Building a Kiosk that Works—and Keeps Working

Thermal considerations for kiosk design

Abstract

Interactive kiosks are common features in many public venues, such as retail stores, airports, and hotels. A well-designed kiosk lets people conveniently perform a range of tasks from retrieving information to buying tickets. However, a kiosk is only useful when it is working. A design that is appealing and functional is, of course, essential, but a truly successful design is also reliable, secure, and easy to maintain.

When a kiosk fails, the failure is often due to overheating of the electronic components inside the kiosk enclosure. Anyone designing a kiosk or enclosure containing electronic devices must consider how to provide an environment in which these device can function reliably.

Concepts key to understanding thermal management in kiosks are presented, such as ambient and operating temperature and heat transfer mechanisms. A set of guidelines for incorporating thermal management into a design is then provided. These guidelines show a kiosk designer how to calculate the heat generated in the enclosure by electronic devices, how to enhance airflow using vents, and how to increase heat dissipation through the use of fans. Options are presented for optimizing a new design or troubleshooting an existing design.

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Including Thermal Management in a Kiosk Design

Heat generated by electronic components inside a interactive electronic kiosk enclosure can reduce the lifetime of these components and increase the likelihood of failure. Designing a kiosk enclosure that takes into account the need to dissipate heat is essential to ensuring the kiosk functions reliably over time.

The basics of heat and airflow are described below and a set of guidelines are provided for you to use throughout the design process to incorporate thermal management features into your design. The information presented will help you create a design that works in terms of thermal management and may also help you troubleshoot an existing kiosk with equipment failures.

Understanding the Basics of Heat and Airflow

Environment

Any system that requires power is going to generate heat. Electronics equipment is typically designed so that when it is located in a relatively open space indoors at room temperature, heat dissipation through the air is sufficient to keep the equipment from overheating. However, when you place a piece of electronic equipment in an enclosure, you are creating a local ecosystem for that equipment. To avoid the overheating of electronic equipment, the heat produced by the equipment must somehow be removed from this local environment to avoid failure due to overheating.

Ambient Temperature and Operating Temperature

Two concepts are key to understanding heat inside an enclosure and how it affects electronic equipment—ambient temperature and operating temperature.

Ambient temperature is the temperature in the area immediately around a piece of electronic equipment. When the device is sitting on a table in an open room, the ambient temperature is the room temperature. Inside an enclosure, the ambient temperature is the temperature of the air around the device inside the enclosure—which is likely to be higher than the room temperature outside the enclosure. If a device is operating in an ambient temperature above the operating temperature range specified for the device, the device may overheat, reducing the lifetime of the device or causing it to fail.

Operating temperature refers to the temperature range within which a piece of electronic equipment will function according to product specifications. The device must be kept well within its operating temperature range to ensure that it continues to operate as designed. A typical operating temperature specification is 10 degrees to 40 degrees Celcius (C).

Types of Heat Transfer

Heat transfer takes place in three ways:

- Conduction takes place when heat travels through material.

- Convection takes place as air circulates and carries heat with it. Natural convection is the result of hot air rising. Forced convection occurs when air is blown across the surface of a device, moving heat away.
- Radiation occurs when heat is transferred electromagnetically away from a device such as a stove top burner, for example. In an enclosure, radiation is typically not a significant heat transfer mechanism.

In most enclosures, the rate that heat is dissipated from the enclosure will depend primarily on heat transfer by convection. Convection can be enhanced by increasing air circulation through appropriate placement of vents, and in some cases, by installing fans.

Design Guidelines

Incorporating the following steps into your design process will help you take thermal considerations into account in your enclosure design:

- Consider heat and airflow in the initial design. As you create your initial kiosk design:
- Estimate the amount of heat that will be generated by electronic equipment in the kiosk.
- Consider how vents can be used help dissipate the heat.
- Consider how fans can be used help dissipate the heat.
- Plan for maintenance. Consider how access will be provided for maintenance as you develop your design.
- Build a prototype of the design. Build a complete kiosk with all equipment installed.
- Test the prototype. Conduct measurements to ensure all equipment is adequately cooled.
- Adjust the design. If tests show some devices are overheating, change the design to address these issues.

