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Advanced Deskew Technology For Sharper Video in Extenders and Switches

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Introduction

Analog video (such as VGA and its higher resolution versions like XGA, UXGA and so forth) generally presents a high quality image to the user who sits in front of a computer workstation or server that's directly connected to the computer by short cables (typically 1 to 2 meters / 3 to 6 feet). In this context, the video quality is limited only by the quality of the computer's video card and of the monitor itself. The short cables involved, unless they are very poor quality, do not tend to degrade the image.

In today's data centers, laboratories, retail environments, and with digital signage, video cables may be quite a bit longer than 2 m/6 ft. Here, conventional VGA video cables are not a good choice because they have up to 17 separate conductors so they are bulky, expensive, and impractical to run at great distances. Moreover, the HDD15 connectors at the ends of a VGA cable cannot be pulled through conduit so each such cable would have to be custom fabricated in place. In less restrictive raised floor environments, conventional VGA cables are still undesirable because the large ends with screw posts tend to snag other cables.

For this reason, in the above mentioned applications it has become common to deploy KVM switches and both KVM and VGA-only extenders that rely upon Category x cables (Cat x here refers to Cat 5, Cat 5e, or Cat 6 cables). Cat x cable's benefits include low cost, widely availability, a broad selection of colors (easier to identify and organize bundles), and they come in many different lengths so that one doesn't have to deploy way too much cable or risk running short of the destination.

Note: It's also easy to cut and terminate Cat x cables to specific lengths at the time of installation, something that's not easy to do with VGA cables. However, we don't recommend custom cutting Cat x cables for KVM applications because even small imperfections in the crimping of the RJ45 modular connector to the wires can cause voltage drop and color shift. Such imperfections are not generally detectable by ordinary Network cable testers so you can wind up with cables that test OK, will pass Ethernet data well, and yet are inconsistent in passing analog video. Factory crimped Cat x cables, on the other hand, tend to have consistently low and uniform contact resistance and thus yield better performance with analog video signals.

Unfortunately, one of the potential drawbacks of using Cat x cables is that their very design tends to induce video distortion.

Fortunately, cable-induced distortion can be corrected. This takes extra circuitry and, if the circuitry is not well implemented, it can waste the user's time. This white paper discusses a particular distortion described variously as skew or time base errors, and some of the methods for correcting it (all of which can be considered to be Deskew technology). Most Deskew implementations rely upon a two-way process of sending test signals down a cable, then waiting for a response from the equipment at the other end to make an automatic adjustment. Some methods requiring the user to make tedious adjustments. A recently patented automatic Deskew method from ATEN operates with one-way signal detection and is therefore very fast.

Why Cat x Cabling Requires Video Compensation

>>Cable Construction

Cat x cables vary somewhat, but of the types used in KVM switching and extension, all have four twisted pairs of wires (a total of 8 conductors), terminating in RJ45

modular plugs.

Cat x cables were originally designed for (and are still largely used for) data and voice communications, not analog video or keyboard/mouse signals. Each pair of wires in the cable is intended to carry one signal, and that signal is reversed in polarity in each of the two conductors. Thus, at the receiving end a transformer or differential amplifier can extract the desired signal by flipping the polarity of the two wires, which doubles the signal strength and simultaneously cancels out "common mode noise" that has entered the cable and imposed itself along the pair of conductors. The twisting of wires in a pair ensures that its conductors are close together so common mode noise voltages are nearly identical in both conductors and thus cancels out completely.

However, in order to reduce the leakage of signals between the four twisted pairs (crosstalk), each pair is twisted at a different pitch. This means one pair has more twists per meter or foot of length than the next, and so forth. Thus, for any given length of the overall cable (think cable jacket), the ACTUAL length of the wires in each of the various pairs will be different; those with a higher pitch have more twists and will be longer than those with a lower pitch. The difference in length of conductors in a 305 meter (1000 foot) can be in the realm of 15 m (50 ft)! See Fig 1.

