
BLACK BOX WHITEPAPER: KVM TECHNOLOGY FOR CONTROL ROOMS AND OPERATIONS CENTERS

LEAVE THE TECH TO US





INTRODUCTION

KVM systems have long been one of the hidden foundations of control rooms. They have evolved from being an occasional-use tool for setup and troubleshooting into one of those infrastructure items, used every moment of the day. However, KVM is often not at the top of the list when describing the features of a new control room. Just like the foundation of a building, the KVM system is one of those unseen elements that supports the entire system.

As computing platforms take on an ever-increasing role in control rooms and operations centers, the ability to gain access quickly and reliably to those platforms becomes more important. Early adopters of KVM systems often found them to be a necessary evil: a solution that provided some of the needed features in terms of usability and space savings,

but that often left users frustrated with system performance and scalability. Modern KVM systems have made enormous progress in addressing and overcoming those frustrations.

Current KVM systems offer a wide range of platforms with a host of options to address the requirements of a control room from direct-connected systems to those that make use of customer-supplied IP networks. These systems enable users to configure the number of inputs and outputs and the overall size of the KVM systems based on requirements. Systems can be architected to accommodate large distances, high performance and varying levels of system redundancy and resiliency. Read on to find out how the latest generation of KVM systems compare to what you know about KVM technology and how they can be integrated into control rooms and operations centers.



EVOLVING TECHNOLOGY

SYSTEM ARCHITECTURE

Traditional analog KVM equipment was architected for a limited use case: to connect a large number of servers to a small number of user stations or user interfaces. These were usually servers running background applications, which needed only occasional user intervention. These systems tended to be deployed in situations where the source devices and user stations were in close proximity to each other. In fact, the analog technology used by these systems required that this be the case.

In many control room applications, this proved to be a case of a square peg in a round hole. The more common use cases were switching rapidly between main and backup equipment in mission-critical applications and sharing high-cost specialized equipment between multiple user stations. In these cases, relatively few sources were shared among a large number of users, and it was also a common occurrence for the source devices to be housed in an equipment room a considerable distance from the UI. Advanced features such as audio support, high speed data buses (USB 2.0/3.0) and serial controls were simply not available.

Modern KVM systems, based on newer digital technologies, eliminate many, if not all, of these architecture limitations. These digital KVM systems typically fall into two main categories: direct connect KVM systems and IP network connected systems. Both of these offer the system designer a great deal of flexibility to tailor all aspects of the system to meet specific requirements.

DIRECT CONNECT SYSTEMS

For most direct connect systems, gone are the days of fixed inputs or outputs that many designers have come to expect. Systems are equipped with data ports that can be configured as inputs or outputs as necessary. A variety of matrix sizes are available, and users can select from fixed port or modular platforms, as dictated by their needs. Numerous options exist for the type of endpoint that can be deployed, as well as for copper or fiber interconnections between endpoints and matrix.

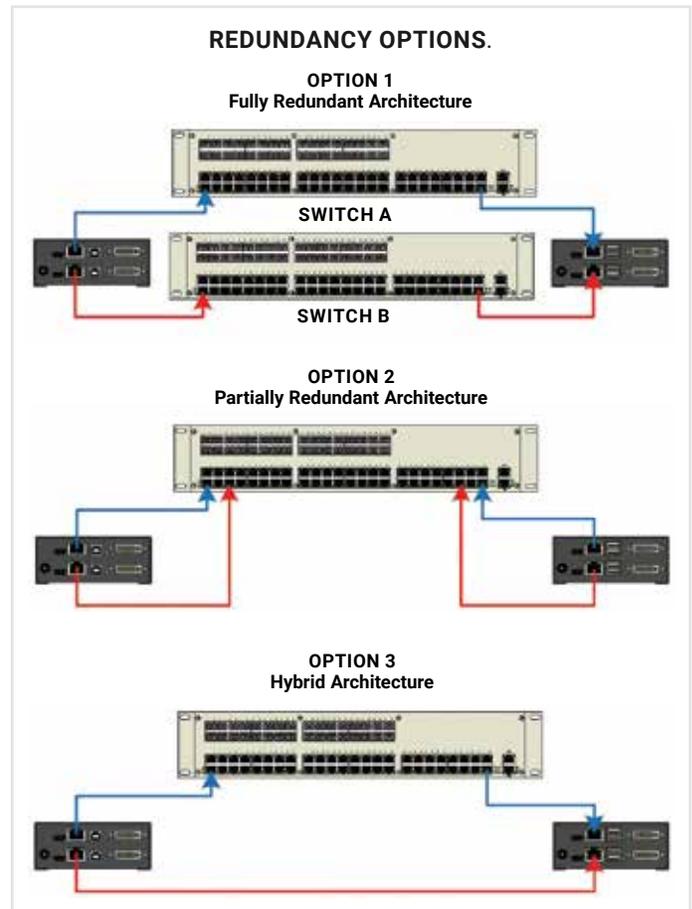
MATRIX CONTROL: Control of the KVM switch can be done using in-band signaling from KVM-equipped UIs or from third-party control systems via an API. Users can select from a source list generated by an on-board on-screen display (OSD) generator housed in the receiver unit or through user-configured hot keys. Sources and destinations can be grouped into containers, including a number of endpoints, with the control system treating each of these containers as a single source or destination. This can enable the more common KVM endpoints to be grouped with specialized endpoints, such as high-speed USB or SDI video, and switched as a single entity.

