Ultra Low Power Optical Links

in Portable

Consumer Devices

White Paper

Silicon Line GmbH

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1. Abstract

This white paper looks at why optical fiber connections are replacing traditional electrical connections in consumer devices. It examines the trends which underpin this transition and the benefits which can be gained. It also highlights optical applications in consumer products such as mobile phones, notebooks / netbooks, TVs, digital still cameras, digital video cameras and PC / PC peripherals.

2. Introduction

Mainstream consumer devices have in the past used electrical cable technology for data transfer. However electrical cable technology has now reached practical limits for speed and length, due to electro-magnetic interference (EMI), increased power consumption, increased cost, mechanical limitations, form factor restrictions and other issues.

Applications such as data centers, networking and telecom communications require multi gigabit speeds and already reached the limits of electrical technology some time ago. In these applications, optical technology is being used because it overcomes the limitations of electrical cables by transmitting data using light instead of electricity.

The data rates in many consumer devices are now approaching the speeds previously only seen in the networking / datacom / telecom markets. The dramatic increase in data rates is being driven by high resolution HD displays, multi mega pixel cameras and now 3D technology. These consumer devices are also now bumping up against the limits of electrical cable technology and start to need optical solutions. However the cost and power consumption requirements in consumer applications are much more demanding than in the industrial markets. This means the optical ICs currently used in the industrial markets cannot be used for consumer and new low cost, low power optical solutions are required.

Additionally many consumer devices tend to be portable / battery powered, have very small and slim form factors, have multiple RF antennas which are susceptible to EMI and also have moving parts which require cables to travel through hinges and be mechanically flexible. All of these trends also favor optical cable technology.

Consumer devices which can benefit from optical cable technology include mobile phones / smartphones, tablets, notebooks / netbooks, TVs, digital still cameras, digital video cameras and PC / PC peripherals.

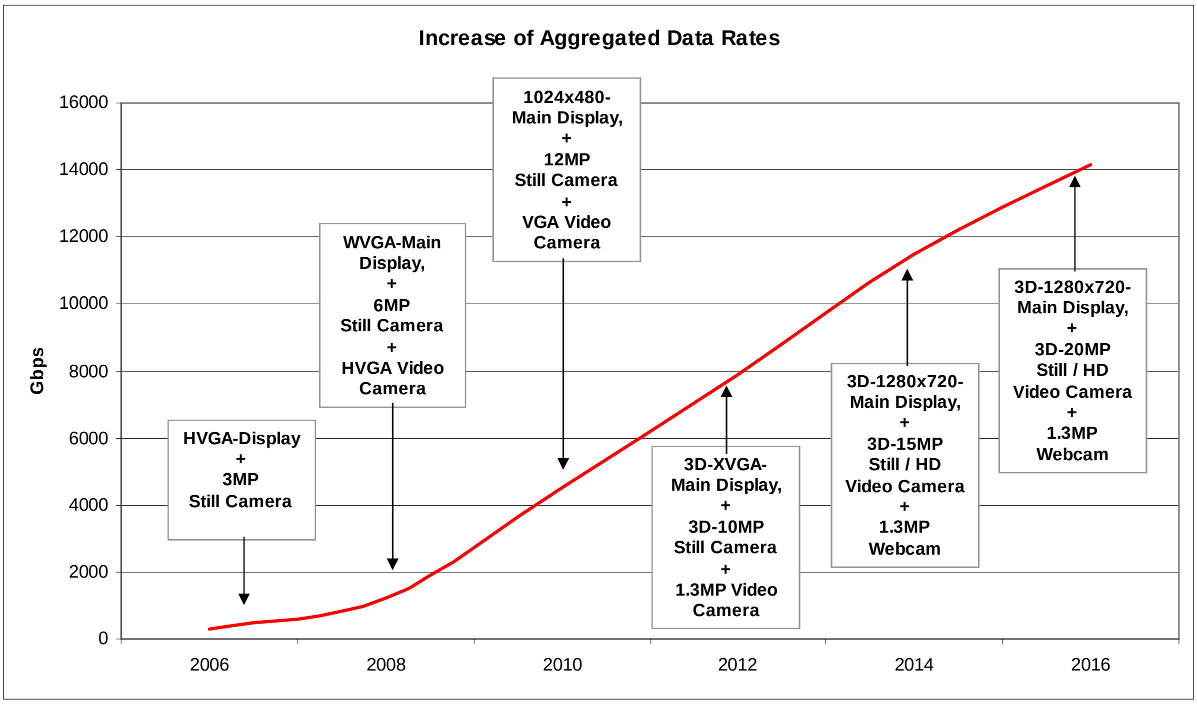
Within the consumer market there are several standardization organizations working on optical enabled high speed data links. These include the MIPI organization which is developing specifications for mobile phones (D-PHY and M-PHY), VESA which is developing DisplayPort specifications for notebooks and TVs (eDP and iDP) and Intel which is developing the Lightpeak specification for PC and PC peripherals.