Considering Heat and Airflow in the Initial Design

Estimating the heat generated inside the enclosure

Due to conservation of energy, all energy (power) used in a system is eventually converted to heat. Some energy is converted to heat immediately due to inefficiencies in the system, while the remaining energy is converted to heat as it is consumed by equipment in the system.

Therefore, an estimate of the power used in a system can be used to represent the amount of heat generated. An estimate based on the assumption that equipment is running at its maximum power rating, will typically over estimate the amount of power that is consumed, but an estimate on the high side allows for other variables that are more difficult to take into account.

The example in Table 1 shows an estimate of heat generated in an enclosure that contains a computer, display, printer, and fan. The estimate was developed using specifications such as voltage, current, and power ratings for the equipment. These specifications are often found on the device label or in the manual for the device.

For equipment other than external power supplies, first look for a power specification to use as the estimate (see the estimate for the computer and the fan). If a power specification isn't available, calculate the power by multiplying together the DC voltage and current ratings (see the estimates for the display and the printer).

A typical external power supply is about 80 percent efficient. This means that 80 percent of the power goes to the device being powered and 20 percent is immediately dissipated in heat. To estimate the contribution of a power supply to the overall heat generated in the enclosure, calculate 20 percent of the power rating (see the estimates for the external power supplies for the display and printer).

The maximum amount of heat that could be generated by the equipment in the example shown in Table 1 is 277 watts.

Table 1. Estimating heat generated in a sample kiosk enclosure.

Device	Operating Temperature (ºC)	AC Volts (VAC)	AC Current (max amps)	DC Volts (volts)	DC Current (amps)	Power Efficiency factor	Heat Loss Factor (volts X amps)	Power Dissipated (watts)
Computer	10 to 40	120	1.66				120 X 1.66	200
Display	10 to 40			12	2		12 X 2	24
External display power supply	10 to 40	120	0.5			80%	0.20 X 120 X 0.5	12
Printer	10 to 50			24	.5		24 X 0.5	12
External printer power supply	15 to 45	120	1.0			80%	0.20 X 120 X 1	24
Fan								5
							Total	**277 watts**

Airflow can be passive, enhanced by strategically placed vents, or it can be supplemented by adding fans to the system. Considerations for adding vents and fans are discussed next.

Adding Vents

Vents in an enclosure provide openings for air to enter and exit, thus allowing air to flow through the enclosure. Some considerations are:

- ***Placement.*** Vents should be placed so that air flows around the devices that need to be cooled. Placing a vent at the bottom on one side of the enclosure and a vent at the top on the other side may help direct air around devices. Vents should also be placed so that rising warm air doesn't become trapped in a "bubble" at the top of the enclosure.

- ***Size.*** Larger vents present less resistance to air flow. For the best airflow, make vent openings as large as is practical for the environment in which the enclosure will be placed.
- ***Types of vents.*** A vent may be as simple as a hole or collection of holes cut or drilled through the side of the enclosure. A vent opening may be uncovered or may be protected by a cover with slots, holes, perforations, a screen, or louvers. Note that any covering increases resistence to air flow.
- ***Vandal-proofing considerations.*** Vandalism is often a concern for kiosks in public places. Vents must be sized and placed so that people can't reach in or insert objects or spill liquids into the enclosure. Sometimes vents can be placed out of reach on the back side or top of the kiosk. In other cases, vents with perforated coverings or louvers will need to be considered.
- ***Dust considerations.*** Electronic equipment must also be protected from dust. Accumulated dust on equipment can reduce the effectiveness of convection to carry heat away. Dust can also affect the visibility of displays. Flammable dust, such as sawdust, can present a fire hazard.

  In some cases, dust entering the enclosure may be minimized simply by placing the lowest vents high enough above the floor of the enclosure to reduce the entry of dust from the floor outside. In more extreme cases, you may need to install vents with perforated openings, or even air filters, to exclude dust. (Air filters, however, reduce air flow and require regular servicing, so consider other alternatives before incorporating air filters into your design.)

