Abstract

With increasing deployment of high-density racks of equipment, the greatest challenge for existing data centers becomes finding ways to extend the life and capacity of the data centers with limited cooling resources. The HP Modular Cooling System Generation 2 (HP MCS G2) makes it possible to achieve hardware densities and power consumption levels that have been difficult—if not impossible—to support with conventional HVAC systems. In particular, the HP MCS G2 can be used in data centers to eliminate specific hot spots without revamping the overall infrastructure.

This paper explains why densification creates power and cooling challenges and how the technologies offered by the HP MCS G2 overcome them.

Introduction

The deployment of high-density racks of equipment is creating power and cooling challenges for data centers worldwide. The server densification trend is intended to create efficiencies in floor space, cabling, and systems management. However, the growth in power density (watts per U of rack space) with each new server generation is causing data centers to limit rack utilization based on cooling capacity. Data centers are in dire need of new cooling solutions to reap the benefits of server densification.

HP has developed innovative cooling solutions that include highly efficient rack enclosures capable of supporting high power and heat loads. The HP MCS G2 (Figure 1) is a closed-loop cooling system that provides cooling for a single IT equipment rack generating up to 35 kW or two IT equipment racks generating 17.5 kW each. The HP MCS G2 is designed to couple with HP 10000 Series G2 Racks (Figure 1) and support all HP 10000 Series G2 rack options.

The HP MCS G2 allows adding computing power in a data center with minimal impact on the facility’s heat load, thus extending the life of the data center.
Data center trends

Originally, data centers were designed to support large, water-cooled mainframes that consumed lots of power and generated intense heat in concentrated areas. As enterprise computers evolved, data center designs changed to support racks of multi-processor servers and storage systems that spread the power and cooling requirements over a larger area. Although this trend allowed data centers to scale easier, it created power distribution, cabling, and system management challenges. The emergence of 1U servers and blade servers allowed organizations to consolidate their data center infrastructures, manage cable clutter, and streamline server management. However, many data centers are having difficulty adjusting to the effect high-density racks have on power and cooling resources.

Increased power demands

A fully loaded 42U rack with dual processor (2P) 1U servers and storage drives can easily exceed 12 kW of power. A 42U rack containing four, fully-populated c7000 enclosures can require as much as 30 kW of power. As data centers try to accommodate more of these high-density racks, they are moving toward high amperage, three-phase infrastructures that are typically more efficient than single-phase power.

Increased cooling demands

The consequence of more power is more heat. Virtually all power consumed by rack-mounted equipment is converted to sensible heat, which increases the temperature of the environment. The sensible heat load is typically expressed in British Thermal Units per hour (BTU/hr), where 1 W equals 3.413 BTU/hr. Therefore, the heat load of each rack can be calculated as follows:

\[ \text{Heat Load} = \text{Power [W]} \times 3.413 \text{ BTU/hr per watt} \]

For example, the heat load for a ProLiant DL360 G5 server in a 2P configuration consuming 500 watts is calculated as follows:

\[ 500 \text{ W } \times 3.413 \text{ BTU/hr/W} = 1706 \text{ BTU/hr} \]

This means that the heat load of a fully-loaded 42U rack of DL360 G5 servers is 71,673 BTU/hr. In the U.S.A., cooling capacity is often expressed in "tons" of refrigeration, which is derived by dividing the sensible heat load by 12,000 BTU/hr per ton. The cooling capacity needed for a fully-loaded rack of DL360 G5 servers is

\[ 71,763 \text{ BTU/hr} \div 12,000 \text{ BTU/hr per ton} = 5.97 \text{ tons} \]

Few existing data centers were designed to provide this amount of cooling capacity for a single rack. Fewer data centers are capable of distributing adequate airflow directly to rows of such racks.

The reasonable limit of rack power and cooling capacity for a conventional forced-air (HVAC) cooled data center is 8 kW per rack, or 27,300 BTU/hr per rack. For power densities approaching 15 kW per rack, facility planners can use advanced thermal modeling technologies such as HP Static Smart Cooling\(^1\) to help determine the best layout of computing rooms and provisioning of cooling resources. For racks requiring more than 15 kW, the latest cooling techniques use a proven medium—water. Water can remove 3,500 times the amount of heat that an equivalent volume of air can remove. To take advantage of the cooling efficiency of water, HP has developed the HP MCS G2 enclosure.