>>Skew – A Degradation Caused by Cable Construction and The Laws of Physics

The progressively longer conductors in each pair result in progressively more overall wire resistance (R). In addition, there is capacitance (C) in the wires, which also increases with wire length. Basic electronic principles explain that the greater the resistance-capacitance coefficient (R x C), the longer the time it takes a signal to arrive at the other end of the wires. That translates to an increasingly shifted location for the display of the pixels in the R-G-B carrying wire pairs as cables grow in length, and it's worse at higher resolutions and/or at faster refresh rates.

In analog KVM and video extension applications, Cat x cable lengths vary from about 3 meters (10 feet) to 305 meters (1000 feet). This maximum is about 3 times longer than the 100 m (328 foot) specified limit for the same Cat x cables used in conventional Ethernet (TCP/IP) packet delivery so it is not surprising that skew

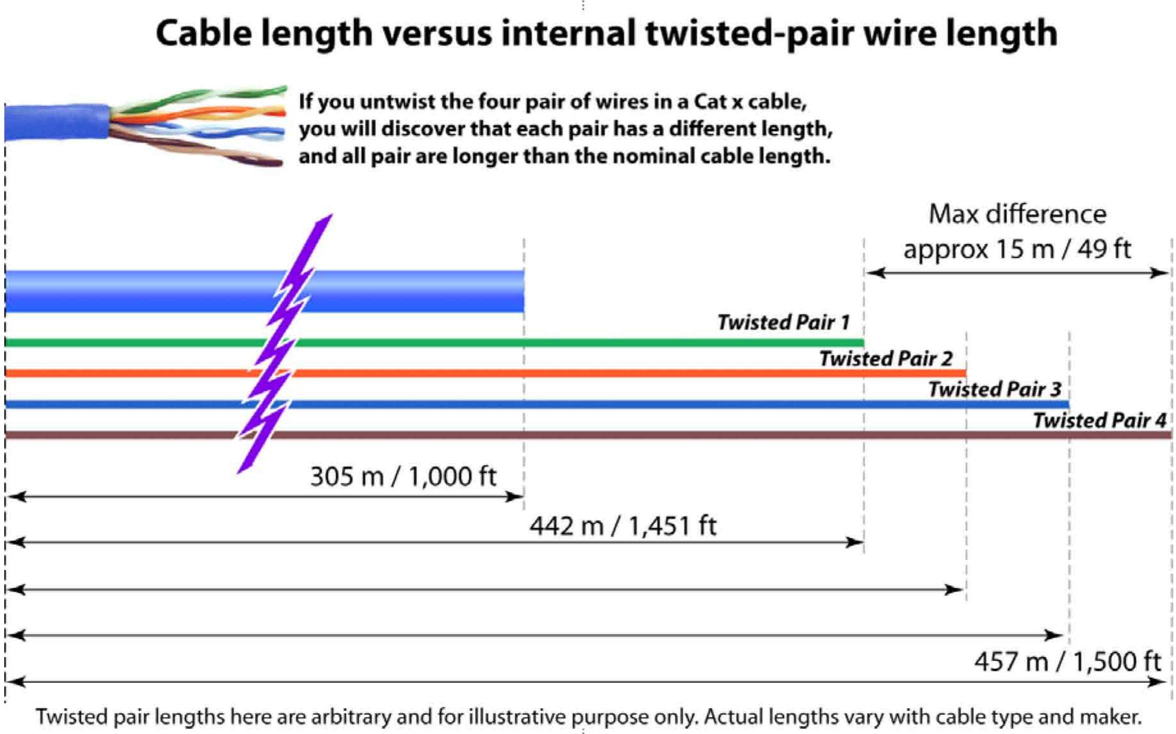


Figure 1. The distinction between nominal cable length and actual twisted pair wire lengths.

compensation is not only beneficial for shorter cables, but essential for the longest ones.

In you view video carried by an uncorrected Cat x cable, you will perceive video skew as a blurred or indistinct image. For example, if a the computer's video card generates a white block displayed on a black background, and you view this image on a distant Cat x connected monitor, it may have a blue leading edge and a red trailing edge on that block. The actual color of these fringes will vary depending upon which pairs of wires (longer/shorter) carry the R, G and B signals. See Fig 2.