Hot keys or macros can be configured to enable multiple endpoints to be switched simultaneously. This would be particularly useful in main/backup scenarios where a number of UIs need to be switched at the same time or where an entire control room needs to be reconfigured between shifts or user groups. The configuration change can occur instantaneously with a single keystroke.

SYSTEM RESILIENCY: The control systems of KVM switching systems have evolved to support 24x7 mission-critical operations. Resiliency is built into the system to ensure that the controllers can be hot swapped quickly.

System protections can also be integrated into the overall design of the system. For high criticality installations, it is possible to use endpoints with redundant matrix connection points. These connections can feed back to different I/O cards of a single matrix or to redundant matrices. For source endpoints, the signals from the source computers would be fed to both matrices simultaneously. For destination endpoints, the receiver would monitor the status of both of the inbound signals. Users can specify the signal to use when both are present. The receiver automatically fails over to the alternate signal if one of the connections is lost. The two matrices communicate with each other over the network to maintain the switch configurations in sync.

A hybrid implementation is also possible for those who cannot support the additional cost of a second matrix. In this scenario, certain endpoints are direct connected via the secondary connection points while the primary points are connected to the matrix. In the event of the failure of the matrix, the receiver would fail over to the alternate connection—a direct connection to the source device transmitter. This architecture would eliminate flexibility and switching functionality in the redundant mode, but provides absolute continuity in the UI connection.





PORT FLEXIBILITY: When configuring the modular platforms of direct connect matrix systems, users can choose from different I/O port speeds to best suit their requirements. Standard connection speeds for keyboard, video and mouse are approximately 1 Gbps at the lower end of the scale with medium and high-speed ports available to support specific applications such as USB 2.0 /3.0 and baseband video signals.

In addition to port speed options there are options for connections between the endpoints and the matrix. I/O cards equipped with SFP cages will accept a variety of SFP modules. Standard ports can be equipped with copper RJ-45 SFPs for use over copper UTP cables or fiber SFPs for use over either single-mode or multimode fiber. Medium- and high-speed ports require fiber SFPs to accommodate higher data rates.

The high speed ports can also take advantage of the recent advancements in SFP technology to allow additional connectivity options. These ports can be equipped with SFPs to allow the direct connection of SDI video, 3G-SDI, HD-SDI or SD-SDI on coax or SDI over fiber, or HDMI version 1.3 sources directly into or out of the KVM matrix without the need for outboard conversion equipment. This allows high resolution video sources to be switched alongside the traditional UI signals for greater flexibility in monitoring options

IP-BASED SYSTEMS

The change to digital technologies in KVM systems has also enabled KVM switching to be implemented over converged IP networks. The dedicated KVM matrix switch is replaced by a COTS Gigabit Ethernet IP switch. KVM transmitters and receivers are connected to the IP switch via standard Ethernet connections. IP-based systems offer even more flexibility than direct connect systems in terms of system architecture. The physical reach of the KVM system has become equal to that of the IP LAN. As long as there is sufficient bandwidth across the network between