3. From Electrical to Optical

Various trends lie behind the transition from electrical cables to optical links in consumer applications.

The first trend is towards greatly increased data rates which are now required in many consumer devices. This is mostly driven by demands for higher resolution video which in turn needs higher resolution displays and cameras. Most recently the introduction of 3D technology is leading to a doubling of video data rates in some cases.

Mobile phones and smartphones are integrating HD displays and also now moving to 3D displays. The cameras in these devices are also becoming multi mega pixel and can capture and record full HD video. Two cameras are needed for 3D image capture. Phones are also starting to capture and playback Full HD video content from the internet, memory cards or from mobile HD TV transmissions. As a result the required data rate has dramatically increased. In response to this the MIPI organization has standardized a D-PHY interface which can run at up to an aggregate speed of 4 Gbps and is now working on a M-PHY interface which can run at 6 or even 12 Gbps per data lane.



Aggregate Data Rate Trend in Mobile Phones

Notebooks and netbooks are also following this trend to higher data rates. 3D displays for gaming and Blu-Ray 3D movie playback are becoming available. Screen resolutions are increasing to Full HD 16:9 widescreen and WUXGA. Data rates of 2 to 3 Gbps are now common and can double when 3D is widely available. As a result, the current technology used to connect the GPU to the display, LVDS, is now being replaced with embedded DisplayPort which can achieve significantly higher data rates.

Also in TVs the trend is towards higher data rates. Full HD at 240 Hz is now common. 3D displays are available. The color bit depth is increasing from 8 bits per color to 12 bits per color. Data rates can now reach over 20 Gbps and are trending higher. Here again LVDS is reaching its limit and will probably be replaced by internal DisplayPort which can cope with the higher data rates.

Using electrical cables at these high data rates creates several problems, most of which add costs and / or reduce system performance or put restrictions on the form factor of the device.

The increased data rates usually require an increase in the number of cables used (for example more LVDS data channels). This of course directly increases costs and also makes the cable larger and bulkier and so limits the form factor of the device. A typical cable harness for a mobile phone can now have up to 70 micro-coaxial connectors and can be very difficult to fit through a hinge.

The increased data rate also consumes more power which causes many problems in portable battery operated devices. End users expect a longer battery life but in this case the battery life is being reduced.

Increased data rates also directly lead to increased EMI. This increases costs by requiring the use of shielded micro-coaxial cables whereas before cheaper FPC cables could be used. In some cases metal shielding is required, for example in a digital TV. The increase in EMI can also negatively impact the RF performance of a device.

In a mobile phone the cables carrying high speed video data to the display and from the camera can pass close to the RF antenna. In this case high EMI can reduce the RF performance and lead to bad call quality or even dropped calls.

Similarly a notebook generally has several antennas integrated near the display, for example WiFi, Bluetooth, GPS, UWB and cellular phone antennas. These signals all pass through the hinge of the notebook together with the cable providing video to the display. EMI from this display cable can interfere with the RF performance of all these antennas.

By contrast plastic optical cables are low cost, have no EMI issues, are low power and can easily fit through restricted physical spaces like hinges. They are also future proof in terms of being ready to support even higher data rates when needed.

The second trend is towards smaller and slimmer form factors. Examples of this are the latest smartphones, tablets, netbooks and TVs using LED edge backlight technology or OLED displays.

The third trend is towards designs which have movable parts or restricted space requirements like hinges. Examples of this are clam shell phones, swivel phones, slider phones and netbooks.

An Example of a Mobile Phone with Movable Parts

The second and third trends are not supported by the bulky and mechanically inflexible nature of electrical cables. However these trends are addressed by using very small, flexible optical links based on plastic optical waveguides. The smallness of the link enables a very small and slim form factor. The smallness and mechanical flexibility of the link enables the link to go through physically limited spaces which move, such as hinges in mobile phones and notebook / netbooks. This in turn frees up valuable hinge space for other connectors and so facilitates functionality such as webcams, microphones and RF antennas which are located in the display part of the netbook and need connection to the main board.