If you use a low resolution video output (such as 800 x 600 pixels) and a low refresh rate (50 Hz to 60 Hz) the effect of skew will not be as noticeable. However, with higher resolution bitmaps that are common nowadays such as 1024 x768 or 1280 x 1024, the skew will quickly render the higher resolutions unusable with all but the shortest cables.

Even if the color inaccuracy or fringing is acceptable, the overall lack of sharpness produced by skew will ultimately cause visual problems (eyestrain, errors in deciphering information, and so forth).

For Techies

We recommend that users of extenders with Deskew technology avoid using low-skew cables. While this may seem counter-intuitive, in reality these deskew extenders work better with standard cable. If you were to use low skew cables without a deskew-equipped extender for long cable runs, you might actually spend more overall and get a less satisfactory result than simply using standard cables and a deskew extender.

Belden 1583A, which uses 4 pair of #24AWG solid copper wire. It has a maximum capacitance imbalance of 330 pico-farads per 100 m, a resistance (DC) of 9.38 ohms per 100 m (at 20 degrees C) and a stated maximum time delay of 538 nanoseconds at 100 MHz per 100 m. Time delay exhibited by a cable (in seconds) = resistance (in ohms) x Capacitance (in farads). If you simply multiply their maximum 538 nanoseconds per 100 m and multiply by 3.05 for a 305 m (1,000 ft) cable you get 1765 nanoseconds, or 1.765 milliseconds maximum delay. The 100 MHz frequency used in Belden's spec happens to be the approximate bandwidth required to handle a 65 Hz UXGA (1600 x 1200 pixel) video signal.

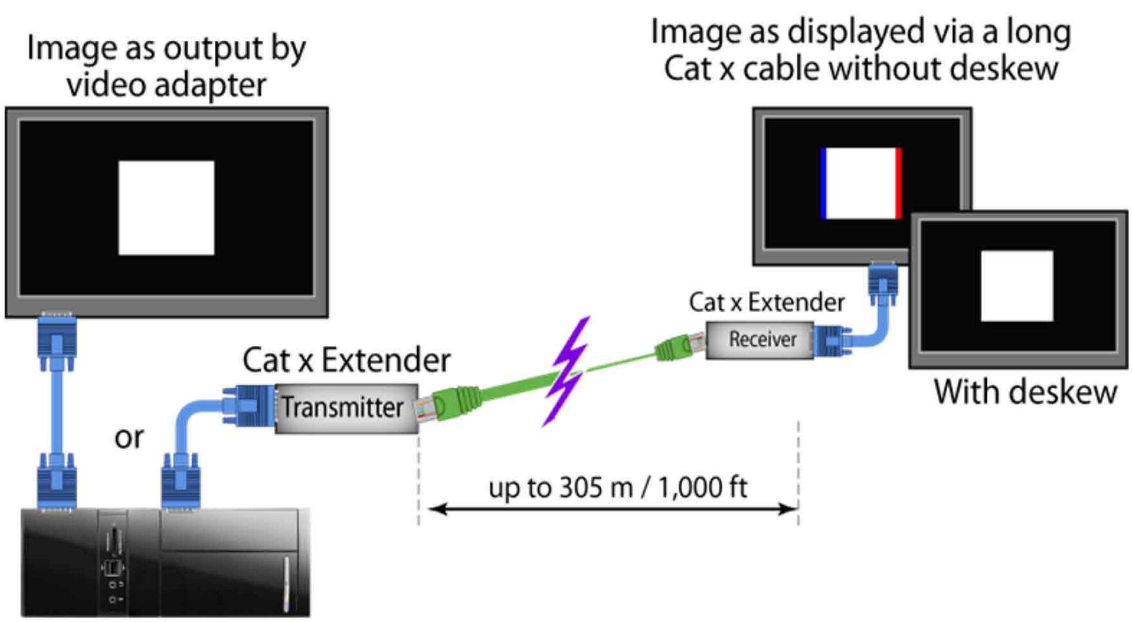


Figure 2. An example of uncorrected and corrected skew in a Cat x extended video signal.