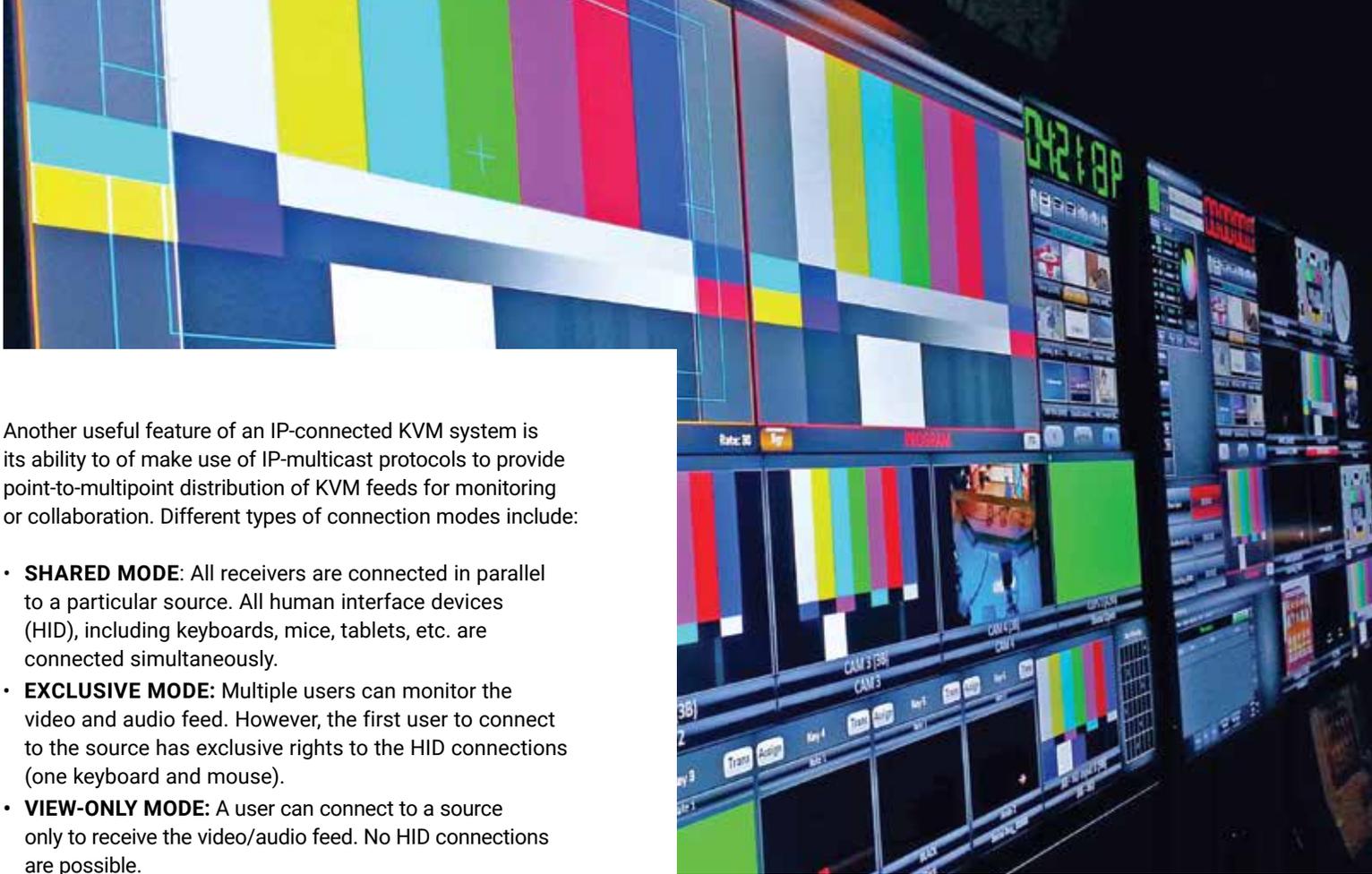
transmitter and receiver, the KVM system is there. It is even possible to design certain configurations of IP-based KVM to reach past the boundaries of the high-speed internal network to make use of public networks or the Internet. IP-based KVM transmitters can be specified with VNC capabilities to enable users to connect to host machines remotely via low bandwidth, high latency networks (WAN or the internet) for certain types of operations.

