PULSE'S "HI-POE" MAGNETICS
--- DESIGN CONSIDERATION BEYOND IEEE802.3BT ---

Introduction

The demand for applications that require more power than is currently allowed under the Power over Ethernet Standard IEEE802.3bt is growing. Even at its highest classification, Type 4, Class 8, the standard is limited to only 72W for the user site. This means that engineers and designers, when looking at supporting power levels above 80W, where the DC load currents will be greater than 800mA, are having to work beyond the limits of the available Ethernet isolation transformer modules approved for IEEE802.3bt use.

If these technologies and applications are to flourish, then the solution is a new breed of high power PoE magnetics designed for end equipment power requirements beyond 100W and data exceeding 1Gigbit. These new products may also need to support multi-Gig and 10Gigabit data rates, which are growing in demand as the short-haul links for mobile data traffic in the small cell architecture of 4G and 5G networks.

Our new modules also look toward future demands, where PoE levels could be providing closer to 200W over CAT6/CAT7 cabling. This means that the isolation transformers, which provide the safety barrier between the analogue and digital circuits, need to able to support the gigabit Ethernet data rates and the higher currents. These currents manifest as DC bias across the transformer windings due to imbalance in the connection path and can be up to 50mA.

Higher Power PoE - The Effects of increased current

As PoE power requirements increase, then so will the current, as PoE works on fixed voltages in the range 42V – 57Vdc. For safety reasons the supply voltage must not exceed the 70Vpk DC as is required under the safety extra low voltage (SELV) standards. Therefore, when there is a fixed maximum voltage limit, the only variable left to increase power rating is the load current:

Power = Volatage x Current

This is important and sometimes gets overlooked as the connector and cable could be the limiting factor due to heating of coiled wire on a spool or the contact to contact rating within the network connectors. Often RJ45 connectors utilise internal PCBs to provide the necessary echo cancellation to achieve CAT5 and CAT5e performance criteria, and these small, traced boards can easily get damaged by the high, 1.0A to 1.5A, currents. By mixing connector style and cabling a solution can be reached which benefits the system. However, dropping down to simplified CAT3 RJ45 designs and cable will degrade the Ethernet signal. Therefore, it is better to use higher rated CAT6 RJ45 connectors, especially when

these connectors use FCC lead frame manipulation and alignment to meet the required CAT6 performance characteristics which remove the need for an internal PCB. The lack of copper tracing, in this case, can allow for the PoE current carrying capability to reach up to 1.5 per contact pin. For cable style and length CAT6 is recommended and at worst CAT5e can be used and any thinner wire used, perhaps in an attempt to save costs, could result in loss of signal, power or in the worst case catch fire due over-heating of old or unknown cabling.

TIA cabling standard specifies that CAT5e cabling should have eight wires, twisted in pairs with a minimum diameter of 0.485mm. For that reason it is often made from AWG24 (0.51mm) giving a current carrying capability of ~2Amps if laid out straight at 60°C.

However, if bunched or in a coil it will present a higher resistance to the current and may catch fire.

The other area that needs special attention is the Isolation signal transformer. This needs to support the digital Ethernet data and the load current on the cable side in addition to providing a blocking path for the DC power (current and voltage) and preventing it from getting across the coils and onto the digital plane. The design must also always comply to the respective IEEE802.3 ethernet standard and the required parameters and waveforms, transferring the differential signals across the windings without a drop in integrity or loss of data. All this must happen while operating within the harsh conditions of the industrial temperature range -40 to +85°C at the same time as supporting the high current DC loading without overload or going into saturation.

Pulse Electronics' "Hi-PoE" magnets are designed to satisfy all of the above, and before we start discussing the benefits of the Pulse's newest magnetics offering, let us first review the issues and limitations of the existing designs.