  Dust can be produced inside the enclosure by a printer. You may want to place any printer away from other equipment or provide a separate enclosure for the printer.

If your enclosure design does not provide adequate ventilation without a fan, and you cannot use fans in your enclosure, you may want to consider hiring a consultant to help optimize your design.

Building a Kiosk that Works—and Keeps Working

Case Study 1

A retail store wanted to create a neater, more pleasant environment by placing electronic equipment out of sight. An esthetically pleasing wood enclosure in which to install desktop computers and monitors was designed. However, the store soon found that the failure rate of equipment placed in the cabinets was unacceptable.

Problem: An assumption had been made that fan in the PC was sufficient to provide adequate cooling, so the enclosure was not adequately vented.

Solution: The store chose to abandon the enclosure and place the equipment back out in the open with monitors mounted directly on counters. A properly designed enclosure would have provided them with an esthetically pleasing solution that also functioned well thermally.

Adding Fans

Estimating the airflow needed to dissipate heat. The equation below shows a simplified method for determining the temperature rise based on air flow through an enclosure.

$$\Delta T = \frac{1.76Q}{G}$$
$$\Delta T = T2 - T1$$

Q is the power dissipated by the equipment in watts

G is the volumetric airflow in cubic feet per minute (CFM)

T2 is the exit temperature in degrees Celcius

T1 is the inlet temperature in degrees Celcius

1.76 is a constant

Figure 1 shows how these parameters relate to an enclosure.

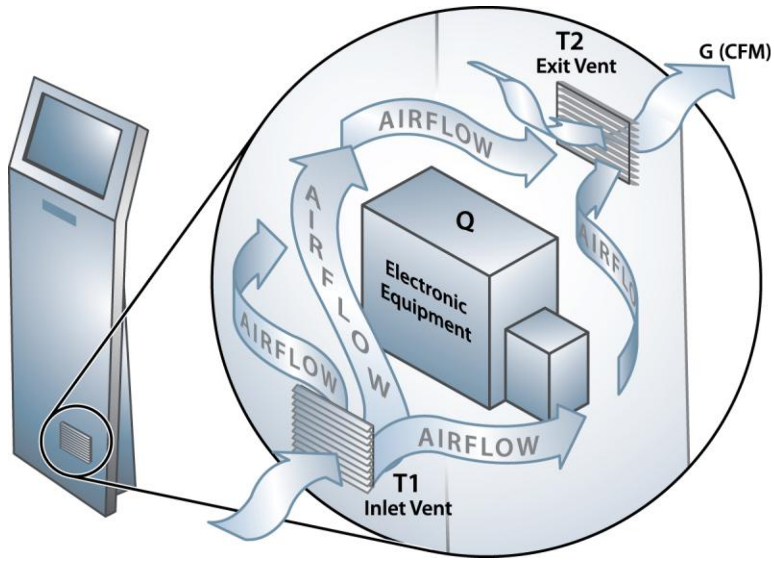

Figure 1. Temperature change in an enclosure

This equation can be rearranged to determine the airflow required to cool the enclosure adequately.

$$G = \frac{1.76Q}{\Delta T}$$
$$\Delta T = T2 - T1$$

G is the airflow out of the enclosure in cubic feet per minute (CFM)

Q is the estimated temperature dissipated by equipment in the enclosure (277 W for the example in Table 1)

ΔT is the calculated temperature rise the enclosure can sustain

T2 is the exit temperature. The exit temperature cannot exceed the lowest maximum specified operating temperature for any device in the enclosure. For the example in Table 1, T2 is 40° C.

T1 is the inlet temperature. The inlet temperature is the highest ambient temperature anticipated at the inlet vent. In a room in which the temperature is controlled at 68° Fahrenheit, T1 = 20° C.

This equation can be solved for the example in Table 1.

$$G = \frac{1.76(277)}{40 - 20} = 24.4$$

Thus, a flow rate of about 25 CFM is required to keep the temperature inside the sample enclosure within the required operating temperature range.