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Access to the KVM system is controlled by user login. The system is configured to provide a unique profile for each user that governs their access to source devices, including the level of access they have. These logins can be based on the user's standard company login through Active Directory. Configuration and status can be created and managed via a secure web-based management suite.

The control system enables the user to configure the data stream that is delivered to the receiver unit. The user can choose from discrete sources (a complete data feed from a transmitter) or create a virtual channel. A channel can be built using source signals from different KVM transmitters, e.g., video from server A and audio from server B. These channels are available in the system source list, much like the complete data feed from a particular KVM transmitter.





Another useful feature of an IP-connected KVM system is its ability to make use of IP-multicast protocols to provide point-to-multipoint distribution of KVM feeds for monitoring or collaboration. Different types of connection modes include:

- **SHARED MODE:** All receivers are connected in parallel to a particular source. All human interface devices (HID), including keyboards, mice, tablets, etc. are connected simultaneously.
- **EXCLUSIVE MODE:** Multiple users can monitor the video and audio feed. However, the first user to connect to the source has exclusive rights to the HID connections (one keyboard and mouse).
- **VIEW-ONLY MODE:** A user can connect to a source only to receive the video/audio feed. No HID connections are possible.
- **PRIVATE MODE:** A single user is granted access to a particular source. Once that connection is made, all other user connection requests are rejected until the user releases the connection. The various modes can enable the use of the KVM system in a number of different workflow scenarios outside of the standard one-to-one mode, such as status monitoring of alarm UIs, training or job shadowing, and signage throughout the facility. But they still provide users with the privacy and security capabilities needed for confidential use, such as email and confidential documents.

SYSTEM RESILIENCY: System status of the IP-connected system is stored in the system manager. Redundant system managers can be operated in an online or hot redundant mode to improve system reliability. Handover from one system manager to the other is seamless. The system manager is only involved prior to the time a switch is made so the user can select the appropriate source. Once the connection is made, communication goes directly between the transmitter and receiver.

IP-based systems take advantage of a persistent link mechanism to retain the connection information in the event of a power cycle. This means that as soon as all the elements in the connection path (transmitter, receiver, and network) are powered up, the units will restore their KVM connection. There is no need to wait while the system manager boots up and resumes operation to restore the KVM connection.

IP-based units can be equipped with redundant Ethernet ports. These ports can be used for redundancy. Or they can be ganged for higher network bandwidth. When used in the ganged mode, a single port can retain the KVM connection in the case of failure of one of the links. The system automatically adjusts the network traffic to route all the KVM data down the single link.

PORT FLEXIBILITY: IP-based systems do not have the same level of port flexibility that direct connect systems are able to provide. Due to the 1-gigabit Ethernet communications protocol, they are equipped with RJ-45 1-Gbps copper ports and a SFP card cage for optional single-mode or multimode 1-Gbps links. Baseband digital video or high-speed data interfaces are not feasible over this type of link. However, the 1 Gbps bandwidth is more than enough to carry standard keyboard, video and mouse signals from a typical UI.

VIRTUALIZATION: IP-based systems can be used to take advantage of the current IT trend towards virtualization. They can be selected to act either as zero clients for virtualized machines or as traditional KVM receivers for connecting PCs via a KVM transmitter. This type of system enables the user to connect to a mix of virtualized and traditional PCs for a gradual transition to a virtualized environment. These types of systems are even suitable for deployment across WAN architectures since they typically require lower bandwidth than the 1 Gigabit connected systems.

SYSTEM SCALE

Traditional analog systems tended to be difficult or impossible to scale past a fixed upper limit. The largest switches available topped out in the range of 64 inputs, while only offering up to 16 outputs. To implement large systems, it was necessary to cascade multiple layers of switches, which tended to be prohibitively expensive and difficult to control and compromised the end-to-end performance.