4. Typical Optical Link for Consumer Applications

A typical optical link for consumer applications consists of the following components:

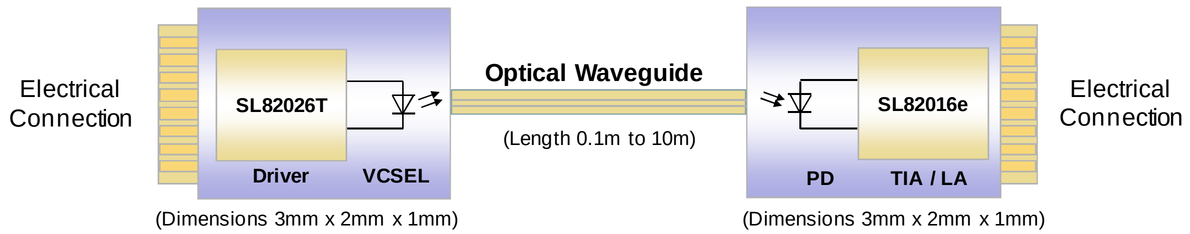
- A VCSEL (Vertical Cavity Surface Emitting Laser)
  This is a low cost GaAs laser which outputs light according to the modulated current at its input. For consumer applications the wavelength of the light is normally 850nm. Typical low cost VCSELs can already reach speeds of up to 15 to 20 Gbps and potentially more than 25 Gbps in future.

- A VCSEL driver IC
  This IC converts the high speed data into a format which is able to drive the VCSEL. The input to the IC is usually a differential voltage with a low voltage swing, for example SLVS-200. This is necessary in order to save power. The IC outputs a modulated current which drives the VCSEL. Normally each VCSEL has different characteristics so the bias current and modulation current of the VCSEL driver IC can be selected according to the VCSEL chosen and are also automatically adapted according to its operating temperature characteristics. The VCSEL driver IC is fabricated from standard CMOS to save costs.

- A POW (Plastic Optical Waveguide)
  In consumer applications POWs using plastic optical fiber (POF) are the medium of choice. POF is preferred due to its potential cost advantage over more traditional glass based optical fibers. The performance of glass fiber is usually better than POF but for short range consumer applications this is not an issue. POF is also more flexible than glass fiber and it is possible to have 2 or more POF waveguides embedded in the same physical media.

- A PD (Photodiode)
  This is a low cost Si or GaAs based device which converts optical signals into electrical current. Si PDs can reach speeds in excess of 1.5 Gbps whereas GaAs PDs can reach speeds well beyond 20 Gbps.

- A TIA (Transimpedance Amplifier) / LA (Limiting Amplifier) IC
  The TIA takes the current output of the PD, converts it to a voltage and amplifies it. The LA converts the analog signal to a digital signal and then outputs the digital signal in a format which can be used by the circuits at the other end of the optical link. This combination of amplification and conversion into the digital domain results in an optimum output signal with a wide open eye, thus reducing bit errors. To save power, the final output of the LA is usually a differential signal with a low voltage swing, for example SLVS-200. In order to save cost for consumer applications, the TIA / LA ICs are fabricated from standard CMOS.



Typical Optical Link using Silicon Line ICs

Today, an optical link as described above can easily reach speeds of up to 20 Gbps. Higher speeds can be attained by using a multi-channel architecture, for example a 4 channel optical link can reach speeds of up to 80 Gbps.

As can be seen, at every stage low cost and low power consumption has been emphasized in the design and selection of the components.

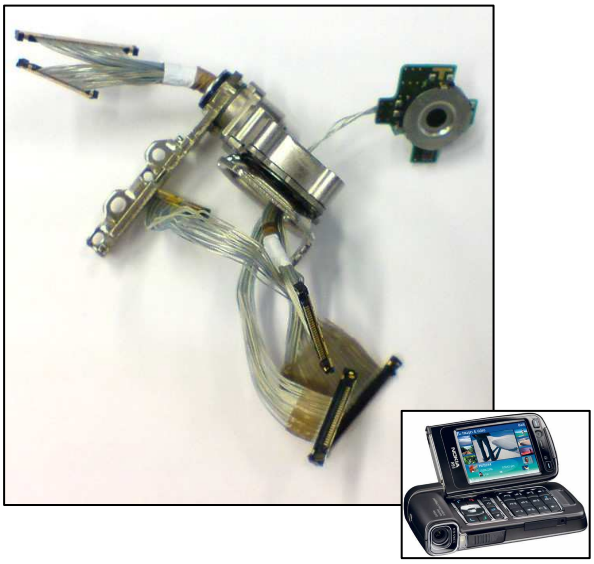
For an optical link to work correctly the input signal must be DC balanced. Many data transmission formats on the market today already provide DC balanced signals eg MIPI M-PHY, DisplayPort, HDMI® and DVI. The DC balance is usually achieved using 8b10b coding. Other formats, like LVDS or RGB, must be first serialized and then DC balanced before they are input to the optical link. Specialized ICs called serializers / deserializers (SerDes) perform this function.