We cite a typical unshielded Cat 5e cable in this example,

About 1.8 thousandths of a second after leaving the computer's video card, the signal arrives at the distant monitor via Cat 5e cable. That isn't a problem, per se. It's the difference in time (mere nanoseconds, or millionths of a second) by which the R-G-B signals differ in arrival times that create the skew problem. Remember that virtually all KVM systems using Cat x cable to carry analog Red, Green and Blue (R-G-B) video apply these signals respectively to three of the four pairs of wires. At 305 meters/1000 feet, the longest pair of wires may be 15 m (49 feet) longer than the shortest pair, which calculates with the Belden specs to roughly 31 nanoseconds time difference. In fact, even standard, non Cat x video cables exhibit skew since they also generally use different pairs of conductors with different twist pitches for signal transmission.

In reality, depending on the actual cable used, its twist pitch and which pairs of wires are used for video (as contrasted to a pair used for keyboard/mouse, etc), the time difference may be more or less between any two pair of wires, and of course this varies with different types of cables. Some 305 m/1000 ft Cat x cables exhibit maximum pair-to-pair time differences as high as 120 ns (nanoseconds). In all cases, the time difference (skew) between the various wire pairs offsets the red, green and blue values at each pixel location and causes video degradation. Here's why.

R-G-B signal values are continuously swept across the monitor's face horizontally and vertically to paint the entire monitor image with tri-color R-G-B pixels at a typical rate of 60 to 75 Hz. To display a 1280 x 1024 pixel image at 60 Hz refresh rate, the time to display one video frame is a mere 16.6 milliseconds (just under 17 thousandths of a second), assuming 1.6 ms for vertical retrace. That leaves 15 ms for the active frame scan time. Given 1024 lines, the time per line is 15 ms/1024= 1.45 ms. However, we allow 1.8 ms for horizontal retrace time, so that leaves a mere 12.8 ms for tracing 1280 pixels. 12.8/1280=.01ms, or 10 nanoseconds time to display one pixel before the scan moves to the next pixel.

Remember, each pixel on the RGB screen is a tri-color pixel, and all three colors have to be the correct value to get the intended color. Thus, a difference in delay time of even the lower value of 31 nanoseconds as cited above will shift the intended color 2 or 3 pixels sideways (or at the end of a horizontal line, way over and down).

The R-G-B values conveyed by each of the three twisted wire pairs carrying them must get to each tri-pixel location on the monitor at the right time or else the displayed color values will be skewed to nearby pixels.

And even if two wires have less differential, say in a 100 m/328 ft cable, the "minimal" delay of 10 to 15 ns will cause the intended color component to shift a pixel away and even smaller delays will "split" pixels to give the wrong color and brightness values at adjacent pixels.

Is Video Skew a New Problem?

In actuality, video skew is a well understood factor that the folks who build television cameras and switchers have known about for a half century; skew is not limited to Cat x cables. In typical TV systems, the way skew develops and is corrected differs from its manifestation in KVM and other analog computer video applications.

It's helpful to recall that the first VGA video hardware (Video Graphics Array) was introduced by IBM in 1987, and became popular in the early 1990s, and at that point is was pretty low resolution, typically 640 x 480 or 800 x 600 pixels with a 60 Hz screen refresh. KVM switches had only begun to appear, and the cables they used were relatively short with many conductors; analog video signals were not being sent down Cat x cables until the late 1990s. At that time, the typical server video bitmap had moved up a bit to SVGA at 1024 x 768 pixels, and a few graphics systems used higher resolutions.

Today's data centers often contain servers with even higher resolutions like 1280 x 1024 pixels, 1600 x 1200 pixels and even up to 1920 x 1080 or 1200 pixels. Greater numbers of servers are deployed in the modern data center, making Cat x cable popular because of its low cost and lower bulk. Because there are larger arrays of cabinets, the cables running between the servers and user consoles are longer, and cables can be quite long by the time they run around ladder track, access floors, plenum and so forth. So while skew is nothing new, it has become a more serious concern that must be effectively corrected, and corrected quickly in today's operating environments.

How Is Skew Corrected?

