

$$\Delta P = BQ^2$$

Analysis has been performed for two cases corresponding to even and uneven spacing of the cards in the array. The loss coefficient B for the Power Supply is constant in both cases and is equal to 3.5 x 10^5 Pa/ $(m^3/s)^2$. The loss coefficient for each passage of the PCB array is listed in Table 28.1. As noted above, all links simply direct the flow between components and offer no resistance to flow. The resistance of the screens at the inlet and at the Power Supply (PS-Sc-1, PS-Sc-2) are computed based on the Standard correlations provided in MacroFlow [2, 3,4]. Each of the cards is assumed to dissipate 50W of heat while the power supply dissipates 167 W.

Table 28.1 Flow characteristics of the card array

	Case I		**Case II**	
Flow Passage	Separation	Resistance Coefficient	Separation	Resistance Coefficient
	cm	$Pa/(m^3/s)^2$	cm	$Pa/(m^3/s)^2$
PCB-12	2.54	1.0e+5	2.54	1.0 x 10^5
PCB-23	2.54	1.0e+5	1.25	4.0 x 10^5
PCB-34	2.54	1.0e+5	1.25	4.0 x 10^5
PCB-45	2.54	1.0e+5	3.75	4.44 x 10^5
PCB-5W	2.54	1.0e+5	3.75	4.44 x 10^5

28.5 Results

The network model predicts the flow distribution and the pressure losses in all parts of the system. Figure 28.3 shows a bar chart for the volumetric flow rate in different parts of the system for Case I (equally spaced PCBs). The flow rate in each passage of the PCB array is identical and much greater than the flow rate through the power supply. This is because the power supply offers a much greater resistance to flow. The pressure losses in various components of the system are shown in Figure28.4. The pressure drop in the inlet grill is a large fraction of the overall pressure drop. The pressure drops across all PCB passages and the power supply is identical since these components are in parallel. The fan creates the head (shown by the negative pressure loss) necessary to create the flow through the enclosure. Figure 28.5 shows the bulk temperatures of the streams exiting the PCB passages and the power supply. The predicted results agree very well with the results of the model presented by Ellison [1].

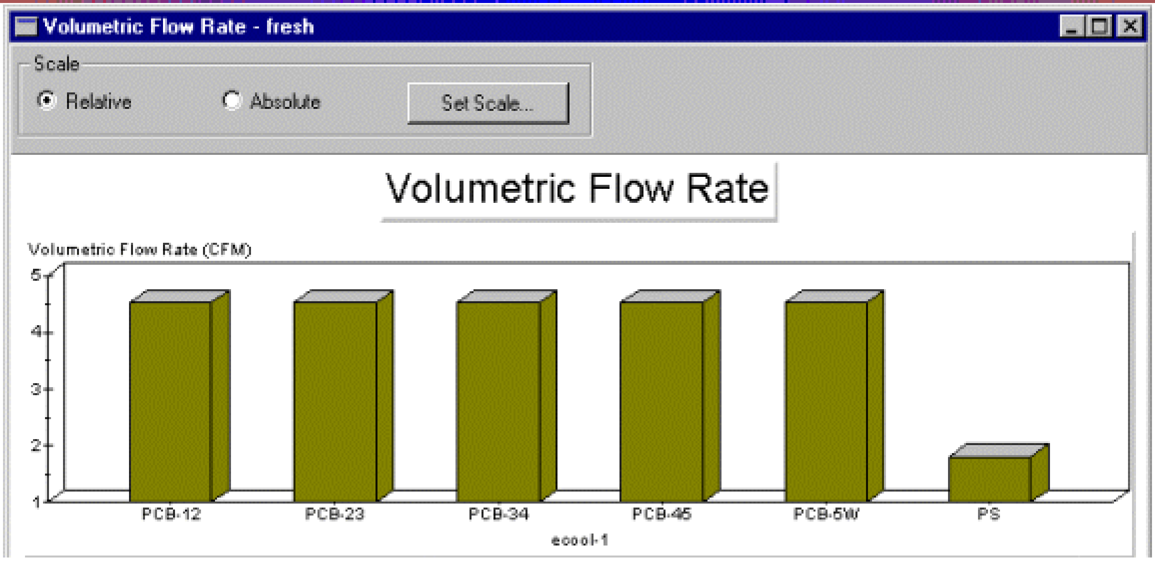

Figure 28.3 Volumetric flow rates for Case I (equally spaced PCB cards)