If an optical link requires a SerDes then the SerDes can be integrated into the optical link itself or mounted on the PCB of the device. Another possibility is to integrate the serializer and the VCSEL driver into one IC and the deserializer and TIA / LA into another IC.

5. Benefits of Optical Links

A typical optical link as described above can consume as little as 10mW at 3 Gbps, including VCSEL bias and modulation currents as well as the currents into the termination load of the TIA / LA. This compares favorably with other high speed electrical technologies such as LVDS. This ultra-low power consumption makes an optical link very suitable for battery operated consumer devices such as mobile phones or notebook / netbook PCs.

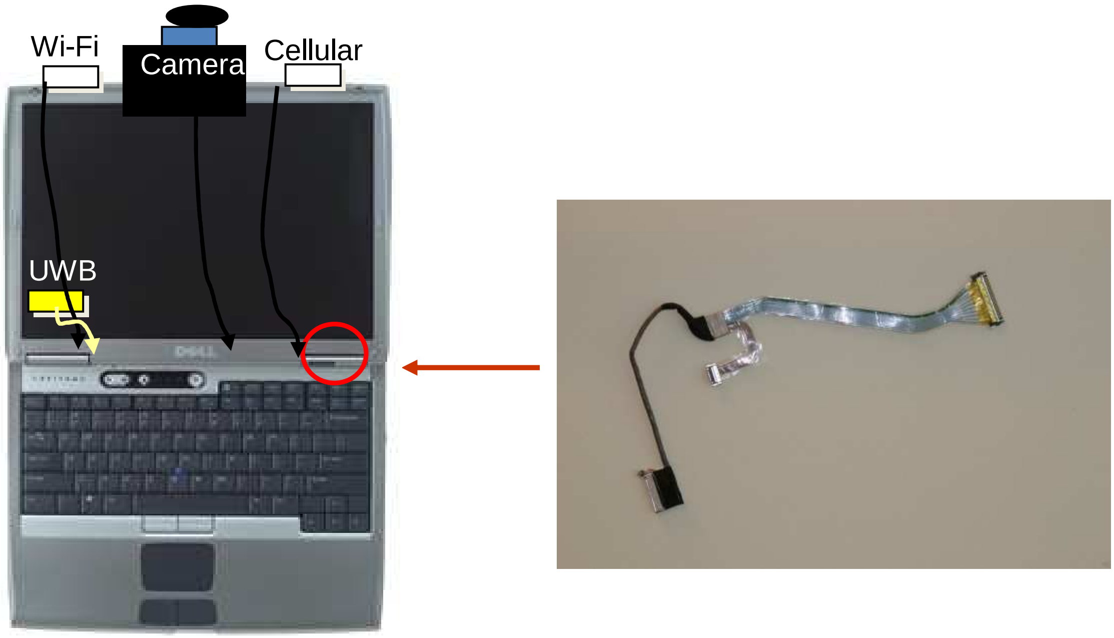
Since low cost components are used in the optical link design, a cost advantage is achieved when compared to some electrical cables. This is particularly so when high data rates require multiple cables which need expensive EMI shielding. For example in a mobile phone, some cable bundles have up to 70 connectors and use expensive micro-coax cables costing as much as $6 or $7. An optical replacement as described above may cost less than half of that in high volume.



Micro-coaxial Cable Harness in a Hinged Mobile Phone

Another cost benefit from using an optical link comes from EMI reduction. An optical link has no EMI issues which can lead to a reduction in shielding costs and better performance for some consumer devices. For example the RF performance of a mobile phone can be severely degraded by the electrical cables going from the camera or display to the applications processor. These cables can pass close to the antenna and so degrade the RF performance. In mobile phones with moving parts (clamshell, slider and swivel designs) the electrical cable is also required to move and is therefore subject to mechanical stress which can wear out the shielding of the cable. This also results in higher EMI and so leads to RF performance issues and can even lead to pixel errors in the display.