>>The Basic Parameters

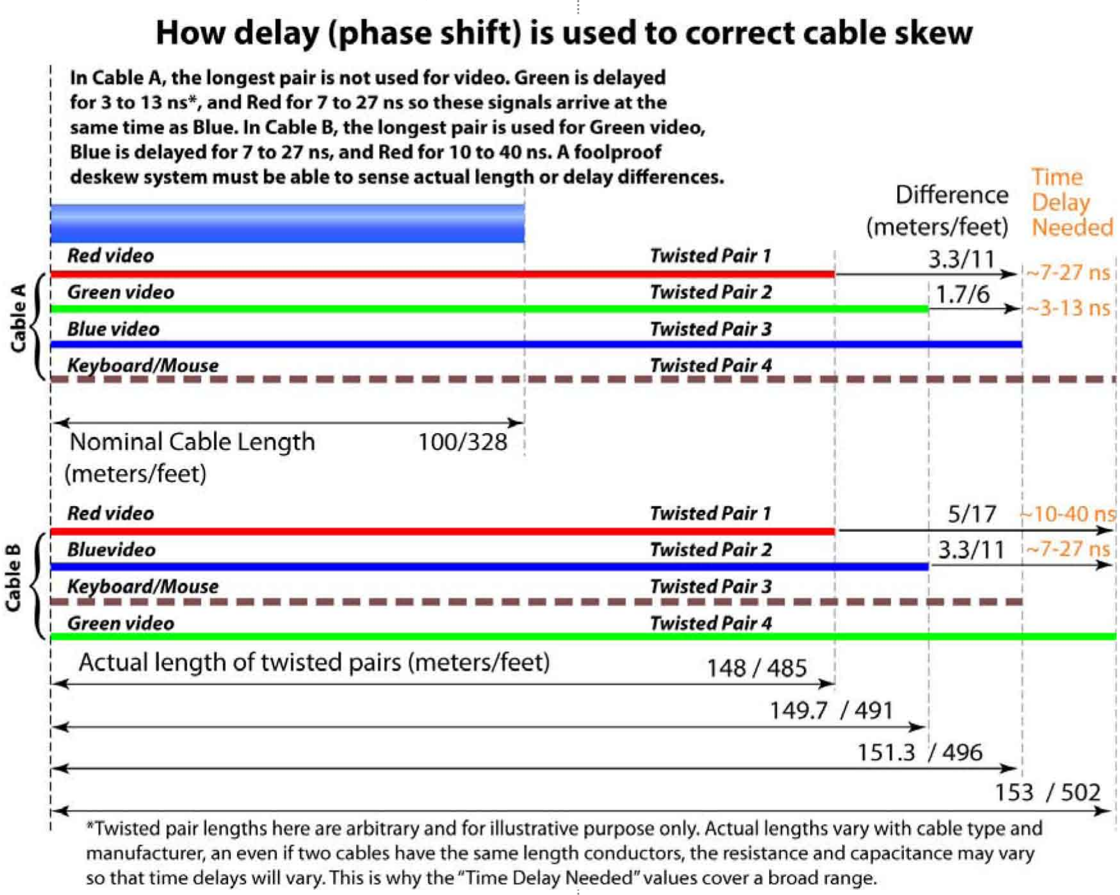
You may wonder, "How much skew is there?" Or, "How much difference in length is there between the wires the longest of cables?" The maximum difference between pairs falls typically at 2 to 2.5 meters per 100 meters of cable, which calculates to be 6.6 to 8.2 feet per 328 feet of cable. However, some cables have as much as 4 to 5 meters wire pair length difference per 100 meters, (13 to 16.5 feet per 328 feet). Remember that100 m (328 feet) is the only value you will see on cable specs because Ethernet is limited to this length. However, KVM and VGA video extension applications triple this limit so the worst-case cable is at 305 meters /1000 feet, in which the difference between the shortest and longest wire pairs may be about 15 meters (49 feet). The difference in signal arrival time between the shortest (lowest pitch) wire pair and the longest (highest pitch) wire pair will vary from about 30 nanoseconds to 120 nanoseconds (a nanosecond is a billionth of a second). See the "For Techies" sidebar to understand why this is actually quite significant difference.

