

# Power Over Ethernet in FTI, Suitability & Challenges

Pat Quinn, Product Line Manager, Data Acquisition  
Curtiss-Wright, Dublin, Ireland  
pquinn@curtisswright.com

## Power Over Ethernet in FTI, Suitability & Challenges:

This paper discusses why Power Over Ethernet (POE) is ideally suited to Flight Test Instrumentation (FTI) and details some of the challenges of designing in POE into FTI hardware and discusses some of the considerations that must be taken when architecting a Flight Test Instrumentation system with POE components.

**Key words:** Data Acquisition, Power Over Ethernet (PoE), Distributed Networks, Reduced Wiring, SWaP Optimized

## What is Power Over Ethernet (PoE)?

Power Over Ethernet (PoE) <sup>[1]</sup> is a method of distributing power and data to networked devices over the same twisted pair Ethernet cabling. PoE has been standardized by IEEE since 2003.

## Power Over Ethernet (PoE) Terminology

In order to understand Power Over Ethernet (PoE) there are some common terms used to describe PoE devices that must be explained.

### 1) Powered Devices (PD) <sup>[2]</sup>

Powered Devices (PD) are defined as any networked device that is powered by PoE.

### 2) Power Sourcing Equipment (PSE) <sup>[3]</sup>

Power Sourcing Equipment (PSE) are devices that send power and data over the Ethernet cabling to the Power Devices (PD)

### 3) PoE Switches

Network Switches that support Power over Ethernet (PoE) directly from the switch itself.

### 4) Power Injectors

Power Sources that add power to the Ethernet cabling from non PoE capable switches to the Powered Devices (PD)

## Types of Power Over Ethernet (PoE)

There are 4 main types of PoE, with the IEEE standards defining a link negotiation protocol on power up in order to determine the level of power required to be delivered from the PSE to the PD. The differences between them relate to the max power that can be delivered, and the voltage levels at the PSE.

## Passive PoE <sup>[4]</sup>

No link negotiation protocol on power up

### PoE - IEEE 802.3af-2003 <sup>[5]</sup>

POE Link negotiation protocol, 44-57V at PSE, Max of 15.4W at PD – Type 1 Devices

### PoE+ - IEEE 802.3at-2009 <sup>[6]</sup>

POE Link negotiation protocol, 50-57V at PSE, Max of 25.5W at PD – Type 2 Devices

### PoE++ / 4PPoE - IEEE 802.3bt-2018 <sup>[7]</sup>





POE Link negotiation protocol, 50-57V at PSE, Max of 51W at PD – Type 3 Devices. Max of 71.3W at PD – Type 4 Devices





## Power Over Ethernet (PoE) Wiring Options





The PoE standards define two wiring schemes for both PSE and PD devices.

For 10/100BT Ethernet speeds, Mode A, 4 wire wiring, puts the DC voltages over the same physical wires as the data, with DC+ on the RX pair and DC- on the TX pair.

Tab. 1: 10/100 BT Mode A Wiring <sup>[8]</sup>

Wire	10/100 MODE A (4 wire)
 White/green stripe	Rx+ / DC +
 Green solid	Rx- / DC +
 White/orange stripe	Tx+ / DC -
 Blue solid	Unused

 White/blue stripe	Unused
 Orange solid	Tx- / DC-
 White/brown stripe	Unused
 Brown solid	Unused









 White/blue stripe	TxRx C-
 Orange solid	TxRx B- DC-
 White/brown stripe	TxRx D+
 Brown solid	TxRx D-









For 10/100BT Ethernet speeds, Mode B, 8 wire wiring, puts the DC voltages on the other 4 wires in the standard Ethernet cables.

For 1000BT speeds, Mode B puts the DC voltages on the C and D bidirectional pairs.

Tab. 2: 10/100 BT Mode B Wiring [8]

Tab. 3: 1000 BT Mode B Wiring [8]

Wire	10/100 MODE B (8 wire)
 White/green stripe	Rx+
 Green solid	Rx-
 White/orange stripe	Tx+
 Blue solid	DC+
 White/blue stripe	DC+
 Orange solid	Tx-
 White/brown stripe	DC-
 Brown solid	DC-





Wire	1000BT MODE B (8 wire)
 White/green stripe	TxRx A+
 Green solid	TxRx A-
 White/orange stripe	TxRx B+
 Blue solid	TxRx C+ / DC+
 White/blue stripe	TxRx C- / DC+
 Orange solid	TxRx B-
 White/brown stripe	TxRx D+ / DC-
 Brown solid	TxRx D- / DC-

For 1000BT speeds, Mode A puts the DC voltages on the A and B bidirectional pairs.

### Why is Power Over Ethernet (PoE) a great fit for FTI?

Tab. 4: 1000 BT Mode A Wiring [8]

The arguments for PoE in FTI are simple, reduced wiring weight and ease of installation. In traditional FTI systems data and power are delivered over separate cables to each device in the FTI system architecture. By leveraging PoE the number of cables required to get both Power and Data to and from the devices is potentially halved.

