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HIGH SPEED MINIATURE CONNECTOR SOLUTIONS



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INTRODUCTION

Abstract: For commercial applications, high speed data cable connectors such as Ethernet, USB® , HDMI® and others, come in a number of different shapes and sizes, typically specified as a part of the protocol standard they support. For many industrial and harsh environment applications, there is a need for ruggedized versions of these connectors to protect against malfunction caused by dirt or fluid contamination, as well as damage that might be caused by excessive external force. The traditional solution adopted by many manufacturers has been to create universal solutions that incorporate current form factors – with mixed results regarding size, performance and usability.

The consequence is that many such loosely designed connectors have a diameter of 30 mm or more. High speed connector manufacturer ODU has taken a different approach, replacing standard connectors by a ruggedized connector family of their own design, which results in a diameter as little as 11.9 mm for protocols such as USB® 3 and 10G Ethernet.* This paper examines the challenges faced by manufacturers in designing ruggedized connectors for high speed data transfer – not only with regard to size, but also factors such as ease-of-use, performance, durability and transmission reliability.

* These ODU specific connectors can transmit common data transmission protocols such as HDMI® 1.3, USB® 3.2 Gen 1x1, FireWire®, and eSATA®, but they are not HDMI®, USB®, FireWire®- or eSATA®-standard connectors.

BATTLEFIELD TESTED

The current evolution of the “Future Soldier” is striving to advance the technology of devices designed for the dismounted soldier. It foresees lightweight, miniaturized and customized devices that enhance the specific role of each category of Warfighter. The applications extend to all areas of Military Humionics used by soldiers, including communication



Fig 1. Glove-mounted LED flashlight

systems, computers and C2 systems, navigation systems, night vision devices, electronic weapon sights, laser rangefinders and pointers, battlefield recovery and IFF devices, gunfire detection and location systems, batteries,

power distribution and generation systems, physiologic status monitors, and human performance enhancement systems (e.g., exoskeletons). Gloves with integrated LED or fiber-optic flashlights, for example, reduce the burden of carrying – and perhaps losing – a traditional flashlight (Figure 1). Similarly, wrist mounted wireless equipment minimizes the time to communicate with field headquarters in critical situations (¹).

In a recent article in Connector + Cable Assembly Supplier (²), examples were presented of wearable devices designed to save lives, not take them. An Air Force program named BATMAN (Battlefield Air Targeting Man-Aided kNowledge) has produced a system that allows pararescue jumpers (PJ's) to effectively manage triage situations in which life-threatening casualties outnumber the available medical staff. The system is known as BATDOK (Battlefield Airmen Trauma Distributed Observation Kit). The system includes vital sign sensors that can be placed on each wounded patient, transmitting data to wrist-mounted or chest-mounted devices such as smart phones or tablets worn by the PJ's. In the event that an unattended patient goes into a critical state, a PJ is alerted by an alarm emitted by his or her wearable device, enabling immediate attention to be directed to that patient.

THE IMPORTANCE OF MINIATURIZATION

According to the team, the overall objective of the BATMAN project is to help lighten the load for service members, both in the physical sense and in the cognitive sense. Figure 2 illustrates just how important it is for the Warfighter's equipment to be as compact and light as possible. The wrist-mounted tablet and chest mounted laptop devices are about optimum in size; any smaller and their screen contents might be unreadable. These devices, however, may also require interconnect cabling both for power and data transfer. Two such cables are visible in Figure 2.

Cable thicknesses are dictated by both electrical and physical constraints. The number of signal lines, plus signal conductivity and shielding requirements are among the electrical constraints, while durability is the primary physical factor. If the cables were too thin, they might be too delicate for use in the harsh environment in which the Warfighter operates. Too thick, and they would become less flexible and too heavy.

The final class of component that plays an important role in the Warfighter's wearable equipment is the cable connector, also visible in Figure 2. Several factors must be considered with regard to the design of connectors:

- They must be as small in diameter as possible, to minimize the possibility of getting snagged by objects – for example, tree branches or brush – in the path of the Warfighter.
- They must support a comprehensive range of protocols.
- They must have no significant impact on the data transfer



Fig 2. Pararescue Jumper with wearable devices

rate for the protocol they support, offering negligible impedance in the data path even under extreme environmental conditions.

