

Silicon Motion's Graphics Display SoCs

Enable 4K High Definition and Low Power

Power and bandwidth: the twin challenges of implementing a solution for bridging any computer to any high-definition display

The trend in the design and configuration of today's office spaces, retail stores, hospitality operations and factories is towards equipment that is more mobile and flexible than ever before. This has important ramifications for the provision of a display user interface in many types of equipment. In particular, users and employers are calling for devices which can connect to portable or shared displays via USB.

USB – the Universal Serial Bus – has fulfilled the promise of its name, and become universal in computing devices such as laptop computers, tablets and smartphones. While a laptop or tablet might not include ports for all the many display interfaces used today, such as HDMI, VGA, DVI and DisplayPort, it will always feature one or more USB interfaces. A USB-to-display bridge device therefore enables any computer to connect to any display.

This makes display arrangements truly flexible. Where before the typical office worker's desk had a fixed desktop PC connected to its own display, now companies are looking to make provision for mobile workers to connect any laptop to any display at any available desk via a USB docking station or dongle.

In the field of factory automation equipment, an OEM can reduce the size and cost of its product by replacing a dedicated embedded display with a USB port for connection to any portable USB display.

In retail, twin USB displays – one customer-facing, one for the sales assistant – may be connected to a point-of-sale terminal with a single USB cable for each display. The single USB cable carries power, data and graphics, providing a simpler and smaller alternative to the use of a VGA, DVI or HDMI interface and a power brick for each display.

There are various graphics processor chips on the market which perform the function of converting a USB graphics input to a high-definition graphics output in a standard display format such as HDMI or DisplayPort. All face the same challenges:

- how to keep to a minimum the graphics, video and audio content to be transported over the USB interface without overloading the host CPU that runs compression algorithms;
- and how to keep power consumption low enough that the USB power supply can drive the graphics system without the need for an external power supply

Different architectures balance the inevitable trade-offs in different ways. This article shows how a new architecture developed by Silicon Motion produces an improved combination of high graphics capability, low latency, efficient data compression and low power consumption.

Users accept no compromise

The availability of a USB-to-HDMI or USB-to-DisplayPort bridge device such as a USB docking station enables any USB host, such as a laptop computer, to connect

to any display (see Figures 1, 2). To the end user, a device such as a docking station appears simple: the technical complexity inside it is completely hidden.

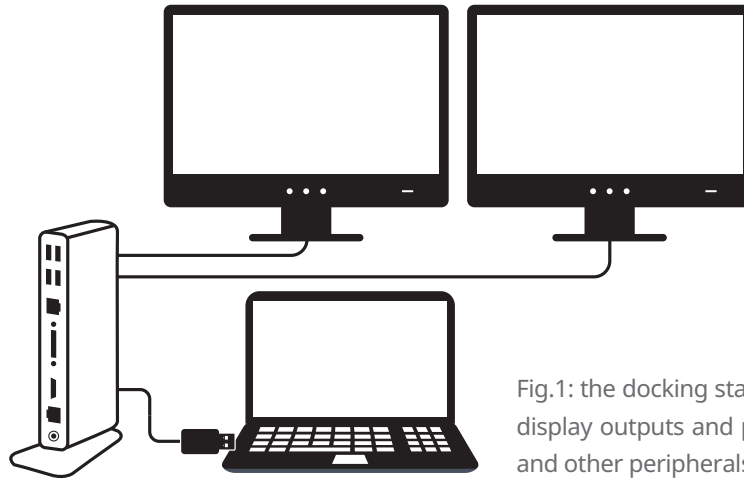


Fig.1: the docking station provides high-definition display outputs and ports for a mouse, keyboard and other peripherals.