---

\(^1\) For more information, please read “Thermal Considerations in Cooling Large Scale High Compute Density Data Centers” at [http://www.hpl.hp.com/research/papers/2002/thermal_may02.pdf](http://www.hpl.hp.com/research/papers/2002/thermal_may02.pdf)
Figure 2 shows two examples of server loading for IT racks. In Figure 2A, a 42U rack is loaded with 42 HP ProLiant DL360 G5 servers, each consuming approximately 500 watts for a total rack consumption of 21 kW. The HP MCS G2 set up in the single rack configuration can easily cool this load. In Figure 2B, a 42U rack is loaded with 21 ProLiant DL380 G5 servers each consuming an average of 600 watts for a rack total of 12.6 kW. An HP MCS G2 in the dual rack configuration could easily cool two of these racks, since the HP MCS G2 can be configured to cool two racks of up to 17.5 kW each.

**Figure 2.** Examples of cooling requirements in IT racks with different server loads
HP MCS G2 technology

The HP MCS G2 is designed for data centers that have reached the limit of their cooling capability or that need to reduce the effect of high-density racks on their facility. The HP MCS G2 allows the use of fully populated high-density racks while eliminating the need to add more facility air conditioning capacity.

HP MCS G2 subsystems

The standard HP MCS G2 enclosure consists of a cooling unit and an empty, modified HP 10000 Series G2 rack. The cooling unit includes the components shown in Figure 3. Three fan controllers control six high-volume, hot-swappable fans. The heat exchanger is an air-to-water heat transfer device that discharges cold air to the front of the rack via a side portal. Chilled water for the heat exchanger is received by the water group from the facility’s chilled water system or by a dedicated chilled water unit (see “Chilled water requirements”).

Figure 3. Key components of the HP MCS G2
**Airflow distribution**

The HP MCS G2 supports the front-to-back cooling principle used in most server designs. The HP MCS G2 evenly distributes cold supply air at the front of the rack of equipment (Figure 4). Each server receives adequate supply air, regardless of its position within the rack or the density of the rack. The servers expel warm exhaust air out the rear of the rack. The fan modules re-direct the warm air from the rear of the rack into the heat exchanger. The air is re-cooled and then re-circulated to the front of the rack. Any condensation that forms is collected in each heat exchanger module and flows through a discharge tube to a condensation tray integrated in the base assembly.

For the HP MCS G2 configured with an expansion rack, the left side panel of the HP MCS G2 cooling unit is removed to allow cool air from the heat exchanger to be evenly distributed to both IT equipment racks. The capability of the HP MCS G2 to cool 35 kW of IT equipment is therefore evenly divided to 17.5 kW for each of the two racks.

**Figure 4.** HP MCS G2 air flow

For controlled airflow, the HP MCS G2 enclosure should be closed during normal operation. The enclosure has solid front and rear doors, sidewalls, and top and bottom covers. Keeping the front and back doors closed ensures that the maximum amount of the cool air is retained within the system to provide maximum cooling efficiency. All rack space must be either filled by equipment or covered by blanking panels so that the cool air is routed exclusively through the equipment and cannot bypass through or around the rack.

An Automatic (emergency) Door Release Kit is included with every HP MCS G2. The kit ships in the accessories box and is to be field-installed. The Automatic Door Release Kit is designed to open the HP MCS G2 front and rear doors in the case of a sudden increase in the temperature inside the HP MCS G2. The open doors will allow the IT equipment to cool using the air from the datacenter.
**Water circulation**
Chilled water for the heat exchanger is regulated by the water group (Figure 5), which includes an actuator valve, check valve, flow meter, main coolant inlet and outlet connections, overflow and condensate hoses, and condensate pump. The condensate drain hose, overflow hose, and main inlet and outlet plumbing can be routed through the back of the cabinet or downward into a raised tile floor. The main coolant inlet and outlet fittings can connect to the facility’s chilled water supply or a closed-loop coolant system.

![Figure 5. Water group](image)

**Power redundancy**
The HP MCS G2 can operate from a single AC power source. It also provides for power redundancy through a transfer switch module (Figure 6) that accepts AC power from two sources for facilities that offer AC redundancy.

![Figure 6. AC Transfer Switch Module](image)
System management

The HP MCS G2 management module provides administrators with web-based capabilities to set, monitor, and control temperatures within the HP MCS G2 via the RJ-45 connector in the patch panel. The management module controls the water flow and fan speed to provide the needed cooling capacity and desired server inlet temperature as set by parameters in the web interface (Figure 7).