- They must be durable, with the ability to be connected and disconnected thousands of times with no impact on their performance (i.e. capable of a high number of mating cycles).

- They must be capable of 'break-away' (i.e. de-mating under excessive force) in the event that their cable does get snagged, so that devices to which they are attached do not get damaged.
- They must be dirt proof and water resistant, as well as capable of operating in a wide range of temperatures.

SIZE CONSIDERATIONS

Several manufacturers offer connectors designed for use in military and industrial applications. Most take the approach shown in *Figure 3*, in which a standard connector (USB®, Ethernet, HDMI®, FireWire®, etc.¹) is simply enclosed in a ruggedized shell. The problems with this approach are that the shells are of varying diameters and that they are large – 25-30 mm or more. While this may be acceptable for many industrial applications, their size and weight disqualifies them from use in Future Soldier equipment.

However, at least one manufacturer, ODU, has taken a different approach (*Figure 4*). Instead of accommodating standard connectors, they have designed a physical interface that can meet all the electrical and functional specifications of diverse high-speed protocols, but in a more compact format. Their ODU AMC® series of in-line connectors uses standard sized shells which for some protocols can be as little as 11.9mm in diameter, and which offers a variety of internal pin/socket configuration options to accommodate the diverse protocols mentioned above:

- Ethernet (1Gbps – 10Gbps)
- USB® – up to 3.2 Gen 1x1¹
- FireWire® S400¹
- HDMI® 1.3¹



Fig 3. Typical ruggedized USB® connector*



Fig 4. ODU AMC® Series connectors



Fig 5. USB® and Gigabit-Ethernet combined*

¹ concerning data transmission protocols please note page 2

DATA TRANSFER RATES

The transfer rates for the various high-speed protocols are shown in *Figure 6*. The design objective for connector manufacturers is to ensure that their products not only achieve these throughput rates, but are capable of doing so under challenging conditions for prolonged periods of time. In an effort to offer comparable miniaturization to ODU's AMC product line, some manufacturers have recently used their existing miniature connectors to interconnect protocol-specific cables. This can cause a variety of problems when "piggy-backing" on engineering from specifications or schemes not designed to meet the current requirements from the ground up. For example, several miniature connectors

are available that contain 7 pins. A USB®* cable only requires 4 pins; so if a 7 pin connector is used in a USB®* cable, 3 pins remain unused. In practice, this works satisfactorily at lower frequencies, but at higher data rates throughput falls off significantly. To achieve full throughput when operating in the multi-gigabit per second range requires specialized connector design specific to each transmission protocol. With that in mind, let's now review the most important electrical, mechanical and environmental factors that manufacturers must consider when developing a high-speed connector family intended for rugged industrial or military applications.



Fig 6. Protocols and Transfer Rates

TYPICAL TRANSFER RATES

Gbit-Ethernet	[1 Gbit/s – 10 Gbit/s]
HDMI® 1.3 ¹	[8.16 Gbit/s]
USB® 3.2 Gen 1x1 ¹	[5 Gbit/s]
FireWire® S3200 ¹	[3.2 Gbit/s]
eSATA® 2.0 / 1.5 ¹	[3.0 Gbit/s / 1.5 Gbit/s]
HD-Video	[2.4 Gbit/s]
FireWire® S800 ¹	[800 Mbit/s]
USB® 2.0 ¹	[480 Mbit/s]
Firewire S400	[400 Mbit/s]
Ethernet	[10 Mbit/s – 100 Mbit/s]
VDSL	[52 Mbit/s]
Profibus ^{®1}	[12 Mbit/s]
USB® 1.1 ¹	[12 Mbit/s]
RS 485	[10 Mbit/s]
FlexRay ^{®1}	[10 Mbit/s]
CAN-Bus	[1 Mbit/s]
RS232	[500 kbit/s]

ELECTRICAL CONSIDERATIONS

There are several electrical characteristics of a connector that govern its operational capabilities; among them:

- Current rating – how many amps of current can the connector pins carry without overheating.
- Insertion loss – the power loss from one side of the connector to the other; the smaller, the better.
- Return loss – a consequence of any mismatch between the impedance of the system and the impedance of

the connector. Such a mismatch results in some signal reflection back to the source, which in high speed data transmission may cause data errors.