There is no physical means to speed up the late-arriving signals (from the longer wire pairs), so instead the faster arriving video signals (from the shorter wire pairs) are intentionally delayed so they arrive in sync with the slowest of the three R, G or B signals. This is the essence of skew correction; adding proportionally more time delay (you can also think of this as phase shift) to the signals in the shorter wire pairs so they "match up" with the signal in the longest wire pair.

>>General Methods of Skew Correction

You may think, "Why not ensure that the longest pair of wires isn't used for an R, G or B signal so the maximum skew is less?" Good idea, you would still find a significant skew among the pairs that do carry the R-G-B signals. It is not necessarily easy to know which of the pairs (with respect to length) is carrying a given color, or therefore how much corrective delay (or phase shift) to apply to each of the R, G and B signals. See Fig 3 to

Figure 3. Using delay to slow earlier-arriving signals so they align with the latest-arriving signal.



understand how cables can confuse an unsophisticated compensation scheme that assumes certain wires to be longer or shorter.

Early Cat x extenders and switches relied upon DIP (dual in-line pin) switches that the user had to set to encode the approximate length of the cable, which would then invoke a particular set of delays for the R-G-B. This was awkward and time consuming, especially since KVM switches would have to be set for each connected server. With 8 binary slide switches, the increments available using DIP switch-controlled compensation are not particularly fine so the correction achieved is only occasionally "just right."

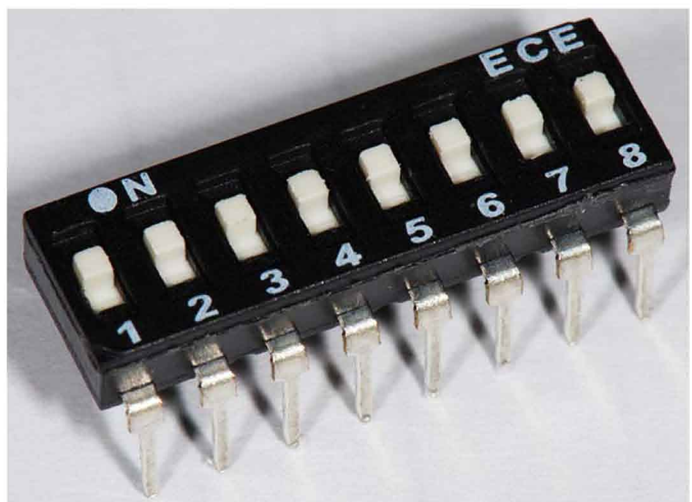
As suggested by the delay diagram in Fig. 3, such lookup-table approaches depend upon the use of a particular standard of Cat x cable (such as TIA568A or TIA568B which supercede Cat 5e) and that specify the particular wire colors and twist-rate of the wire pairs going to each set of pins on the RJ45. Only then can the lookup table select appropriate values for the shorter, intermediate and longer twisted pairs. This isn't always successful because (a) different brands and types of Cat x cables have different electrical characteristics, as pointed out by cables A and B in Fig. 3, so the correction would be ideal only if the user selected exactly the same cable as used by the factory for its setup. This is seldom the case. Sometimes people haphazardly mix different brands or types of cables in the same installation, and those Deskew compensation methods that rely upon lookup tables based on nominal cable length (without actually measuring) are thus not going to work well.

>>What is really needed for effective Deskew?

The method used to apply Deskew must be largely automatic and rapid so that users' don't have to put their time and energy into setup. It has to be effective in correcting the video so a sharp, clear, undistorted image appears at any specified cable length. Moreover, the Deskew method has to provide independent correction at each user console (monitor) on a multi-user KVM switch or an extender/synchronizer with multiple consoles. The Deskew system should work seamlessly with any of the standard Cat x cable infrastructures such as Cat 5 (not a good choice for any but the shortest cables), Cat 5e, and Cat 6, as well as with the variations such as TIA/EIA-568-A/or -568B. (Note: TIA is Telecommunications Industry Association, an offshoot of the Electronic Industry Association.) While the TIA-568-A standard for network cable wiring was made obsolete by TIA-568-B, some of it still exists and so the Deskew system really has to be flexible in automatically working with the wide variety of possible cable types that may be encountered.