To provide the increasing power levels over ethernet cabling, the carrying current (per pair) has to increase from 300mA to 1000mA or higher as the voltage is limited by SELV and ANSI/ETSI standards to 70Vpk DC. This means the resulting designs needs to support:

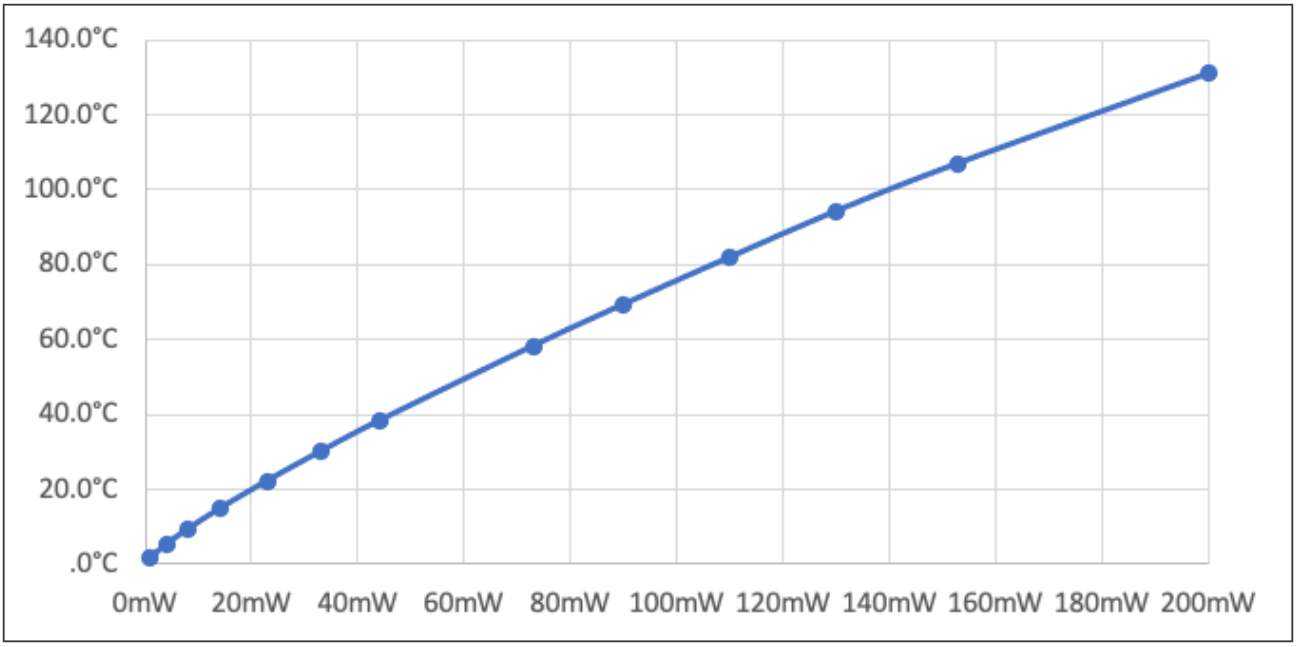
a.) High Power - this will be dissipated within transformer component windings as heat and appear as temperature rise above ambient around or within the component (as in the case of PulseJack™ ICM). integrated Connector module.

b.) High DC bias - this will appear across each transformer windings on the cable side as the drive current is injected on to the central tap of each transformer pairing. It then travels through the windings and out along the cable pair – any imbalance in the DC path lengths will show up as a differential resistance/impedance and manifest as a DC bias across the split windings – too large a bias current and these small coils will be driven into magnetic saturation. A point where the ferrite core ceases to operate as a transformer and becomes resistive, leading to loss of power output and increased conversion to heat. Therefore, designs need to be wound as symmetrically as possible to keep these current imbalances low.

Power Limitations of Existing Designs – Temperature Rise

Let us start by looking at **Temperature Rise** caused by power dissipation and the **effect of temperature** on a typical PoE signal transformer coil design. Some experimental data is given to help with the calculations:

Dissipated Power vs Temperature on the Core



Using the curve, and knowing the winding resistance of the coil., we can get a rough estimate of the power dissipated within the device and its temperature rise.