- Susceptibility to electromagnetic interference (EMI) – the better the quality of shielding surrounding the connector pins and cable wires, the lower the potentially disruptive effects of EMI.

¹ concerning data transmission protocols please note page 2

MECHANICAL CONSIDERATIONS

The relevant mechanical characteristics of a connector that determine its suitability for rugged applications are durability and reaction to physical stress. In this case, durability refers to the number of times the two halves of the connector can be mated and unmated without diminishing its performance – i.e. the maximum number of mating cycles.

In battlefield conditions, the likelihood is very high that cables interconnecting wearable devices (*referring back to Figure 2*) will receive substantial physical punishment – such as

ground contact or being snagged by tree branches. If the connector halves fail to separate under physical stress, the result could be that the devices themselves would get ripped out of the Warfighter's uniform, possibly resulting in irreparable damage. The ability of a connector to separate cleanly under duress is referred to as "break-away" – an essential option for dismounted applications.

ENVIRONMENTAL CONSIDERATIONS

Numerous factors define harsh environments. These include temperature extremes, humidity extremes, dust and dirt contamination, exposure to chemicals and gases, and immersion in water.

The degree of protection against intrusion by particulate matter and fluids are defined by the IEC standard 60529, which provides a means of rating products known as the Ingress Protection (IP) marking. For example, IP67 means that the product is completely dust-tight and capable of operating when submersed in water at a depth of up to 1 meter. IP68 applies for depths greater than 1 meter, often interpreted by manufacturers as meaning 20 meters or more.

VALUE ADDED SUPPORT

Finally, no matter how good the connectors are in the middle and at the ends of a cable assembly, their advantages can be completely negated by a poor quality cable or by poor manufacturing. To circumvent such potential shortcomings, some connector manufacturers, ODU for example, offer custom cable assembly services to their customers.

MILITARY APPLICATIONS

This paper has focused on the importance of small size and weight for cable connectors used in Future Soldier applications. The same advantages of connectors such as the ODU AMC® series also apply to most other military applications, since much of the interconnected equipment resides onboard vehicles operating in hostile environments. Whether those vehicles are tanks, jeeps, aircraft, rockets, boats or submarines, space and weight are always at a premium. Here are just a couple of examples of vehicle-mounted equipment in military use.

Figure 7 shows a thermal imager used for observation, reconnaissance and target acquisition during both day time and night time operations. Image data is transferred



Fig 7. Thermal Imager with 10Gbps cable

to display screens or to transmission equipment via a high-speed cable at rates up to 10Gbps. The cable and its connector must of course be highly reliable and offer excellent signal shielding.

A second example is illustrated in Figure 8, a multi-com control unit used to manually switch up to three audio sources to a headset. In this case the IP68 rating of the unit and its cable connectors allow it to operate under water to a depth of 20 meters. The ODU connectors shown here are mechanically keyed to prevent incorrect cable connections and color-coded to make correct selection easier.



Fig 8. Multi-Com Control Unit

INDUSTRIAL APPLICATIONS

As frequently happens, leading edge products developed for military applications also fill the needs of equipment designed for harsh industrial environments. That has certainly been the case for the miniature connectors discussed here. Figure 9 illustrates one such example – a high-speed camera utilizing several panel-mounted connectors from the ODU AMC® product line. With an extraordinarily high frame capture rate, a camera like this continuously generates gigabytes of data that must be rapidly transferred to external processing or storage devices. Equipment and cable reliability is of paramount importance, since any single point of failure could

result in the loss of critical video data.

Other industrial applications that place similar demands on equipment and high-speed cables include vehicle production lines, laboratory testing and measurement facilities, critical care medical systems and, of course, all types of transportation systems.



Fig 9. High-Speed Camera with multiple interfaces



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CONCLUSION

A recent article in Connector + Cable Assembly Supplier (3) notes that “2015 saw great leaps forward in technology, many of which were enabled by developments in connector design and manufacture.” Driving these advances were the needs for ever-increasing data transfer rates and miniaturization, to keep up with the interconnection demands of correspondingly faster and smaller equipment. This paper

has illustrated the way in which connector manufacturers have responded to these demands through innovative techniques best exemplified by ODU’s protocol-specific ODU AMC® series. How much smaller and faster will connectors need to get as these trends continue? One certainty is that the next 3 - 5 years will offer connector designers some exciting new challenges!

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