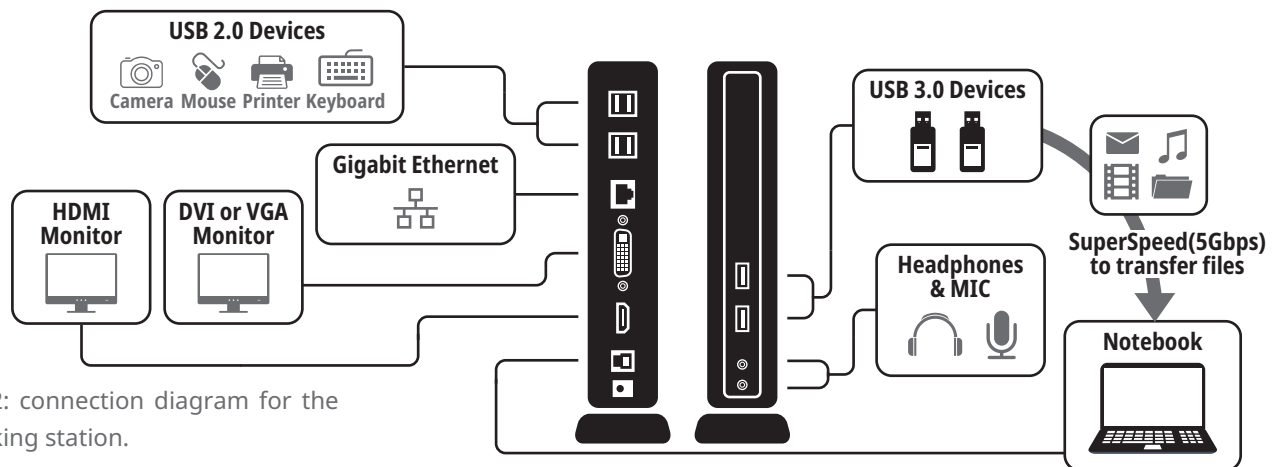


Fig.2: connection diagram for the docking station.

This means that the user will expect the experience of using a laptop, for instance, with an external display connected via a docking station to be no different from using the laptop in conventional stand-alone mode. Users will expect the docking station to support high-resolution formats up to UHD, with the ability to support a dual display output, and with no noticeable slowing or impairment of the laptop's normal operation.

Behind the scenes, however, the USB-to-display bridge performs various complex functions. The more efficiently these functions are performed, the less risk there is of impairing the user experience.

In particular, the host computer connected to a docking station has to implement compression algorithms, reducing the screen content data for transfer over the USB interface. The docking station or display bridge then recompiles the screen content on the display side (see Figure 3). This compression is necessary because a single USB channel between the host laptop and the docking station has to carry not only the screen content, but also potentially Ethernet traffic, as well as other USB data such as information sent to and from a printer/scanner. Reducing the size of the screen content data leaves more headroom for these other data types to be transferred simultaneously.

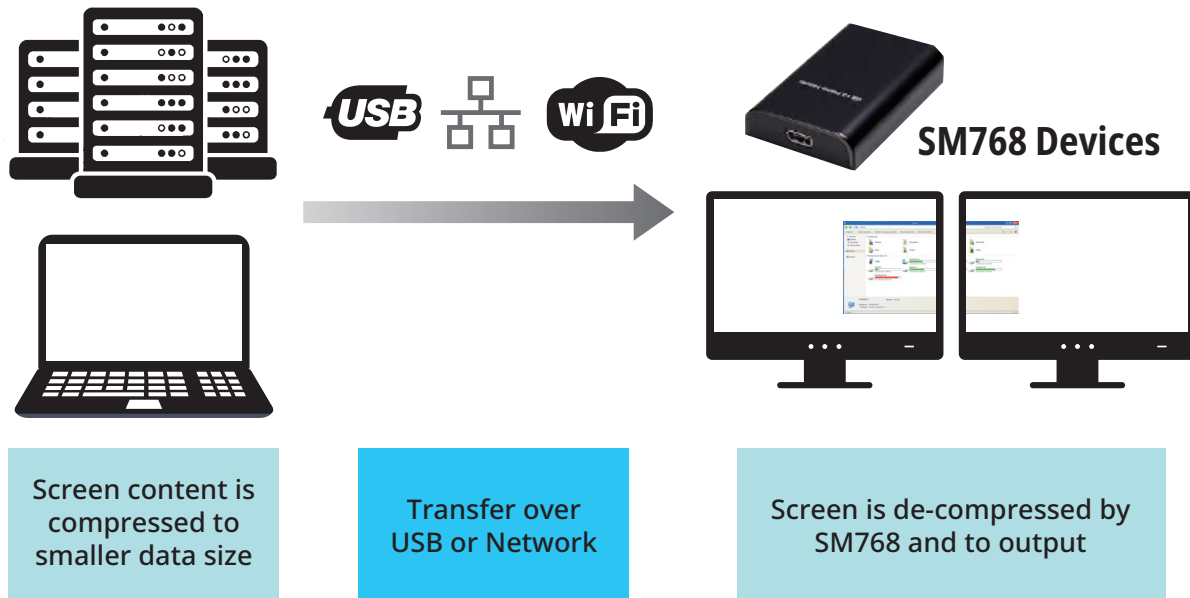


Fig.3: graphics signals are compressed for transfer over USB cable, or over an Ethernet or Wi-Fi network