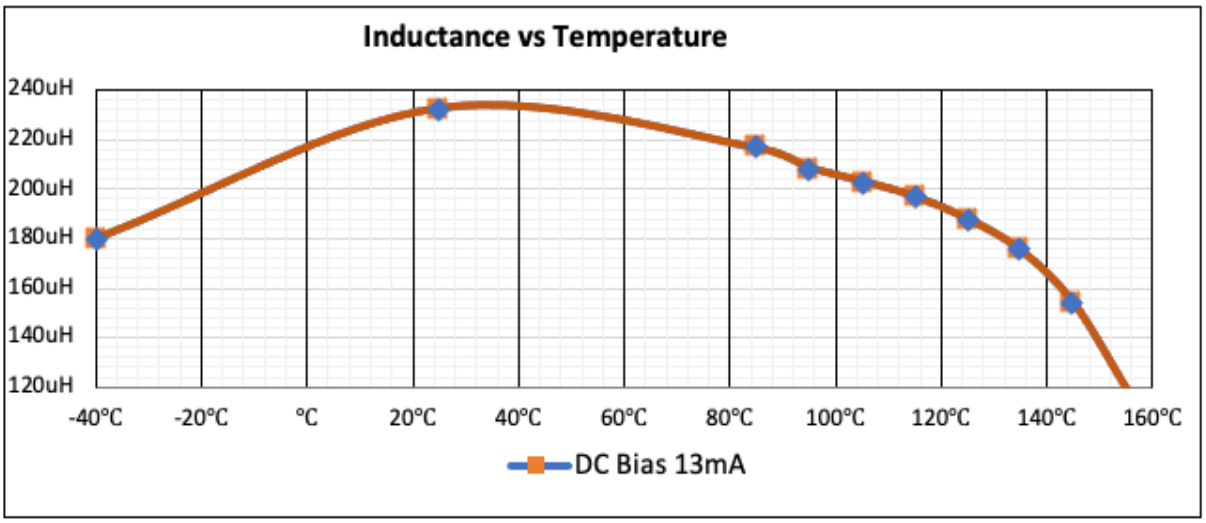
A typical DCR value of transformer half winding is around 300mΩ, whe the carrying curent reaches to 1000mA per pair, the power dissipation on the coil will be I^2.R = 0.15 Watt (150mW),this is a fairly big number considering all the power dissipation (Watt) is converted in to head (Joule).

Therefore, under the assumption above for 1Amp load, if this product is used on a commercial application with an environment temperature 0°C - 70°C, under worst case conditions at RT the transformer might reach as high as +135°C . Calculated by adding RT (+25°C) to the temperature rise taken of the graph at 150mW (+ 105°C_{rise}). However, this is +75°C (25°C+45°C_{rise}) for 600mA load, as this equates to 54mw per winding - but even this this may continue to cause the ambient surrounding temperature to increase unless there is some cooling employed.

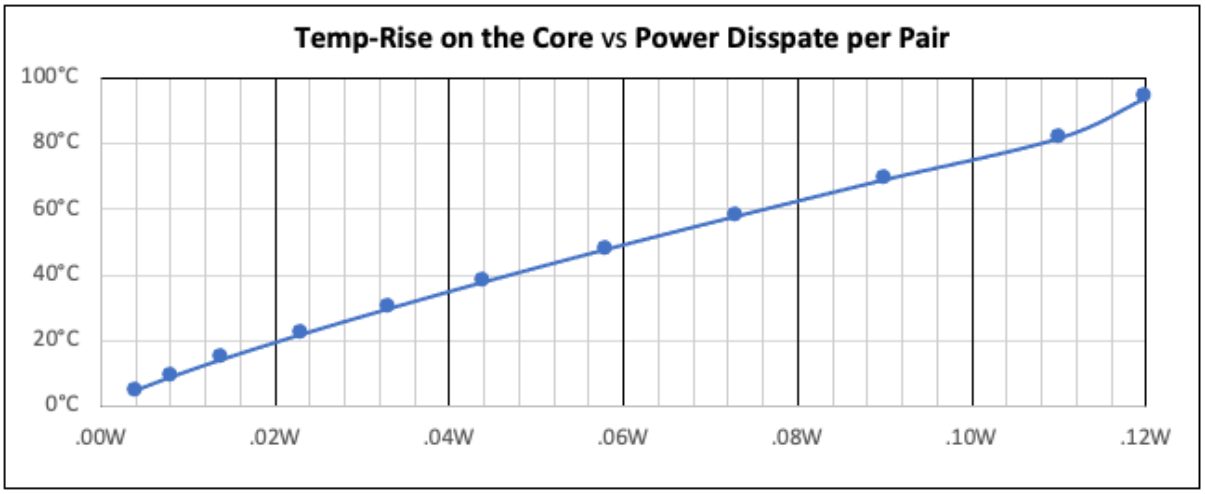
Therefore, designers must try to keep heat rise to a minimum and reduce the I2R loses to an acceptable level otherwise they need to deploy cooling solutions (fans or Heatsinks) for both their PSE and PD devices. But by planning and choosing the right PoE component in the early design stages, this can be mitigated.