Current KVM technologies have largely eliminated the issue of system scale. For the direct connect system, small to large systems can be accommodated in a single frame, while very large systems are possible using tie lines between matrices managed by a sophisticated control system. With an IP-connected system it is possible to implement an even larger range of scales, from two endpoints to thousands of endpoints, with theoretically no upper limit to the size of the system. KVM systems can now easily be deployed on a scale that spans the entire operations site or campus, with every computer UI connected to a single integrated system. *SEE FIGURE-ENTERPRISE KVM SYSTEM.*

This type of enterprise-wide deployment can provide an organization with a number of benefits:

- **FLEXIBILITY** – Users can access systems from any location throughout the facility.
- **EFFICIENCY** – Staff can accomplish tasks faster and with less organizational latency.
- **RESPONSIVENESS** – Staff can quickly respond to emergencies and failures, assess the problem and switch to a backup system to restore operations.
- **REDUCED COST** – Capital costs and licenses fees can be reduced as users are better able to make use of resources by sharing devices and user interfaces.
- **IMPROVED WORKSPACE** – The design of operational environments can be streamlined with the KVM system, providing access to a variety of interfaces at a single position, improving ergonomics, and reducing clutter.

DIRECT CONNECTED SYSTEMS

Matrix frames can range in size from just a few ports up to approximately 600 ports. Switches can be supplied as fixed-port systems with a specific number of CATx or fiber ports or as a modular chassis with empty slots that can enable the user to grow the system as their needs evolve or as new features are added to the platform.

In addition to platform options for the matrix switch, there are options for the KVM transmit units, as well. High-density, card-based solutions are available for the KVM transmit modules. These frames decrease the space required by the KVM transmitters while simplifying installation and providing redundant power supplies to the active components.

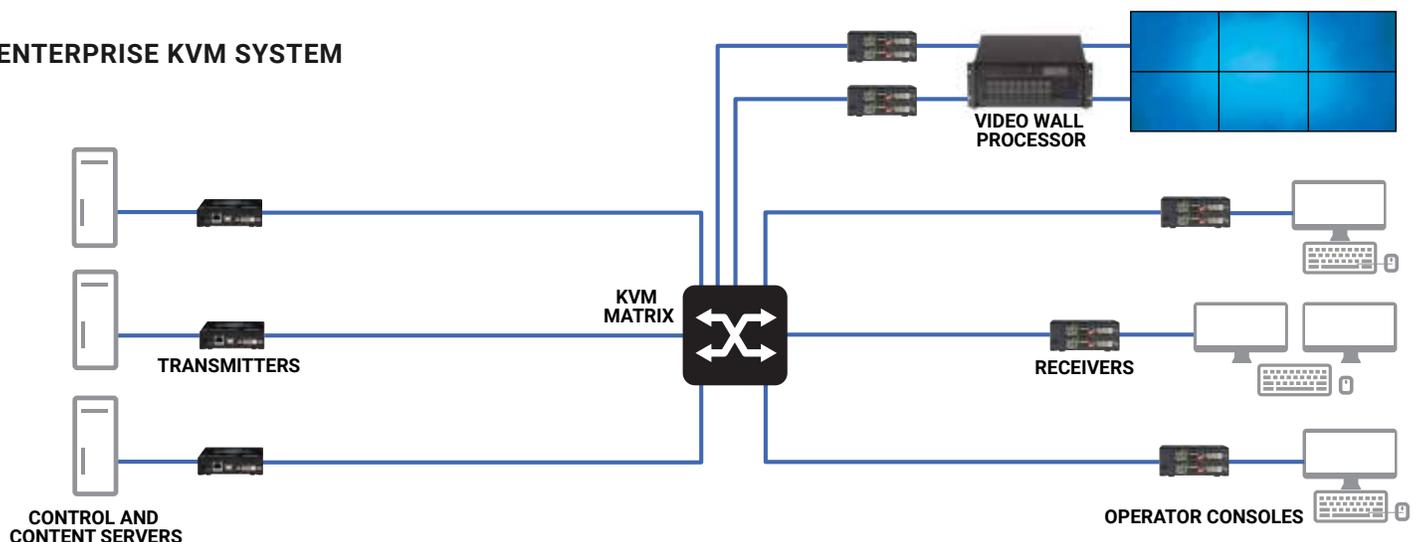
KVM TRANSMITTER FRAME



IP-BASED SYSTEMS

IP-based systems offer even more flexibility in terms of system architecture. There is no theoretical limit to the number of end points that can be added to an IP-based KVM system. The only practical limitation is the bandwidth of the user-supplied network that supports the system. IP-based systems are considered the best choice for very large systems. It is recommended to examine the load that the KVM system may impose upon the network and consider dedicated network infrastructure for the KVM system to ensure performance.