Fortunately, more accurate methods have been developed that establish the actual cable length (or at least its delay characteristics) automatically by injecting test signals into one end of each of the pairs of wires in the cable, measuring the arrival of these signals at the other end of the cable, and then self-adjusting compensation circuits to apply the appropriate delay. When this is done for each wire pair, it doesn't matter so much what wiring standard is used or how the electrical characteristics of the cables vary.

Figure 4. Typical Dual In-Line Pin (DIP) selector switch



For most modern systems, the resolution of the delay settings is better than legacy DIP-switch set delays, so that corrections can be more accurate. However, there are tradeoffs made with respect to holding down the cost and other compromises based on the chosen Deskew technology. If you have just a single video output to extend to a single monitor, a small extra cost for more sophisticated circuitry is easy to absorb. When you are dealing with many, many computers and/or monitors, the compensation circuitry becomes more complex, and can become a significant cost factor. Hence, a significant concern of KVM manufacturers has been to come up with a Deskew solution that is effective, as noted above, and that is also economical.

>>What's been done?

Some Deskew systems are sold which contain circuit boards with etched wire traces to physically lengthen the signal path (these are called track cards); progressively longer tracks (hence longer delays) are switched into the path for the shorter Cat x pairs to approximate the length of the longest pair. This also introduces unnecessary resistance (and hence signal loss) in the lengthened paths. Such systems may work for a single Cat x extension, but they are rather impractical for a KVM where each combination of a given server accessed by one of multiple users requires a different path length.

Most Deskew systems employ multiple analog delay circuits rather than using track cards to literally extend the wire path length. To set the delay lines, the systems send a series of different frequency measurement tones or pulses from one device in the system (e.g., the KVM switch) to another device (e.g., the KVM user console), for the purpose of measuring and comparing the performance of the various pairs of wires in the cable. The results of such tests are detected by the device at the receiving end, and the results are then sent back down the cable to the sending end so the correction can be made. The video itself must be temporarily blanked out (it cannot be sent down the cable while the testing and adjusting is occurring), and the adjusting circuits at the sending end must wait for feedback from the device at the receiving end of the cable. This two-way method is a relatively slow process. As a result, one manufacturer makes the deskew corrections progressively over several server-selection cycles. If the correction is made over several server switching cycles on a KVM switch, then video appears quickly but it's not fully corrected for a while. Other manufacturers' deskew technology forces users to wait for video to appear.

Note: *We are using the terms* ***phase*** *and* ***delay*** *interchangeably. In fact, longer time differences are considered to be delay, and extremely short time differences are considered to be phase, which is all relative to the frequency of the signal. In fact, gross time delay adjustments can be made based on cable length measurements, and then finer time delay adjustments can be tuned by comparing the phase of the signals.*

In 2006, ATEN developed a new, very fast and effective Deskew process for which they have subsequently been granted multiple patents. In other manufacturers' systems, the Deskew correction takes at least twice the time as ATEN's new method. Legacy Deskew systems send test signals the length of the cable (encountering the first cable-induced delay); remote circuits then measure the arriving signal and generate a correction signal, and a second cable-induced delay occurs as the corrections signal travel back down the same cable to complete the auto-adjustment cycle. With ATEN's one-way process, test signals are applied to all the wire pairs at the signal source end, these are detected at the far end of the cable, their relative phase (delay) is established, and variable delay elements are automatically and precisely adjusted at that end of the cable – no wait for a return trip down the cable.

Deskew Enhances ROI (Return On Investment)

The deployment of KVM extenders, switches and synchronizers that rely upon Cat x cables, enhanced by automatic Deskew technology embedded in the hardware, can save a lot of money. A single Cat 5e or Cat 6 cable now can be used where previously a fiber optic device was the only viable choice. Not only is fiber optic hardware more costly than the Cat x equivalent, the installation of fiber cables is more costly as well.

A sometimes overlooked benefit of using corrected-corrected Cat x for extended VGA video or KVM extension is that it may be possible to tap into existing cable infrastructure. Thus, newer, higher resolution computer video adapters and monitors can be put into use without having to pull new cables (such as fiber optic or Cat 6 instead of an existing Cat 5e cable for example).

