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Electronics WORLD

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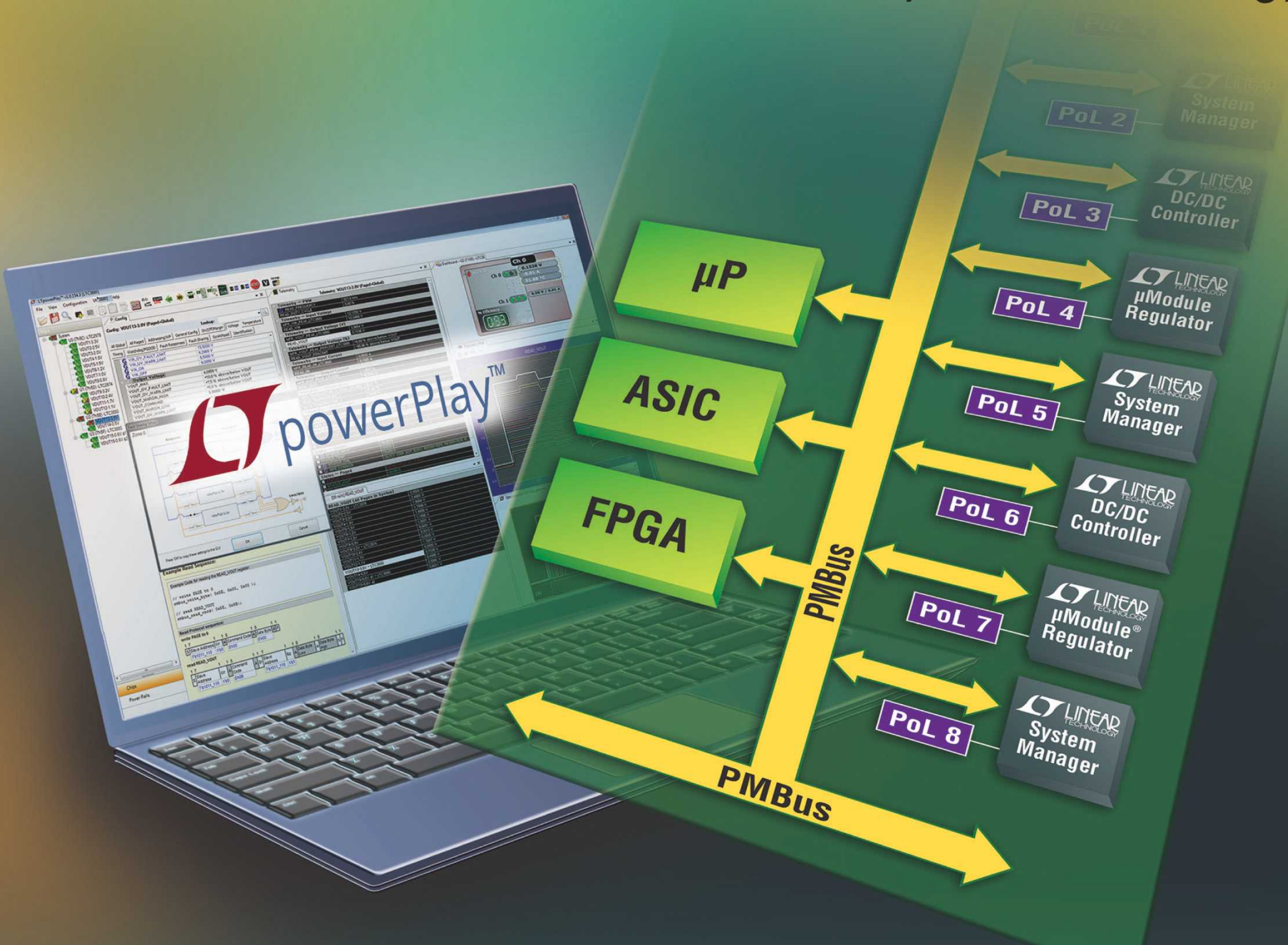
Digital Power System Management for Every Occasion

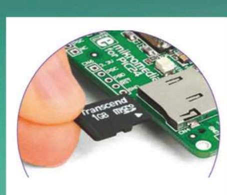
By Linear Technology



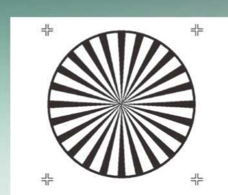
SPECIAL REPORT – Optical Communications

Design • Systems • Materials • Cleaning

Technology
European innovation action for SMEs



Embedded Design Series
User interface design on a budget



Features
Optical information encryption

ARCHITECTURE OF OPTICAL COMMUNICATIONS AND SYSTEMS

STOJCE DIMOV ILCEV FROM DURBAN UNIVERSITY OF TECHNOLOGY IN SOUTH AFRICA INTRODUCES THE ARCHITECTURE OF OPTICAL COMMUNICATIONS IN CIVILIAN AND MILITARY APPLICATIONS THAT REQUIRE HIGH QUALITY AND HIGH SPEED SIGNALS

Since its invention in the early 1970s, the use and demand for optical fibre have grown tremendously. With the explosion of information traffic due to the Internet, electronic commerce, computer networks, multimedia, voice, data and video, the need for a transmission medium with bandwidth capabilities large enough to handle such vast amounts of information is paramount.