The temperature of the server intake air is constantly monitored and controlled by varying the opening of the water valve inside the MCS unit. When the server intake air temperature rises above the Server Intake Temperature Set Point, the water valve opening is increased. When the server intake air temperature falls below the Server Intake Temperature Set Point, the water valve opening is decreased. The fan speed level for each unit is controlled by the control system, which constantly monitors the server intake and server exhaust temperatures.

The management module can be configured to send alert traps to HP Systems Insight Manager (SIM), HP OpenView, and other SNMP management applications if an alarm condition is detected. Administrators can use HP SIM to:

- Discover management modules
- Receive SNMP traps from the management module
- Conveniently launch the management module web interface

Figure 7. MCS G2 management module interface

Administrators can monitor the operation of the HP MCS G2 by using the Overview screen on the Home tab (Figure 8). The Overview screen displays graphic meters for server intake temperature and cooling system parameters.

Network monitoring, control, and feedback capabilities are provided through the operator display on the outside of the HP MCS G2 front door and also through the RJ-45 network connector in the patch panel. When the management module issues an alarm or warning, the message appears on the operator display, on the Alarms menu, and on the Alarm History menu in the web interface.
Cooling capacity versus system footprint

An HP 10000 Series G2 rack with an attached HP MCS G2 requires approximately 1.5 times the width and 1.25 times the depth of a standard server rack (to allow for the fan and heat exchanger modules and front and rear airflow). IT equipment generating 35 kW of power generally requires three or four racks for safe and effective forced-air cooling (Figure 9A). However, the HP MCS G2 enclosure has enough water cooling ability to support the heat load of 35 kW. For high-density computing systems that can physically consolidate that much power into one IT rack, the HP MCS G2 occupies 50+ percent less floor space than four standard-footprint racks (Figure 9B). Two IT racks with a power consumption of 17.5 kW each (or less) can be cooled by a single HP MCS G2 in an expansion (dual) rack configuration for a 30 percent savings in space (Figure 9C).

Figure 9. Footprint comparison of 35 kW heat load
Facility limitations

The HP MCS G2 is designed for installation in a standard raised-floor data center environment. There are two basic ways to deploy the HP MCS G2: as a stand-alone unit or adjacent to an existing row of HP 10000 Series G2 cabinets.

The following are some important factors to consider before installing the HP MCS G2:

- Floor loading capacity
- Chilled water requirements
- Cooling requirements
- Space requirements
- Power requirements

For more detailed information about installation considerations for the HP MCS G2, refer to the HP Modular Cooling System Generation 2 Site Preparation Guide, the HP Modular Cooling System Generation 2 Web Interface User Guide, or the HP Modular Cooling System Generation 2 User Guide at the links listed in the “For more information” section.

Floor loading in raised floor facilities

Weight is one of the most important factors to consider when installing the HP MCS G2 in a raised floor facility. The raised floor must be able to support the static load of the fully assembled HP MCS G2 and server cabinet as well as the weight of any additional cabinets as they are moved into position. Raised floor loading is not only a function of the weight, but also of the positioning of the equipment relative to the raised floor grid. The packaged weight of the HP MCS G2, which includes all packaging materials such as the skid and cartons, is 1310 lb (594 kg). The weight of a fully assembled HP MCS G2 and an empty HP 10000 Series G2 Rack is 1130 lb (513 kg). The weight of a populated server rack depends on the equipment installed in the rack.\(^3\)

Table 1 lists the ratings of a typical raised floor system that is satisfactory for the installation of the HP MCS G2.

<table>
<thead>
<tr>
<th>Item</th>
<th>Rating</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead load</td>
<td>7 lb/ft(^2) (34.2 kg/m(^2))</td>
<td>The weight of the raised panel floor system, including the understructure</td>
</tr>
<tr>
<td>Live load</td>
<td>313 lb/ft(^2) (1528.3 kg/m(^2))</td>
<td>The load that the floor system can safely support</td>
</tr>
<tr>
<td>Concentrated load</td>
<td>1250 lb (567 kg) per panel</td>
<td>The load that a floor panel can support on a 1-in(^2) (6.45-cm(^2)) area at the panel’s weakest point</td>
</tr>
<tr>
<td>Ultimate load</td>
<td>4000 lb (1814 kg) per panel</td>
<td>The maximum load (per floor panel) that the floor system can support without failure (breaking or bending)</td>
</tr>
<tr>
<td>Rolling load</td>
<td>400 lb (181 kg) per panel</td>
<td>The load a floor panel can support (without failure) when a wheel of specified diameter and width is rolled across the panel</td>
</tr>
<tr>
<td>Average floor load</td>
<td>500 lb/ft(^2) (227 kg/m(^2))</td>
<td>Computed by dividing total equipment weight by the area of its footprint. This value is expressed in lb/ft(^2) (kg/m(^2)).</td>
</tr>
</tbody>
</table>