Selecting a fan. The graph in Figure 2 shows how the efficiency of a fan is affected by the environment in which it is used. Fan manufacturers describe the capabilities of a particular fan using a *fan curve* such as the one shown in Figure 2. The fan curve shows how the static pressure, or back pressure, of the system affects the amount of air the fan moves. Back pressure affects how freely air flows through the fan. As the back pressure increases, the amount of air flow from the fan decreases. The manufacturer's fan rating is the highest airflow the fan can achieve in the most ideal conditions. As Figure 2 shows, in an enclosure, a fan will move signicantly less air than that represented by its rating.

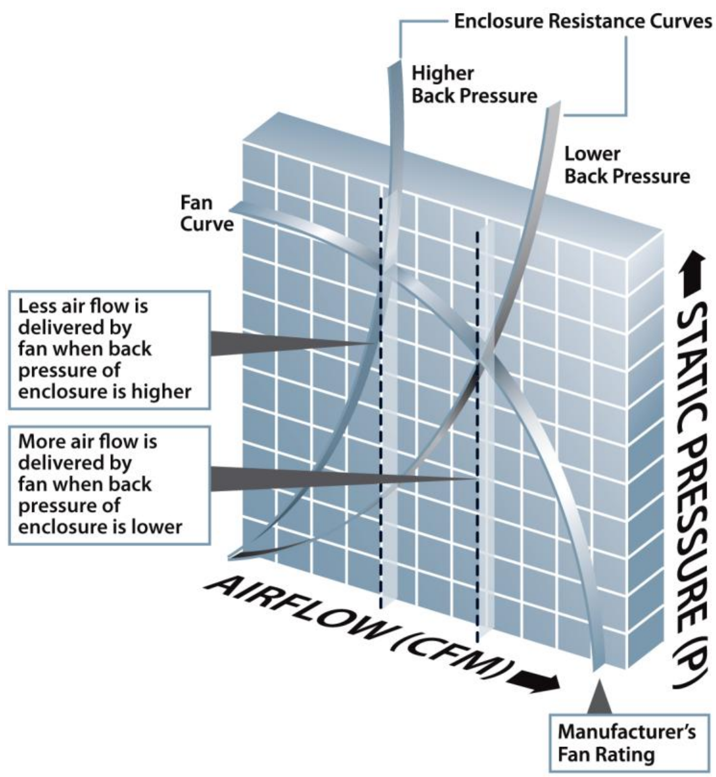

Figure 2. Determining fan efficiency in a particular system.

An *enclosure resistance curve* shows the amount of pressure required within a particular enclosure to achieve a certain air flow. As more air flow is needed, more fan pressure is required to achieve that airflow. The enclosure resistance curve can be moved lower and to the right by reducing the back pressure of the enclosure by, for example, adding more vents.

The point where the enclosure resistance curve crosses the fan curve indicates the amount of airflow the fan will produce inside the enclosure. Any given fan can only deliver one flow rate at one pressure in a given enclosure.

The sample graph shown in Figure 2 indicates that, as a rough rule of thumb, to achieve the desired air flow in your enclosure, you should select a fan rated for at least twice the flow rate you calculated. For example, since the flow rate needed is about 25 CFM, at least one 50 CFM fan or two 25 CFM fans should be installed to help ensure delivery of a 50 CFM flow rate. (Note that adding fans to the enclosure will increase the amount of heat generated in the enclosure.)

The fan rating is typically provided on the manufacturer's label on the fan, and a fan curve is usually included in the specification sheet for the fan. Most fan manufacturers also provide fan specifications and design guides on their Web sites.

Optimizing fan efficiency. As Figure 2 shows, lowering the back pressure of the system allows the fan to operate closer to its rated value. Increasing the number and size of vents decreases the back pressure of the system, allowing the efficiency of the fan to increase. Placement of equipment within the enclosure can also affect back pressure. The more open the pathways where air can flow, the less back pressure.