The rise in temperature, above the environmental ambient, is also a huge concern for

conditioning the ethernet data signal. The curve below shows the effect of external temperature on the coil inductance – this is also attributed as a measure of the core and coils ability to operate as a pulse transformer and meet the requirements of IEEE802.3x standards for chosen data rate and the PoE+ (IEEE802.3bt) limits.



From this curve and the requirements of IEEE802.3bt - minimum inductance of 120uH without high DC Bias can be achieved up to 140oC. However, DC bias can appear across the winding - caused by resistive/impedance imbalance in the PoE Path. This can be due to differences in the winding, PCB tracking, Connector and additional connections in the link and Cabling lengths – everything really needs to be considered at the out-set of the design.



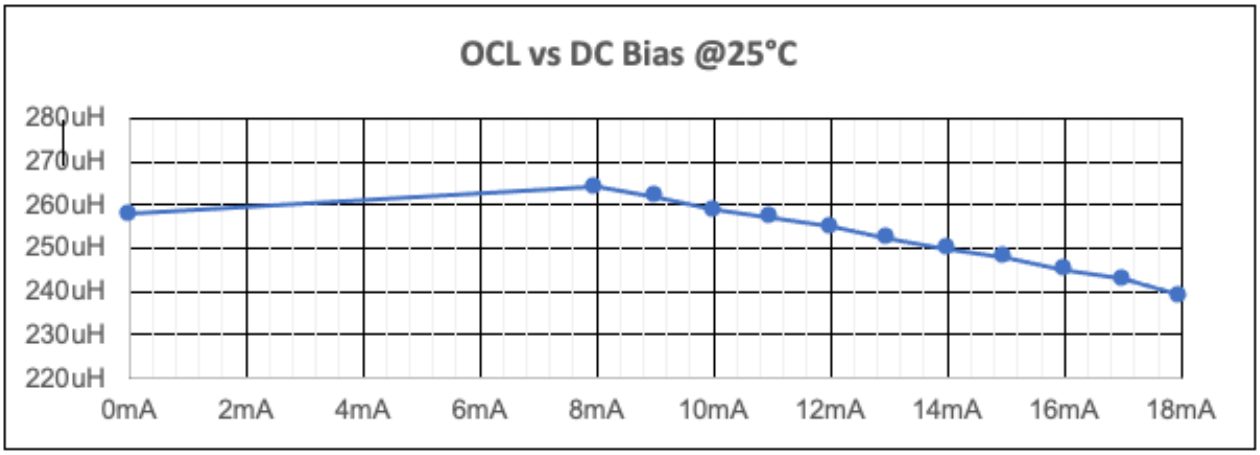
Power Limitations of Existing Designs – DC Bias