The situation is similar in a notebook / netbook. Recent notebook designs include several RF antennas for eg WiFi, Bluetooth and cellular. These antennas are normally in the display part of the device and the high speed electrical cables running to the display cause EMI which can impact on the performance of these antennas. This leads to metal shielding costs which can be eliminated when using an optical link.



LVDS and RF Cables Passing through a Hinge in a Notebook

The optical link itself is very small, mechanically robust and highly flexible. The semiconductor components in the link are usually sold as bare dies which make it easy to manufacture very small optical connectors. This makes optical links an ideal solution for the new small form factor designs coming to the market in mobile phones / smart phones, netbooks and slim LCD TVs using LED edge backlights. They are also an ideal solution for designs which have movable parts or restricted spaces for the cables e.g. clam shell phones, swivel and slider phones, slim netbooks with small hinges, digital still cameras, digital video cameras etc.

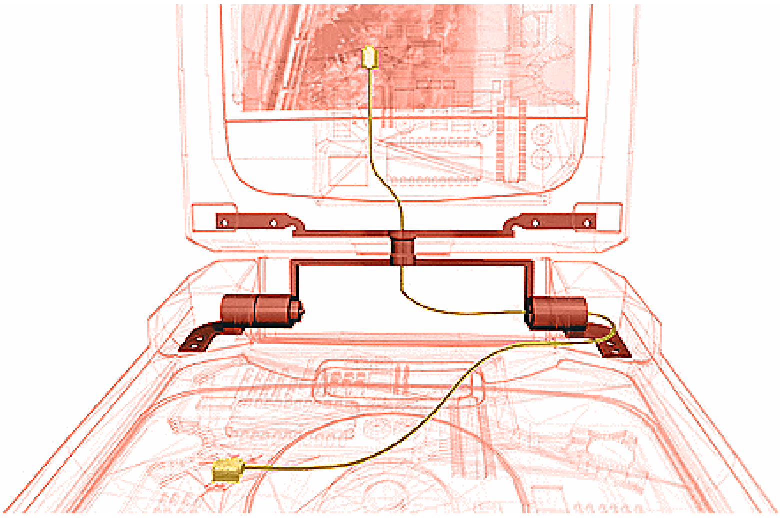
6. Ultra Low Power Optical Consumer Applications

Mobile phones and smartphones are examples of consumer products which greatly benefit from optical links. They are highly cost sensitive and power consumption is a major issue. The design of these phones is becoming very slim and also often features clam shell, slider and swivel variants.

In addition the data rates are exploding due to requirements to playback Full HD video content downloaded from the internet, memory cards, from mobile HD TV transmissions (e.g. ISDB-Tmm in Japan) or indeed from the HD video cameras already integrated into the phone. 3D displays and cameras are also being developed. RF antennas in these highly constrained spaces are very susceptible to EMI generated by these high data rates.

In response to the increasing demand for bandwidth, the MIPI organization has already specified a high speed scalable serial interface (D-PHY) which can operate at an aggregated data rate of around 4 Gbps and is also issuing a new standard (M-PHY) which is optical enabled and can operate at data rates of 6 Gbps or even 12 Gbps per data lane.

In future it is possible for radically new ultra slim and foldable form factors to emerge, driven by OLED displays. It will not be possible to use large and bulky electrical cables in these designs, but an optical link would be an ideal solution.



Example of an Optical Link Passing Through a Hinge in a Mobile Phone

Notebooks and netbooks are another example of products which benefit from optical links. These products are also highly cost and power consumption sensitive. Smaller and slimmer form factors are coming into play (eg LED backlight models) and there are many connectors which need to pass through the very small hinge from the display to the main board. These include the display cable itself, cables from webcams and microphones which are integrated into the display board and signals from various antennas eg WiFi, Bluetooth and cellular. Large and bulky electrical cables carrying video to the display through the hinge and emitting EMI are not ideal for these designs. They take up too much space and cause RF performance degradation. EMI creates more and more problems as the data rates increase due to the higher resolution HD and 3D displays needed for the new generation of video games and 3D / HD movies on Blu-Ray.