Wire	1000BT MODE A (8 wire)
 White/green stripe	TxRx A+ / DC+
 Green solid	TxRx A- / DC+
 White/orange stripe	TxRx B+ / DC-
 Blue solid	TxRx C+

Every Flight test engineer is aware of the paperwork and approvals needed for FTI installation drawings and document management, reducing the wiring leads to less overhead required for their installations.

Today, typical FTI installations are distributed throughout the airframe, requiring power and data cables to be routed all over the airframe,

through bulkheads and around critical systems. Reducing the number of cables here makes perfect sense.

However, given the nature of the FTI hardware and the power required by them, not all of them are suitable for PoE implementation. Take for example a Data Acquisition unit running multiple strain channels, this could easily exceed the power levels available from the PoE standards.

As stated before, FTI architectures are, these days, distributed throughout the airframe, getting the Data Acquisition closer to the sensors is in-fact a much greater weight saver than just combining the power and ethernet cables to the DAU. Reducing the length of the cable harness from the sensor back to the data acquisition unit by making the unit miniaturized and SWaP optimized and PoE capable balances all the above. The challenges and considerations of such a system architecture are discussed in the next sections.

#### **The challenges of designing miniature, SWaP optimized PoE FTI hardware.**

The target for the design of PoE capable FTI hardware can be summarized as:

- 1) Keep it small.

For mounting in restricted spaces, closer to the sensors, the smaller you can make the design the better.

- 2) Use standard connectors if possible.

Flight test hardware uses many different connector types already, typically either flying leads or crimp able field rewirable connectors.

- 3) Simple to manufacture.

It should not be so complex to build that the costs of manufacture make it unfeasible.

- 4) Flexible design

There are a multitude of analog sensors used in flight test, and many different avionic busses that are captured in flight test campaigns. In the hardest to reach places on the airframe these are typically analog measurements for Strain / voltage / temperature / vibration. As many of these should be supported as possible.

- 5) Daisy chainable

Running PoE cables to each device would be one approach, but better to make the devices possible to daisy chain so a single cable can deliver the power and data to multiple devices in the same location on the airframe.

- 6) Compatible with existing products on the same network

Bearing in mind that these devices are most likely to be part of a larger FTI system they must be supported by the same configuration tools and generate the same data formats as the rest of the system.

#### 7) Getting Power and Data to the devices

While there are many PoE switches and power injectors available, very few of them are suitable for FTI applications. Networked FTI systems use PTP IEEE 1588 to synchronize and there are very few PoE switches available that support PoE. Therefore, a method of delivering the power and data to the system as part of a flight qualified FTI system is a concern.

To expand on one of these topics in more detail, Daisy chaining, let us consider what this entails.

From a PoE point of view a daisy chainable PoE device must act as both a Powered device (PD) and as Power Source Equipment (PSE). It must be able to take power in from the source and deliver power down to all the devices in the chain. It must also be able to aggregate the data from all downstream devices back to the main network. A consideration here would be what happens if the chain breaks, due to wiring damage or other causes of failure. Potentially, all the data down stream from the fault would be lost.

If the device chain supported loop back wiring, where the devices could be powered from both the input and output ports and could be designed to automatically switch the traffic flow direction in the case of a single device failure, loss of data could be minimized.

#### **Considerations for Architecting PoE as part of an FTI system**

Power Over Ethernet (PoE) brings a very different set of challenges and considerations that should be taken into account when architecting your FTI system.

##### **Cable Power Losses**

PoE uses high voltages out of the PSE's to account for loss over the cable itself. There must be enough voltage left at the end of the cable to power the device.

CAT5E has a cable resistance of 0.188Ω/meter<sup>[9]</sup>. From a 48V PSE source to a chain of 8 PoE devices, each drawing 4W over a 100 Meter total chain length would result in a voltage drop of about 25% by the end of the chain.

For CAT6, with a cable resistance of 0.14 Ω/meter<sup>[10]</sup> the same setup would have about a 19% drop.

## Chain Throughput

The aggregated data from the chain of PoE devices is also something to consider. How you construct and schedule your traffic is important to be aware of, so as not to over run the capacity of your link. For example, an 8 channel device sampling at 50Ksps could produce up to 60Mbps if each channel was sampled in its own high rate / short packet. The same sample rates can be achieved using slower larger / packets reducing the device throughput to about 6Mbps.

## Power

The number of devices drives the power requirement of the full chain. Each device must be able to provide enough power to power the rest of the devices downstream from it, and the PoE Power budget for the PSE must be able to provide enough power for the full chain.

## Summary

This paper has shown how Power over Ethernet (PoE) is ideally suited to Flight Test applications, considering the advantages of reduced wiring weight, especially for distributed networked FTI systems when designed into SWaP optimized, daisy chainable miniature devices.

## References

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