Because Deskew improves video clarity, operators can work more efficiently with less fatigue and fewer human errors. It's easy to understand that this translates into more productivity per worker. In some cases an error avoided, providing immeasurable benefit (e.g., avoiding an incorrectly deleted file/directory because the filename or the cursor was not clearly displayed).

Examples of Products Employing Deskew Technology

>> ATEN CE770 KVM Extender

The CE770 is a USB based KVM Extender with Deskew function. The automatic signal compensation and RS-232 serial functionality allow access to a computer system from a remote USB console (USB keyboard, monitor and USB mouse). The CE770's automatic delay line synchronizing relies on patented ATEN technology to correct RGB phase and timing errors that occur over longer cables. It also enables you to tune the R/G/B signal settings, store the settings, and retrieve them later using the memory button.

- Superior RGB Deskew Function – automatically synchronizes the time delay of RGB signals to compensate for distance
- High resolution widescreen video – up to 1920 x 1200 pixels @ 60 Hz (150m) or 1280 x 1024 pixels @ 60 Hz (300m/1000 ft) with DDC, DDC2 and DDC2B support for local monitors
- Useful for control and security purpose – place the computer or KVM switch in a secure location and extend console up to 300m (1000 ft) for user convenience
- Dual console operation – control the computer (or KVM switch) from both the local and remote USB keyboard, monitor and mouse consoles
- RS-232 serial ports support a serial terminal or devices (e.g. touch screens and barcode scanners)
- Superior Audio support (stereo speakers and microphone) – no quality loss at 300m (1000 ft)
- Overcurrent protection and static/surge suppression
- Hot pluggable and rack mountable

>>ATEN KM0532/KM0932 5/9 Console x 32 Port Matrix KVM Switch with KA7240 Console Module

- KM0532/KM0932 5/9-Console 32-Port Matrix KVM Switch
- KM0032 32-Port Matrix Expansion KVM Switch

KA7230

PS/2-USB Console Module

- PS/2 and USB interface
- RS-232 Port
- Dual RJ-45 Ports
- External PC Port

KA7240

Virtual Media PS/2-USB Console Module

- PS/2 and USB interface
- RS-232 Port
- Dual RJ-45 Ports
- External PC Port
- Virtual Media Port
- Audio Ports
- Superior RGB Deskew Function

System

- 1 Rack-unit high chassis supports 5 or 9 independent console ports (KM0532 or KM0932) for simultaneous control of up to 32 directly connected servers
- Flexible expansion: up to 7 Matrix Expansion KVM switches can be daisy chained from master switch, and switches can be cascaded three levels for management of over 8,000 computers
- Dual-root configuration allows up to 18 consoles to access any servers in the installation
- Redundant AC power supplies for 24/7 reliability

Video

- User's display automatically adjusts to resolution differences on the remote servers
- Superior video quality: 1280 x 104 pixels @ 60 Hz out to 300m (1000 ft)
- Auto Signal Compensation (ASC) assures optimum video resolution for distances up to 300m (1000 ft) between computers and consoles without any need for DIP switch setting
- Enhanced video quality via superior RGB deskew function support for KA7240 console module and newer KVM adaptor cable series (KA7120, KA7170, KA7130, KA7176)

Other Features (partial list)

- Virtual media support for DVD/CD drives and USB mass storage devices; works with USB enabled servers at O/S and BIOS levels
- Supports 1024 users and 255 group accounts with 3-level password security
- Stringent password policy with password expiration, account disabling and account expiration.
- RS-232 port admin login for master control of all connected consoles from a single point
- Settings/configuration backup and restore with event log support

>>ATEN VE510 Video Synchronizer

The VE510 Video Synchronizer is designed to compensate for video signal delays over large distances. The VE510's line synchronizing function corrects color phase and timing errors that occur over long distance transmissions. It also enables you to manually tune the RGB signal settings, store the settings, and retrieve them later using the memory button.

- Connects VGA based video devices to VGA displays and enhances video quality in long-cable installations
- Superior RGB Deskew Function - RGB tuning and skew equalization
- Compatible with ATEN KVM Extenders, Video Extenders and KVM switches