\(^3\) For instructions on how to calculate the weight load of each HP Modular Cooling System, including installed equipment, refer to the HP Modular Cooling System Site Preparation Guide.
Chilled water requirements

There are three potential sources of chilled water for the HP Modular Cooling System:

- Direct connection to the building’s chilled water system
- A dedicated chilled water system
- A water-to-water heat exchanger unit connected to a chilled water or building water system

The HP MCS G2 has been designed to connect directly to the facility’s chilled water supply. In a chilled-water system, an external refrigeration system cools water typically between 40°F and 45°F (4.4°C and 7.2°C). This chilled water is pumped throughout the building for use by air-to-liquid heat exchangers. However, if the water quality, flow, pressure, or temperature does not meet the standards identified in the HP MCS G2 Site Preparation Guide, HP recommends that the water loop for the HP MCS G2 be an isolated loop from the building’s water system or a dedicated chiller unit. A water loop provides for line isolation, better control of individual systems, and the ability to regulate water quality.

When it is necessary to isolate the HP MCS G2 fluid supply/return loop from the main building water system, HP recommends a separate water-to-water heat exchanger. The heat exchanger provides easier control and monitoring of water quality. It also provides more flexibility to maintain the water at a higher temperature to reduce condensation.

Cooling requirements

The HP MCS G2 is designed to add minimal heat-load in the room. Most of the heat generated inside the HP MCS G2 cabinet is removed via the chilled water loop. The HP MCS G2 exchanges a small amount of air with the room during normal operation. Depending on the room temperature, rack power consumption, and system configuration, up to 10 percent of the total internal heat load may be passed to the room.

In anticipation of future heat loads, isolated-loop, chilled water piping should be designed and installed to support:

- Specific heat load increments (35kW or 150kW)
- The specific number of HP Modular Cooling Systems per row or loop
- Other site build-out planning parameters

As cooling, rack space, and equipment density requirements increase, the HP MCS G2 can be quick-coupled into the isolated chilled water system.
Space requirements

The packaged size of the HP MCS G2 (including shock pallet and cartons) is approximately 88.5 inches (2170 mm) high x 48 inches (1220 mm) wide x 70 inches (1778 mm) deep. The size of the single rack configuration from hinge to handle is 78.7 inches (1999 mm) high x 35.8 inches (909 mm) wide x 51 inches (1295 mm) deep (see Figure 10). Two high-density HP MCS G2 systems occupy the equivalent floor space of three standard HP racks. The HP MCS G2 can be aligned flush at the front or at the rear of an existing cabinet row to maintain an organized and uniform data center layout. The minimum recommended front and back clearances for performing maintenance on servers supported by an HP MCS G2 are 48 inches (1219 mm) and 36 inches (914 mm), respectively.

*NOTE:* The HP MCS G2 is shipped with a metal stabilizing bracket bolted to the top of the MCS assembly. This bracket is for shipping only and can be removed before system installation.
Figure 11 shows the operational dimensions for the HP MCS G2 in the dual rack configuration.

**Figure 11.** HP MCS G2 dual rack operational dimensions (approximate)

The HP MCS G2 with server rack requires considerations such as weight and aisle spacing. The system includes leveling feet and does not require fastening to the floor. Care should be taken while loading the equipment to ensure that the enclosure will remain stable during operation and servicing to avoid personal or equipment damage.
Power requirements

The HP MCS G2 uses minimal electrical power (see Table 2) to create the cool air required by the equipment in the rack. Therefore, the HP MCS G2 can be powered from existing 208/220V AC power in the enclosure/rack power strip. Electrical connections are made through a patch panel that provides connectors for AC power and a RJ-45 network interface. Two AC power connectors are provided for redundant power sources.