Fibre optics technology, with its nearly unlimited bandwidth, has proven to be the solution for today's telecommunication networks. Terrestrial telecommunication companies today use optical fibre cable to carry plain old telephone service across their nationwide networks. Local telephone service providers use fibre to carry this same service between central office switches at more local levels and sometimes as far as the neighbourhood, small business or individual home.

Optical fibre is also used extensively for transmission of data by large corporations, banks, universities, business firms and others with their own private networks, all requiring secure and reliable systems to transfer information between buildings, to desktop terminals and around the world. Cable television companies find fibre useful for modern video services; the high bandwidth of fibre makes it the perfect choice for transmitting signals to subscribers, and the security inherent in optical fibre is a major benefit.

Increased Data Rates

Fibre optic systems can maximize overall connectivity and efficiency. Optical cable with 50μm Optimized Multimode (OM) fibre, such as OM3 and OM4, provides bandwidth capabilities that support transmissions up to 10GB/s for existing applications, as well as future applications requiring 16-100GB/s and beyond. Transmission performance, data-rate scalability, pathway and space utilization, electronics port density, power and cooling efficiencies and ease of installation and testing are factors that make optical connectivity a serious competitor to 10GBase-T and copper connectivity in the data centre.

The optical 10Gbit Ethernet standard of 2002 (802.3ae), with 10GBase-SR Physical Media Dependent (PMD) for short-range links up to 300 meters, is emerging as the dominant and best-suited 10GB connectivity solution using OM3 fibre.

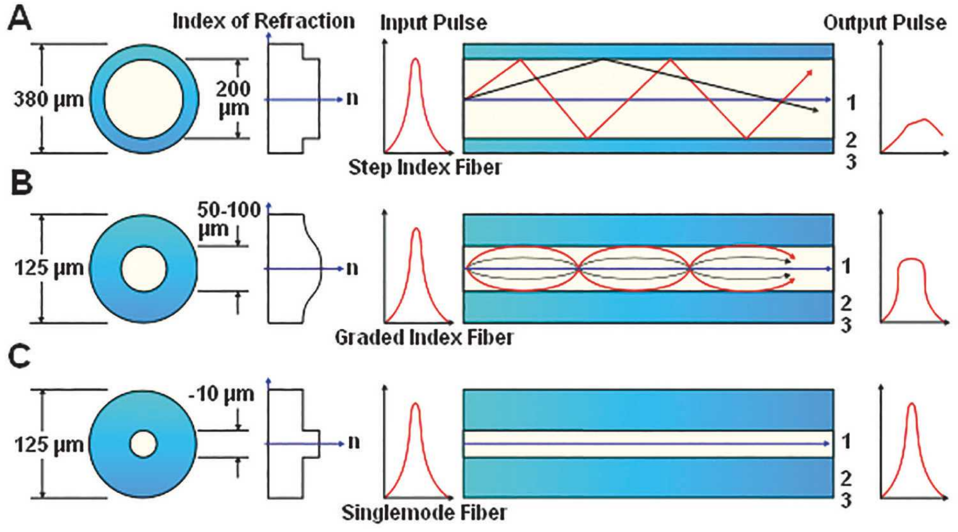


Figure 1: SDR scheme

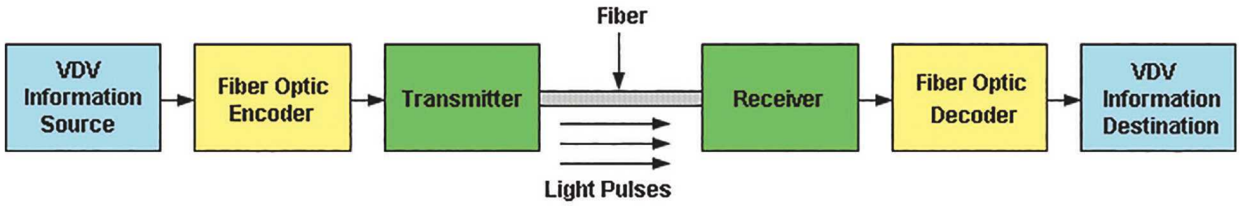


Figure 2: Primary elements of an optical fibre network

Optical Fibre Communication Benefits

The 'fibre' world began in the early 1980s in the US. At that time, systems operated at 90MB/s, a data rate at which a single optical fibre could handle approximately 1300 simultaneous voice channels. Today, systems commonly operate at 10GB/s and above, which translates to over 130,000 simultaneous voice channels.