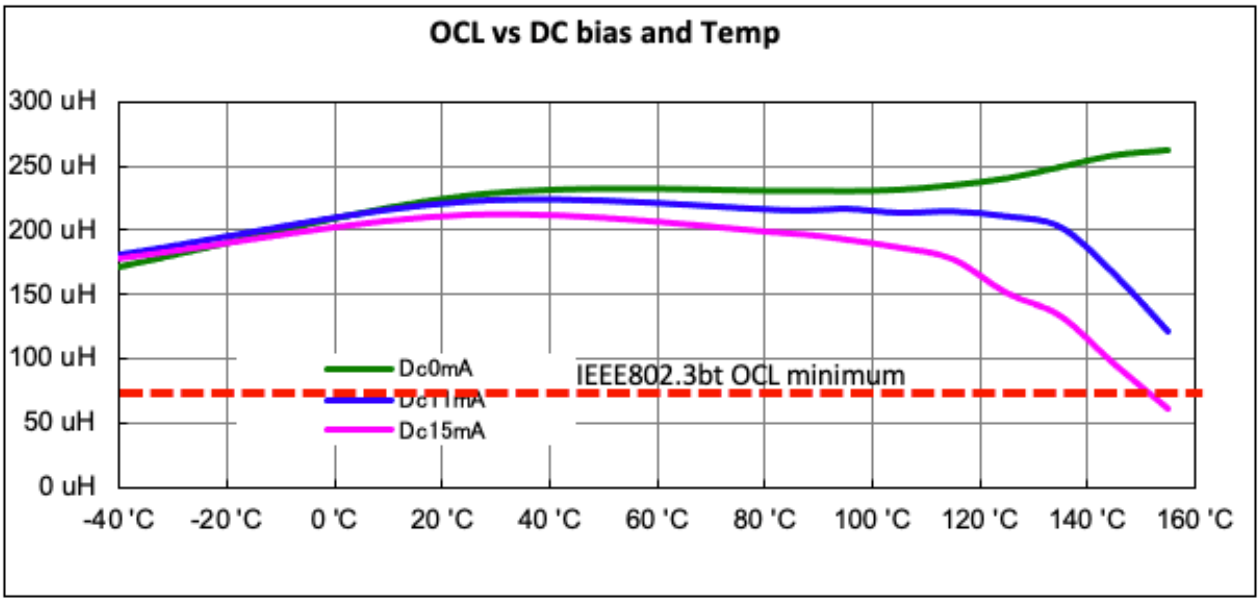
The other key factor is the DC Bias across the windings and to support this in Pulse's "Hi-PoE" Signal magnetic design. We use the allowances within the industry IEEE802.3 standards. This allocates a resistance variance of +/-3% between conductor path lengths or along an ethernet cable pairing supporting PoE. That makes it easy to calculate the DC bias applied across the transformer windings using:

$$I_{DC\ Bias} = I_{Carrying\ Current\ per\ pair} * 1.5\%$$

Too much DC bias pushes the transformer core towards saturation, which can cause Ethernet data transmission error at low frequency range and Droop failure in IEEE system tests. As well as the reported thermal issues connected to power dissipation.

The following graphs show the effect of DC bias on a Pulse "Hi-PoE" transformers inductance (OCL) under 100Khz, 100mV test conditions, and the droop associated with it at the higher operating temperatures which are often forgotten as it equates to Temperature rise above ambient temperature





New Designs for High Power PoE

We have now seen the damaging effect of load current and temperature on the performance of standard transformers, and we use this to steer our "Hi-PoE+" transformer designs to prevent core saturation and signal waveform failure.

A typical design specification for a "Hi-PoE" product from Pulse is given below with a goal of only reaching +30°C temperature rise by selecting the correct combination of wire and core sizes.

- **Pulse 120 Watts "Hi-PoE" parts electrical specifications:**

Parameter	Specification
Operating Temp	-40°C ~ +85°C
Temperature Rise	30°C Max
OCL*	140uH Min.@100KHz,0.1V,17.5mA DC Bias at -40°C ~ +115°C
PoE Voltage	48Vdc - 57Vdc
Capability of PoE Carrying Current	1150mA per Pair continues
PoE Power	120W @ 52Vdc

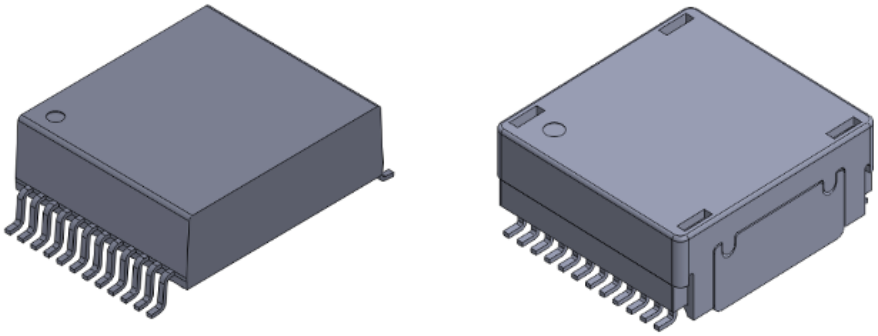
*Note that under were only supporting 1Gigabit data rates and above under IEEE802.3bt requirements.