Table 2. Power requirements of HP MCS G2

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Value</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of power cords</td>
<td>2 (for redundancy), cord length: 98 in. (2.5 m)</td>
<td>System ships with 2 cords terminated with: L6-20P plugs for North America model or IEC 309 plugs for international model</td>
</tr>
<tr>
<td></td>
<td></td>
<td>North America/Japan – Plug L6-20P</td>
</tr>
<tr>
<td></td>
<td></td>
<td>International – Plug IEC309</td>
</tr>
<tr>
<td>Minimum operating voltage</td>
<td>208 VAC</td>
<td>(200 VAC in Japan)</td>
</tr>
<tr>
<td>Maximum operating voltage</td>
<td>240 VAC</td>
<td></td>
</tr>
<tr>
<td>Frequency range</td>
<td>50/60 Hz</td>
<td></td>
</tr>
<tr>
<td>Number of phases</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Rated line current</td>
<td>15 A</td>
<td>Per line cord</td>
</tr>
<tr>
<td>Maximum operating power</td>
<td>1900 VA</td>
<td>Maximum power is the sum of the worst-case power consumption of every subsystem in the box and should be used to size worst-case power consumption for facility installation.</td>
</tr>
</tbody>
</table>

For other power considerations, such as grounding, electrostatic discharge (ESD), conductor/circuit breaker sizing, and power cord connectors, refer to the HP Modular Cooling System Site Preparation Guide available at the URL listed in the “For more information” section.
Environmental requirements

The HP MCS G2 specifications are based on requirements for an HP Environmental Class C2 computer room environment where products are subject only to controlled temperature and humidity levels. The allowable and recommended temperatures and relative humidity (RH) values are shown in Table 3. High humidity can cause galvanic action to occur between some dissimilar metals. Galvanic action can result in high electrical resistance between connections.

Table 3. Allowable and recommended temperature and humidity values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended temperature*</td>
<td>68°F (20°C) to 77°F (25°C)</td>
</tr>
<tr>
<td>Allowable temperature*</td>
<td>59°F (15°C) to 90°F (32°C)</td>
</tr>
<tr>
<td>Recommended relative humidity</td>
<td>40% to 55% RH</td>
</tr>
<tr>
<td>Allowable relative humidity</td>
<td>20% to 80% RH</td>
</tr>
</tbody>
</table>

*The temperature ranges identified in this table are for locations 0 to 5,000 feet above sea level. The maximum operating temperature must be de-rated by 1°C per 1,000 feet for locations 5,000 to 10,000 feet above sea level.

HP MCS G2 installation and maintenance services

HP provides worldwide Site Datacenter Thermal Quick Assessment Services along with installation and maintenance Care Pack services to streamline deployment of the HP MCS G2. The HP MCS G2 Care Pack services help increase uptime and productivity with rapid-response support on a 24x7 or 13x5 basis. The HP MCS G2 Care Pack services are independent of Care Pack services for other HP rack and power products. For more information about these services, access the services Web page at http://h20219.www2.hp.com/services/cache/111072-0-0-225-121.html.

Conclusion

Use of the HP MCS G2 can extend the life and capacity of data centers with limited cooling resources in multiple ways:

- Providing a path for customers to increase power density up to 35 kW per rack
- Supporting fully populated high-density racks while reducing the overall heat load on the facility
- Making economical use of valuable floor space and cooling resources that would be required for under-utilized racks

The HP MCS G2 integrates with existing and future HP universal server cabinets and does not affect how servers are currently deployed, operated, and maintained.

For detailed information about installation considerations for the HP MCS G2, refer to the HP Modular Cooling System Site Preparation Guide, the HP Modular Cooling System Web Interface User Guide, and the HP Modular Cooling System User Guide. The Web links for these documents are listed in the “For more information” section on the following page.
For more information

For addition information related to installing and using the HP MCS G2, refer to the sources listed in the following table.

<table>
<thead>
<tr>
<th>Resource description</th>
<th>Web address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Considerations in Cooling Large Scale High Compute Density Data Centers (for information about HP Static Smart Cooling)</td>
<td><a href="http://www.hpl.hp.com/research/papers/2002/thermal_may02.pdf">http://www.hpl.hp.com/research/papers/2002/thermal_may02.pdf</a></td>
</tr>
</tbody>
</table>

Call to action

Send comments about this paper to TechCom@HP.com.