ENTERPRISE KVM SYSTEM



PERFORMANCE

Legacy KVM systems, with their use of analog connections, had limits on the resolution and distance that the signals could be transmitted. Complex and difficult to configure skew compensation circuits were required to overcome the video issues generated by the KVM transmission technology. In addition, the devices often functioned as USB hubs for peripherals, requiring a re-enumeration of the USB devices each time a switch was made. This resulted in a 10 -15 second delay after each switch until the UI became usable.

Digital KVM systems have evolved to overcome both of these performance issues. Video compression techniques are applied to video signals to reduce the data that needs to be exchanged between transmitter and receiver. USB devices are handled differently as well. KVM transmitters used in these systems ensure the host computers maintain the peripheral devices as active, enabling in-band control and instantaneous response of peripheral devices.

Frame rates of modern digital KVM systems have been designed for high performance while carrying high-resolution, full-motion video. A frame rate of 50 fps or greater is required to support smooth mouse or tablet tracking. These rates are easily supported by the current systems for all video resolutions below 4K. Systems supporting 4K 60fps video are also available.

End-to-end processing latency is the second major factor that impacts usability of KVM systems. Video compression is typically the main contributor to end-to-end delay. Currently, these delays are typically in the range of 24 milliseconds (ms) one way or 48ms round trip. This starts to become noticeable for the user once it reaches the range of 70-80ms, making the latency performance of a typical KVM system well below this threshold.

Video compression parameters can be adjusted by the user to ensure that they are given the highest priority in the compression process. For applications where colorimetry is important, color depth can be preserved while video frame rate is decreased. In cases where video resolution may be more important, frame rate is preserved and color depth is reduced. These parameters can be set per transmit device to optimize the performance of each source on the system.

The bandwidth required by a digital KVM link is dependent primarily on the content of the video portion of the KVM signal. High-resolution, full-motion video can require the system to provide the maximum bandwidth of the channel (approaching 1 Gbps for standard connections). For much of the video included in typical UI display, all or some portion of the screen will be static text or backgrounds. This significantly reduces the required bandwidth of the connection. While full-motion video could require a bandwidth of up to 950 Mbps, a typical control screen of text and backgrounds might only need a bandwidth in the 50-70 Mbps range. This would place significantly lower loads on the switching fabric supporting the KVM system.



DIRECT CONNECTED SYSTEMS

Direct connect systems have flexibility in the port speed at the KVM matrix. This enables higher speed ports to be used to support those signals that require higher performance. A DVI single-link connection with full-motion video can have a data rate of up to 3.6 Gbps. For data port speeds of 1 Gbps, a compression ratio of approximately 4:1 is applied to the signals to enable them to pass through the system. This ratio can be reduced for higher speed ports. For applications where uncompressed video is required, smaller scale direct connected systems can be deployed that apply no compression to the video signal. This provides a cost-effective solution that allows approximately 20 -25 sources to be connected to a small number of users over UTP copper cabling. These systems can support uncompressed video resolutions up to 1920 x 1200 through DVI-D or DisplayPort interfaces.

IP-BASED SYSTEMS

IP-based KVM systems are currently limited to the 1 Gbps uplink speed of the endpoint devices. But this provides enough bandwidth to carry full-motion video in a visually lossless mode and more than enough bandwidth for a typical UI video display. IP-based systems are subject to the same compression delays for the video portion of the UI, approximately 24ms for each path. In addition, there would be the end-to-end switching latency of the network. These figures tend to be very small, ranging from almost unperceivable in small networks to in the range of 1ms end-to-end for very large campus-style distributed networks. This performance places these systems well within the range of acceptable hand eye coordination of a maximum of 70ms latency outlined above.