> Anyone with a vested interest in telecommunications would be wise to learn more about the tremendous advantages of fibre optic communication

Over the past 15 years, new technologies such as Dense Wavelength Division Multiplexing (DWDM) and Erbium Doped Fibre Amplifiers (EDFA) have been used successfully to further increase data rates to over a terabit per second or > 1000GB/s over distances above 100km. This is equivalent to transmitting 13 million simultaneous phone calls through a single hair-size glass fibre.

The growth of the fibre optics industry over the past fifteen years has been explosive, and it is expected to continue to grow at a tremendous rate well into the next decade and beyond. Anyone with a vested interest in telecommunications would be wise to learn more about the tremendous advantages of fibre optic communication, some of which are:

- Immense bandwidth;
- Total electrical isolation in the transmission medium;
- Very low transmission loss, small size and light weight;
- High signal security, immunity to interference and crosstalk;
- Very low power consumption and wide scope for system expansion.

Due to the variety of advantages optical fibre communication systems offer, they have a wide range of applications in different fields.

- Public networks that include trunk, junction and local access networks, and submerged and synchronous systems among others;
- Radio and satellite fixed, mobile and military applications;
- Civil, consumer and industrial applications, including research.

There are three primary types of transmission modes using optical fibre:

1. Step Index – It has a large core, so light tends to bounce around inside the core, reflecting off the cladding. This causes some rays to take a longer or shorter path through the core, with some taking the direct path with hardly any reflections while others bounce back and forth. The process results in light arriving at the receiver at different times, and the signal with lengthened pulses. Light emitting diode (LED) sources are used and typical core diameter is 62.5 microns.
2. Graded Index – A gradual change in the core's refractive index, causing light to gradually bend back into the core path (see Figure 1B). The result is a better receive signal than with step index. LED sources are used and typical core diameter is 62.5 microns.

   Both step and graded indices refer to multimode optical fibres and dielectric waveguides, which can have many propagation modes. In Figures 1A and B, regions 1, 2 and 3 are the core, cladding and coating, respectively. The coating is a plastic that protects the glass from abrasion. The cladding glass has a refractive index, a parameter related to the dielectric constant, which is slightly lower than the refractive index of the core glass.
3. Single Mode – It has separate distinct refractive indexes for the cladding and core, see Figure 1cC. In this case there is no pulse spreading at all, due to the different propagation time of the various modes. Light passes through the core with relatively few reflections off the cladding, thus this mode is used for single-source light (one colour) operations. It requires a laser source and the core is very small, 10 microns.

The Optical Fibre Medium

A basic fibre optic system is a link connecting two electronic circuits at a distance, and there are three fundamental parts, shown in Figure 2.

- Transmitter - This unit converts electrical voice, data and video (VDV) signals to an optical signal, using a fibre optic encoder. The light source is typically a light-emitting diode or laser diode. The driving circuit for the light source changes the electrical signal into the driving current.
- Fibre Optic Cable – This is the transmission medium carrying light between transmitters and receivers.
- Receiver – This unit accepts the light or photons and using a

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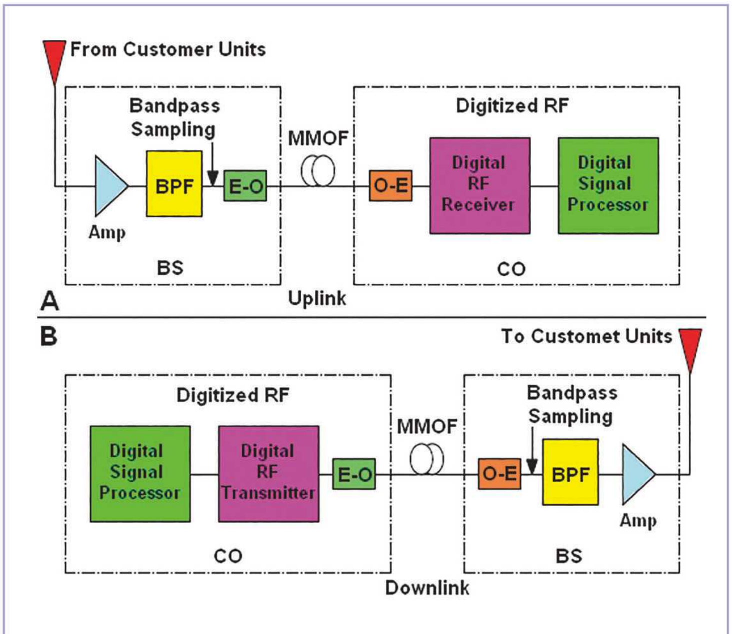