In notebooks the traditional method of transporting video data to the display was LVDS. However as data rates increase, LVDS is being replaced by embedded DisplayPort technology. DisplayPort is a technology which is optical enabled and has a maximum aggregated bandwidth of 21.6 Gbps.

Other examples of portable consumer products which benefit from optical links are digital still cameras and digital video cameras. Like all portable consumer devices, cost and power consumption are an issue. These products also have built in LCD screens which are hinged and movable and so need the cables carrying video to the display to be small and flexible. They are also experiencing the trend towards slimmer form factors and are increasingly integrating GPS functionality which is of course EMI sensitive. The first HD and 3D camcorder is planned to be on the market by the end of 2010. These new 3D camcorders can also be expected to follow the increasing data rate trend.

7. Other Optical Consumer Applications

Digital TVs, although not so sensitive to power consumption, can also benefit from optical links. The form factor of these products is becoming ever slimmer with the introduction of LED backlight models. Future OLED displays will be even thinner.

Data rates in TVs are already extremely high and rising. Full HD displays operating at 240Hz are common. New trends include 3D, a move to 12 bits per color and in future Quad HD display resolution. This can lead to data rates of over 20 Gbps, rising to in excess of 100 Gbps for Quad HD displays. The EMI generated from this requires extensive metal shielding and can lead to pixel errors on the display.

The traditional method of transporting the video data to the display has been using LVDS. However as the data rates have increased more and more LVDS cables are required, adding cost and generating more EMI. LVDS will most likely be replaced by internal DisplayPort (iDP) which is optical enabled and can support these higher data rates.

Another application is multi-function printers which have a need for transporting high speed data through sometimes restricted spaces from high resolution scan heads which are rapidly moving. Here the smallness, flexibility and robustness of an optical link are beneficial.

The applications discussed so far all use optical links inside the product. However there are some applications which use optical links externally.

One example is HDMI® optical cables. HDMI® is the AV connection method of choice in the consumer market. Blu-ray players providing Full HD are widespread. The trends for 3D, higher TV screen resolution (Quad HD) and increased color bit depth are all driving the need for the high speed AV transmission which HDMI® enables. However, due to the high transmission speeds required, electrical HDMI® cables are restricted in their length to a relatively short distance. For those applications which require longer distances an optical cable is the preferred solution. Compared to copper cables, optical cables can extend for 100m or more without needing amplifiers or repeaters. Applications include home theater systems, digital FPDs, PDPs and projectors in conference rooms and auditoriums, digital display systems and kiosks with FPDs.

Another example is the recently announced Lightpeak standard from Intel. This standard uses optical technology to connect all PC peripherals to a PC using one common optical cable which will be capable of speeds of up to 100 Gbps. Intel expects the first Lightpeak products will be ready to ship by the end of 2010.

8. Conclusions

Most portable consumer devices now require very high data rates due mainly to the explosion of HD and 3D video content now available and being demanded by end users. These devices also require low cost, low power components and are increasingly available in thin and slim form factor designs. They also require a low EMI environment to prevent interference with the multiple RF antennas which are now being integrated into these devices to satisfy the end user demand to always be connected.

Existing electrical cable technology cannot meet these multiple demands. At these higher data rates electrical cables are high cost, consume a lot of power, emit more EMI, are not mechanically flexible and are large and bulky.

However optical links can address all of these needs and are being introduced more and more into these consumer devices. Optical is going mainstream!

Silicon Line has developed a new generation of ultra-low power, low cost, high speed optical ICs which are ideal for these new consumer applications.

9. References

More information about optical links, standards and applications can be found using the following links.

Mobile Industry Processor Interface (MIPI): http://www.mipi.org

DisplayPort: http://www.displayport.org/

Intel LightPeak technology: http://techresearch.intel.com/articles/None/1813.htm

Optical products from Silicon Line: http://www.silicon-line.com/products

Silicon Line application video: http://www.silicon-line.com/video_siliconline1.htm

10. About Silicon Line

Silicon Line is a fabless analog IC company designing and providing physical layer technologies that enable optical links at multi-gigabit rates for mobile platforms.

Silicon Line was founded in February 2005 in Munich, Germany with the vision to provide highly advanced analog signal ICs for mobile and consumer applications. Our IC solutions are fine tuned to the needs of portable electronic systems that are sensitive to power consumption.

Our products include single and multi-channel VCSEL drivers, transimpedance amplifiers, serializers and deserializers for applications which require high data rate connections combined with low power, low EMI and mechanical flexibility.

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