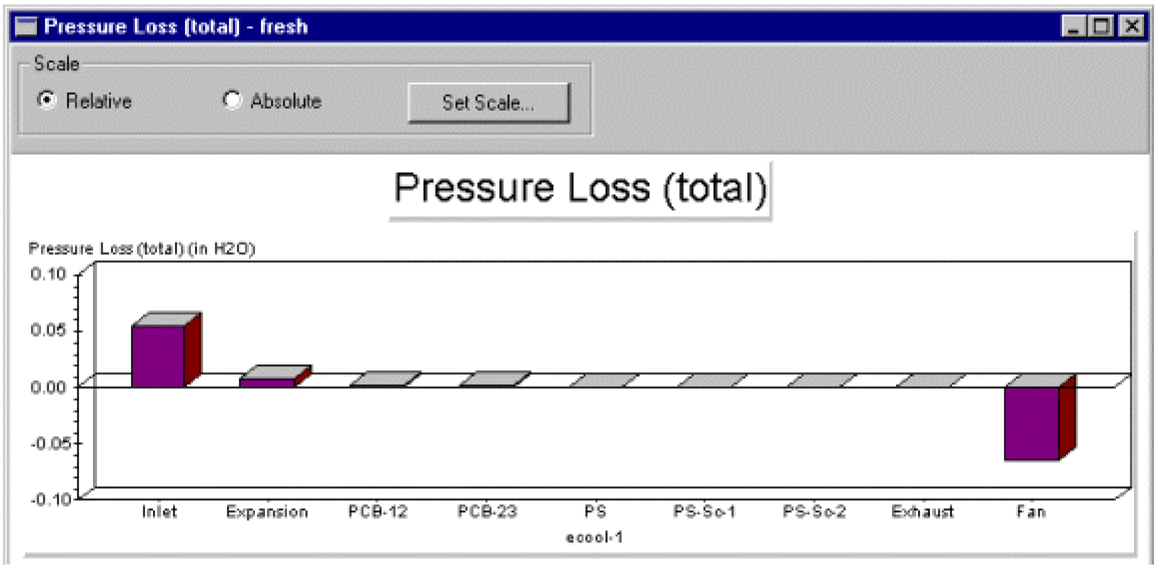

Figure 28.4 Pressure losses for Case I (equally spaced PCB cards)

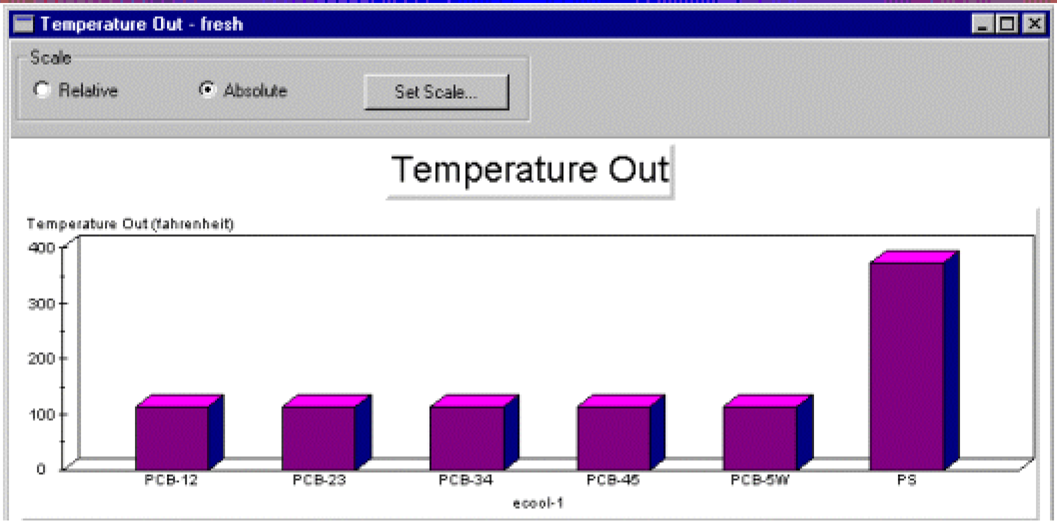

Figure 28.5 Bulk temperatures of the air streams exiting the PCB and the Power Supply for Case I (equally spaced PCB cards)