Figure 6: Digitized Radio over Fibre (DROF) uplink and downlink

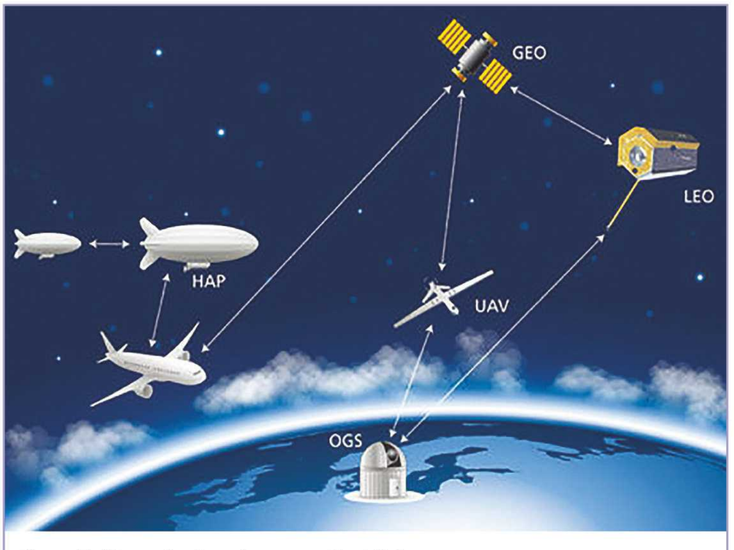

Figure 7: Atmospheric and space optical links

The PON system is a single optical fibre connected to the equipment of the Service Provider (SP), such as Optical Line Terminals (OLT). At the exchange it is split using an optical coupler and is connected to devices in subscribers' homes, known as Optical Network Units (ONU). For example, subscriber A uses 10G-EPON, but even if subscriber B is using an existing GE-PON system, it is still possible for them both to employ the same OLT. This characteristic is very important for practical purposes, because it will enable a smooth, low-cost transition to 10G-EPON, while existing systems such as GE-PON are still in use. In addition, the prototype system conforms to the global IEEE802.3av standard, with a view toward its diffusion both domestically and internationally.

Digital Radio Over Fibre Link

The Digital Radio over Fibre (DROF) system is a hybrid architecture consisting of optical fibre and wireless systems, such as Local Area Network (LAN), Wide LAN (WLAN), Worldwide Interoperability for Microwave Access (WiMAX), WiFi (Wireless Fidelity), cellular, atmospherics and space optical networks. By integrating fibre and digital wireless networks, key requirements for future generation of fixed and mobile broadband, such as large operating bandwidth and high flexibility, can easily be met.

A Fibre Wireless (FiWi) network results from the integration of optical fibre and wireless broadband infrastructures. The transmission of analogue signals requires high linearity and high dynamic range of the optical link.

A typical ROF architecture is shown in Figure 5.

The FiWi network refers to the transmission of radio frequency (RF) signals from a trunk network via central office (CO) and route nodes (RN) to the base stations (BS) over optical fibre and wireless communication to the user. The advantage of this system is that it combines the capacity of optical networks with the flexibility and mobility of wireless networks to provide broadband multimedia access.

> "Looking toward future needs, Mitsubishi has developed a prototype 10G-EPON system that increases the transmission speed of GE-PON tenfold to 10GB/s

Figure 6A shows a DROF uplink, which uses a technique based on bandpass sampling. The uplink DROF transmission path from the customer units enters via an antenna to a CO passing amplifier (amp), bandpass filter (BPF) and Electrical-to-Optical (E-O) unit. Then, the signal passes via Multimode Optical Fibre (MMOF) using a digital-to-analogue converter (DAC) in conjunction with BPF and entering the BS receiver via O-E. At the BS end, data is sampled and quantized by an analogue-to-digital converter (ADC) with a sampling rate determined by the bandpass sampling theory.

In the MMOF system data is detected by the Intensity Modulation/Direct Detection (IMDD) in CO and the uplink wireless signal is reconstructed and recovered. Figure 6B shows the opposite path of DROF downlink, where data from digital signal processor, transmitter and E-O passes via MMOF into the BS. Then data goes via O-E, BPF, amp and antenna to the customer unit.

Free Space Optical (FSO) links over long distances have been made possible by the development of different key technologies in the near-infrared domain: high-power lasers, high-speed components, high-sensitivity detectors and cost efficient optics, see Figure 7. The FSO links connect Geostationary Earth Orbits (GEO) and Low Earth Orbits (LEO) with Optical Ground Stations (OGS) directly or via High Altitude Platforms (HAP) and Unmanned Aerial Vehicles (UAV). ●