Case Study 2

A retail store chain was experiencing a high rate of failure of kiosks in its retail stores. The enclosure design included a fan and good venting. A measurement of the air temperature at the output vent of the enclosure showed that the air leaving the enclosure was within the operating temperature range of all the devices in the enclosure, apparently confirming that the airflow through the enclosure was adequate.

Problem: The air intake and exit vents were within inches of each other, essentially short-circuiting the air flow so that it did not go to the components that needed to be cooled.

Solution: A deflector was added inside the enclosure to direct cool air to the components.

Noise considerations. Noise is caused by air turbulence or vibration in the system. For example, the position of the fan with respect to a vent can affect noise. Moving the fan away from a vent can make it quieter. However, moving the fan away from the vent also makes it less efficient, so you will need to consider this tradeoff in your design.

A smaller, faster fan tends to produce more noise that a larger, slower fan with the same airflow rating. Check manufacturing data for information about fan noise levels.

Planning for Maintenance

All systems require maintenance. Consider the following as you develop your design:

- Allow for easy serviceability of fans, which often have a high failure rate over time.
- Provide access to filters for cleaning or filter changes.
- Provide access to printers which may require regular replenishment of ink or paper.
- Providing access to equipment in case of failure.

Also consider developing a maintenance plan for the kiosk with a checklist and schedule for maintenance tasks.

Implementing a Prototype of the Design

Before putting your kiosk design into production, first build a prototype kiosk. Install all the equipment to be used and test the kiosk for a period of time in an environment typical of the worst-case conditions in which it will be deployed. This will give you an opportunity to optimize the thermal aspects of the design before deploying multiple units.

Testing the Design Prototype

Checking temperatures at various points in the enclosure will ensure that all electronic equipment is operating within specified operating temperature ranges. To do so, complete the steps below.

1. *Use a thermocouple to measure the air temperature at all vents in the system.*

   Measure the temperature at all inlet vents and exit vents (see T1 and T2 in Figure 1). The temperature difference between any two vents should be no more than ΔT, the calculated maximum temperature rise the enclosure can sustain. At no vent should the temperature be higher than the calculated value for T2.

2. *Use the thermocouple to check that all devices in the enclosure are operating within their specified operating temperature range.*

   Even though overall airflow through the enclosure may appear to be adequate, areas within the enclosure may not be receiving adequate airflow. A critical component located in a hotter area inside the enclosure may be operating outside its specified operating range, putting it at risk of failure.

If measurements show that the airflow through the enclosure is not adequate or that hot spots exist within the enclosure, see the next section *"Optimizing Your Kiosk Design"* for possible solutions.

Optimizing Your Kiosk Design

A number of options are available for optimizing a kiosk design, though not all options are appropriate for all systems. To address issues in your design, consider the options below:

- Redirect air to optimize air flow to hot areas using deflectors.
- Reposition components to provide more open space to improve air flow.
- Place components more directly into an existing air flow.
- Add more vents or make existing vent openings larger.
- Position vents to improve airflow, such as placing intake vents below equipment and output vents near the top of the enclosure, so that air is directed over hot components.
- Replace vent covers with covers that have more or larger openings, if requirements for excluding dust or minimizing the risk of vandalism don't preclude doing this.
- If airflow from an existing fan is not adequate, replace the fan with a higher rated fan or add more fans.
- Check that hot air is not being trapped at the top of the kiosk or elsewhere within the kiosk.

- Replace electronic components with equivalent models that generate less heat. Don't oversize components.

Conclusion

Designing and building a self-service kiosk presents a variety of challenges. One of those challenges is to incorporate good thermal management into the design. A basic understanding of heat and airflow, venting, and use of fans will often be enough to enable design of a simple kiosk enclosure that provides a healthy environment for electronic equipment. A familiarity with key concepts related to thermal design will also help you work more effectively with a professional designer to help ensure that your kiosk design will continue to work reliably over time.

For more information about self-service kiosks, please visit www.planarembedded.com/kiosk-digital-signage.

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See the web sites of fan manufacturers for fan specifications and design guidelines.

Contributors

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