The volumetric flow rates, pressure losses, and bulk temperatures for Case II are shown in Figures 28.6 and 28.7, and 28.8 respectively. For Case II, an important feature to be observed is that the flow between the PCBs is different due to the unequal separation between them. Since the net system impedance is different than for equally spaced cards, the total induced flow is also different from the configuration with equally spaced cards in Case I. The uneven spacing of the PCBs causes uneven distribution of the bulk temperatures of the air stream exiting the PCB flow passages.

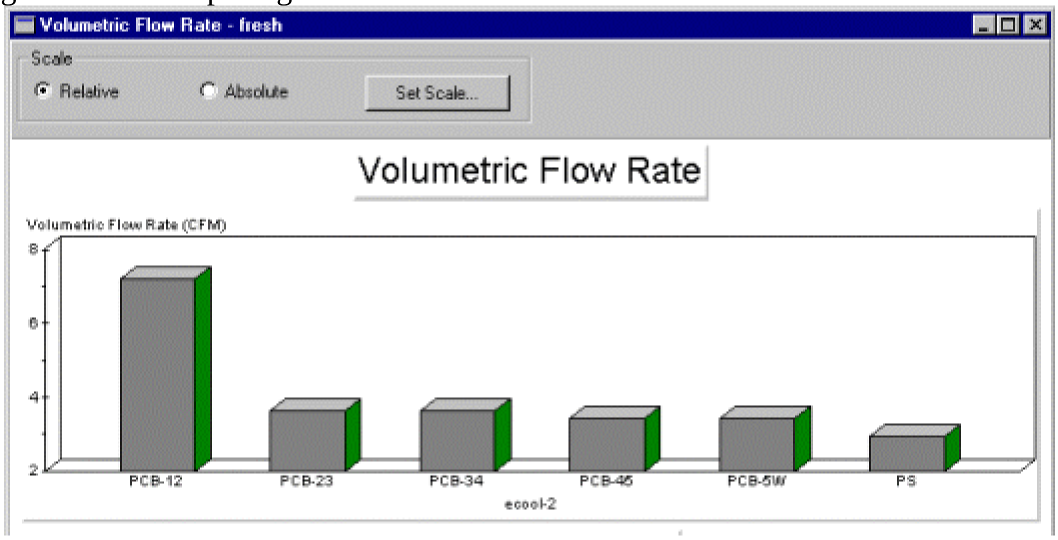

Figure 28.6 Volumetric flow rates for Case II (unequally spaced PCB cards)