FORMAT FLEXIBILITY

Legacy KVM systems were limited in the signals that they were able to support. Video resolution was limited to an upper limit of 1920 x 1440 single link, and the interface was often required to be analog VGA. PS2, SUN and USB peripherals were supported, but USB was limited to HID class devices only. No high-speed data connectivity was available. The transition to digital technology for KVM has enabled a much broader range of connection types.

DIRECT CONNECTED SYSTEMS

SIGNAL SUPPORT – A variety of video and data formats are currently supported in the direct connected KVM systems. UI video can be supplied to the KVM system in VGA, DVI (single or dual link), DisplayPort, HDMI or even SDI. Resolutions up to 4K or 3840 x 2160 at 60 frames per second are supported.

SDI and HDMI signals can be supported in two different ways. These signals can be used as the video portion of a KVM signal by feeding them to a KVM transmitter to be packaged with the keyboard and mouse signals or they can be fed directly to the matrix via signal processing SFPs to provide monitor only signals.

Keyboard and mouse signals via standard USB or legacy PS/2 connections are addressed by the base transmit and receive units. Advanced control options such as USB HID or embedded USB 2.0 can be accommodated by correctly equipped transmit and receive units. This method is also used to address audio and RS-422 serial control signals. Digital audio (SPDIF on coax or Toslink) and analog computer audio can be carried embedded in the KVM signal using correctly equipped end units. The same applies to RS-422.

IP-BASED SYSTEMS

IP-based systems are limited in the formats they can accept. IP systems are limited to DVI video input, although dual single-link DVI and DVI dual-link video with resolutions up to 2560 x 1600 can be supported. For server type systems that only offer VGA outputs, specially designed converters can be supplied that are port powered and integrate well into the rear of the server for a clean installation. USB connectivity is available for HID class devices such as keyboards, mice, and touch screens. Serial and analog computer audio is supported as well.

ADVANCED FEATURES

The use of digital technology in KVM systems facilitates a number of advanced features not previously possible in legacy KVM systems.

EXTENDED DESKTOP: Hardware devices and applications are currently available to enable users to share keyboard and mouse functions across multiple discrete workstations. As the mouse travels off the edge of a desktop display, the interface to that

device is handed from one computer to another. Keyboard connectivity tracks the mouse movement, and the keyboard is interfaced to whichever device displays the mouse pointer. This type of functionality is integrated into direct connect KVM matrix systems. User stations connected to adjacent ports of a matrix I/O card can be configured to share a single keyboard and mouse across up to four source devices. This can provide significant space savings and reduce clutter at an operator position. This functionality can also be added through an external keyboard-mouse (KM) switch for either type of KVM architecture.

SOURCE THUMBNAIL SWITCHING: Selected direct connected KVM systems are capable of generating low-resolution thumbnail images of the various sources connected to the KVM switch. On each output of the switch, the user can view a grid of thumbnail images of the sources available to that user station. The user can use these thumbnails as a source selector to switch the full UI of the user station to that source.

MULTI-VIEW KVM: It is possible to include an outboard device to the KVM system to enable up to four KVM video outputs to be displayed on a single monitor. Four discrete KVM receivers would be connected to this downstream unit with the output feeding a single display. That display would enable the user to view up to four full-motion video feeds simultaneously on a single UI. Keyboard and mouse are also connected to the multi-view generator allowing the user to select which desktop they wish to interact with by clicking on the related image. The user can configure the number of images displayed from one to four, and can size and position the images to suit their needs including picture-in-picture and windowed display formats.

CONCLUSION

KVM systems have come a long way from their roots, buried at the heart of a data center rack room. They continue to evolve, providing the vital link between the operations staff and the technologies used to create and distribute content. These important tools have continued to evolve to keep pace with an ever-expanding array of technology and platforms, while at the same time increasing their usability, performance, and reliability. Regardless of your requirements, it is possible to choose the right combination of equipment to fit those needs, whether that is extending a single user interface on a workstation or a complex virtual environment with thousands of endpoints operating to the latest performance specifications. As with any complex system, the path to a successful deployment lies with correctly determining the objectives for the system, then choosing the partner best suited to assist you in selecting from the widest possible range of solutions to arrive at the mix of products that best fits your needs in terms of functionality, performance and budget.