This compression process has to meet the competing requirements of reducing the data to a small fraction of its original size while at the same time placing as little a burden on the host CPU as possible. Excessive 'CPU loading', as it is known, can affect the performance of the host computer, slowing down the implementation of other functions not related to the display so much that the user sees a noticeable lag.

Now a new approach to compression pioneered by graphics system-on-chip (SoC) manufacturer Silicon Motion combines excellent image quality with dramatically lower CPU loading than other graphics processors can achieve. Silicon Motion's Content Adaptive Technology (CAT™) system, which runs on host computers based on the Windows, MacOS or Linux operating systems, takes advantage of hardware acceleration capabilities in graphics chipsets from Intel and Nvidia. By contrast, competing USB graphics processors are not configured for

execution by hardware acceleration engines, and their compression algorithms therefore have to run entirely in software.

By offloading much of the compression work to a hardware accelerator, the CAT technology from Silicon Motion both runs faster and imposes less loading on the CPU. As will be shown later, this helps the SM768 – the first Silicon Motion graphics processor to use the latest CAT algorithms – to achieve very low.

CPU loading depends on many variables, including the type of graphics or video signals to be compressed, the host CPU/graphics chipset, the amount of RAM available and the operating system. But in tests compressing an HD video clip for transfer over USB to dual HD displays on an Intel Core i5 chipset, the SM768 achieved an average loading some 22%-32% lower than that of competing devices (see Figure 4).

USB graphics processor	Test set-up	CPU loading, range	CPU loading, average	Frame rate per second	Average CPU load/frames per second	Average reduction in CPU loading when using SM768
SM768	Dual 1080p displays, USB 3.0 interface	33% - 48%	39.22%	102	0.3821	
Competitor 1	Dual 1080p displays, USB 3.0 interface	42% - 58%	50.13%	102	0.4915	22%
Competitor 2	Dual 1080p displays, USB 3.0 interface	46% - 61%	50.99%	91.34	0.5583	32%

Fig.4: comparison of CPU loading between SM768 and two competing USB graphics processors when transferring an HD video clip in .mp4 format

Despite this low loading, the CAT system achieves high image quality because of its intelligent approach to compression: it distinguishes between different content types, and applies appropriate compression techniques to each type:

- Graphics and 3D images are processed by a high compression-ratio MJPEG codec
- Text is compressed by a proprietary lossless protocol developed by Silicon Motion
- Video is transferred in its original compressed format, such as MPEG4

In the SM768, the implementation of decompression on the display side is enabled by the architecture of the device: it is configured as a graphics SoC, not as a pure graphics processor, since it combines an Arm® Cortex®-R5 CPU core alongside proprietary graphics and display engines (see Figure 5). The Arm CPU is able to take care of coordination of decompression, as well as running the USB protocol stack, thus providing the system designer with a complete, single-chip solution for USB-to-display bridging.