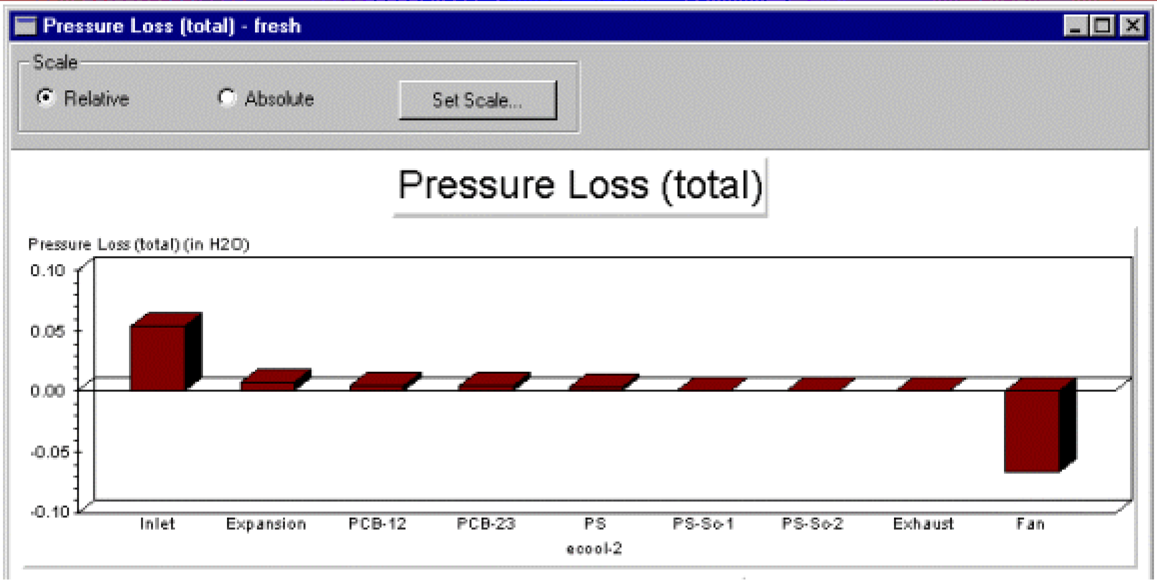

Figure 28.7 Pressure losses for Case II (unequally spaced PCB cards)

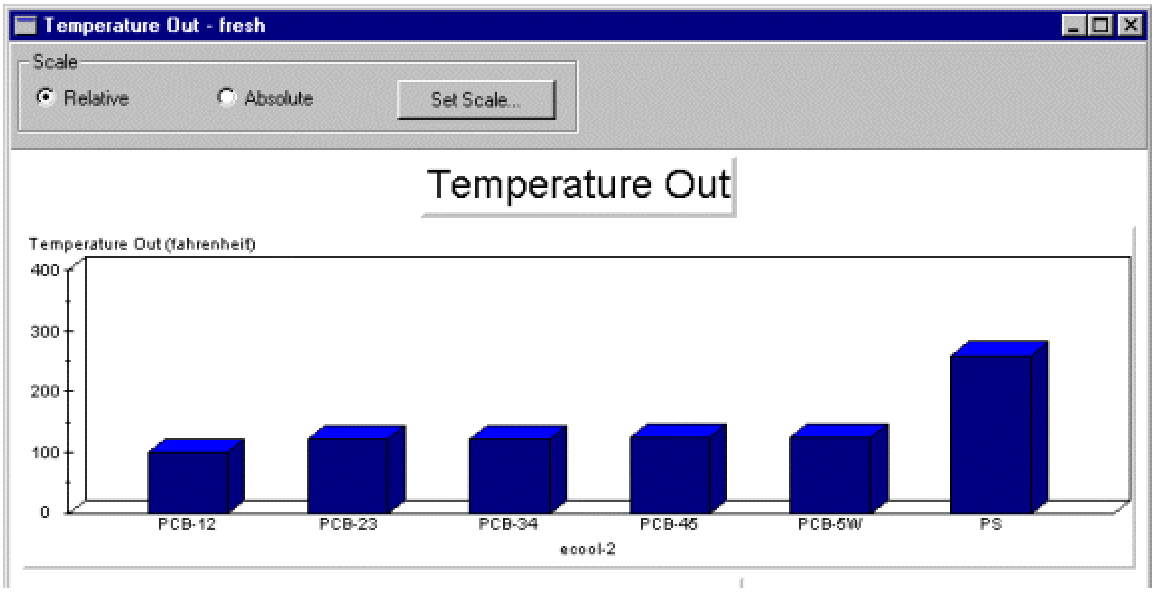

Figure 28.8 Bulk temperatures of the air streams exiting the PCB and the Power Supply for Case II (unequally spaced PCB cards)

28.6 Concluding Remarks

The above example illustrates the simplicity and the speed with which MacroFlow models of practical computer systems can be constructed for accurate predictions of system wide airflow and bulk temperature distributions. MacroFlow-based network modeling enables quick and reliable assessment of the thermal feasibility of competing system layouts and rapid analysis of what-if scenarios. Therefore, use of MacroFlow significantly shortens the overall cycle of designing practical electronic cooling systems and improves the reliability of the system package.