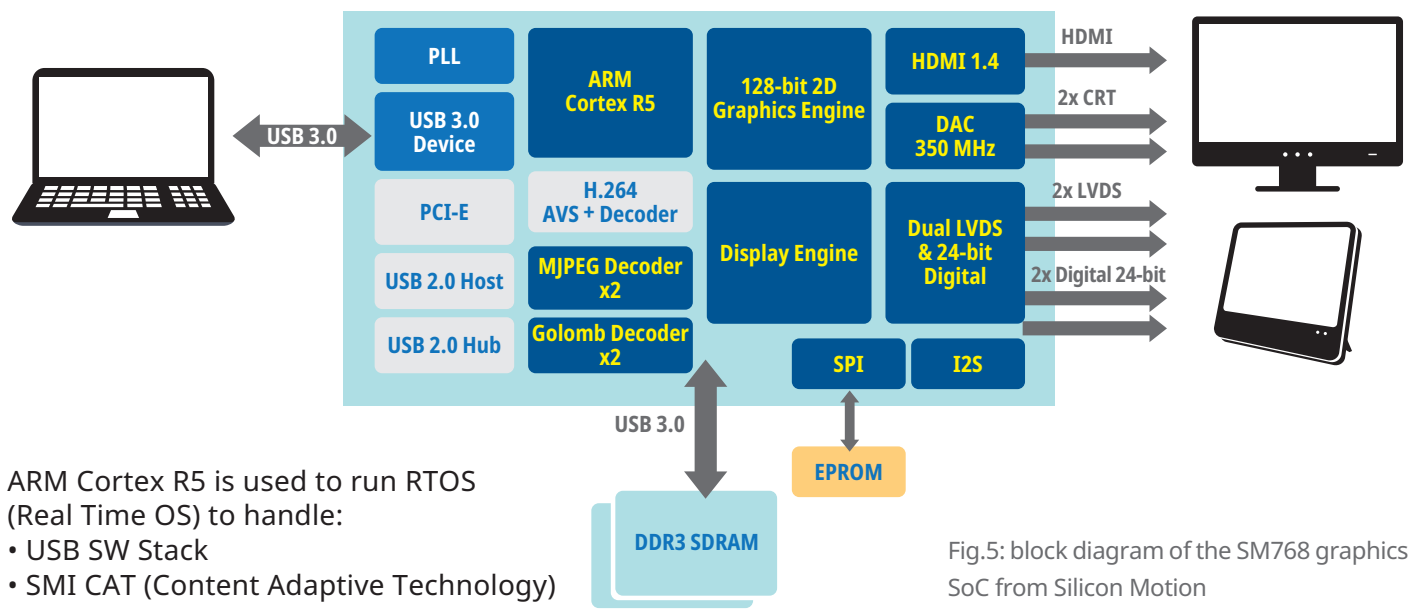


Fig.5: block diagram of the SM768 graphics SoC from Silicon Motion

Importance of low-power performance

The efficiency of the SM768's CAT feature, the low-power ARM Cortex-R5 core and the lean graphics and display engines combine to produce high-speed operation with low power consumption.

High-speed operation produces low latency of <16ms for a Full HD frame. This latency is invisible to the human eye. A test set-up similar to that proposed by Microsoft for testing Miracast shows a native display connection alongside a display connected via an SM768 graphics SoC (see Figure 6): the two displays show the same frames at the same time.



Fig.6: testing side-by-side with a native display connection shows that the latency of the SM768 is invisible

This high-speed operation is produced at low power: the SM768 consumes <2.5W when bridging dual Full HD or single 4K displays to a host device over a USB 3.0 connection. This low power consumption is very important: first, it enables the bridging system to operate from USB power without needing an external power brick.

Second, the high efficiency of the SM768's operation means that it can operate without a heat sink, enabling OEMs to implement very compact, easily portable product designs, a crucial feature in device types such as USB display dongles. The SM768 itself is a small BGA chip with a 19mm x 19mm footprint. It can alternatively be specified as a multi-chip module with 256MB of DDR3 DRAM for even greater space savings.

(The SM768 chip supports up to 1GB of external DRAM.)

Comprehensive system solution for USB-to-display bridging

Compared to competing devices, then, the SM768 graphics SoC offers much lower host CPU loading for an unimpaired user experience. This is backed by the excellent picture quality provided by the CAT compression feature, low latency in dual-display mode, low power consumption and compact dimensions.

The architecture chosen by Silicon Motion also enables OEMs to implement complete docking station and other product designs with few external components. The USB and CAT software as well as a real-time operating system run inside the SM768. The device also provides four USB 2.0 channels for connecting Human Interface Devices (HIDs) such as a wireless keyboard, mouse and dongle as well as a printer.

This explains how it is able to support the latest docking station and dongle designs which are helping to bring greater flexibility, convenience and portability to many types of computing equipment in the home, office, store and factory.

It is also worth noting that the same SM768 device also features a PCI-e interface for use with other types of hosts, enabling OEMs to develop designs both for the USB market and for other applications.

For more information about SM768, please go to www.siliconmotion.com