The discrete products require all 4 channels on the cabling side to be linked to the PoE supply line via their central taps and the PCB traces need to be capable of handling the load currents along with the chosen style of connector.

The **"Hi-PoE"** product have increased height to accommodate the large cores needed to withstand the current and use two open packages, Gull-wing and Beetle (inverted header and cap). The later design gives maximum usable space for a given footprint when compared to the gull-wing option and is preferred in the highest power designs for 1~10G at 120~140W and can also support the high-definition, uncompressed video/audio signals defined by the HDBase-T Alliance and associated standards.

Pulse Discrete "Hi-PoE" platform:

1G/2.5G/5G/10GBase-T 4PPoE Open header structure

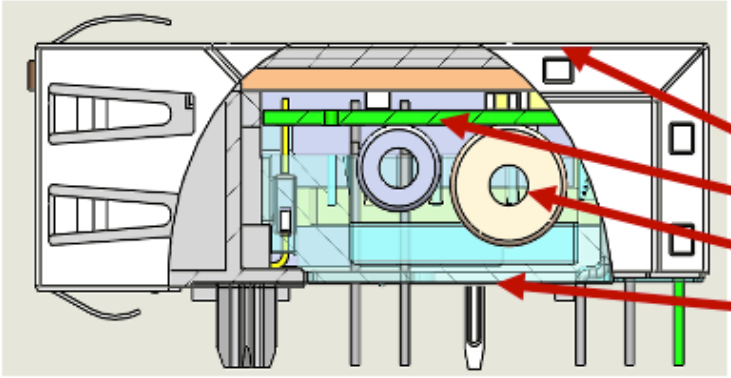


"Gull-Wing" "Beetle"

These discrete designs can also be taken into the PulseJack™ integrated connector module (ICM) platforms and the choice of these is limited as consideration regarding working temperature rises must be made as the shielding prevents cooling internally by convection or forced air.

The below figure shows the distribution of temperature raise within a typical Hi-PoE PulseJack design supporting 120W (52V x 2.3A) in the JXT7 and JXK0 platform

Pulse Hi-PoE ICM product inside Temperature Rise:

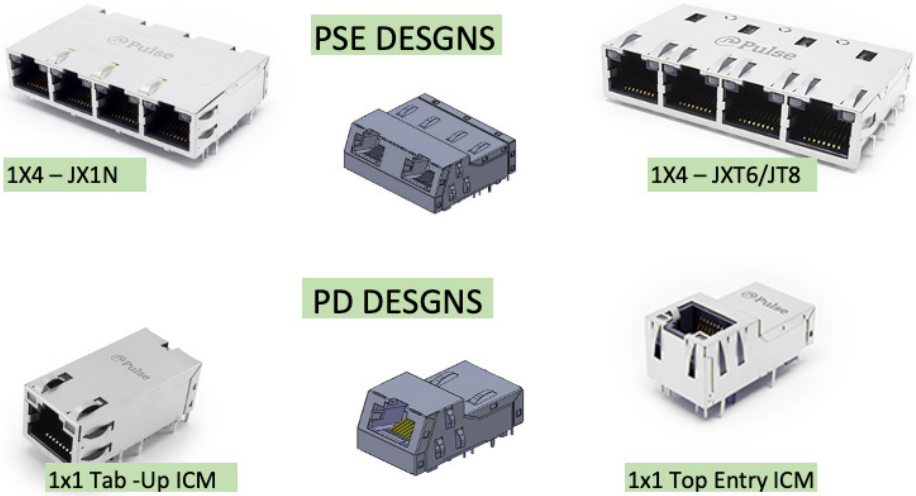


Location	Typ. Temp-Rise
Metal shield	15°C
Inner PCB	18°C
Coil center	25°C
Header Plastic	20°C

In the figure below are some of the NEW ICM platforms that can support the "Hi-PoE" magnetic configurations

Summary

Pulse's "Hi-PoE" magnet product range provides higher than 100 watts power conveying solution, which enable the component an adequate margin in current IEEE802.3bt applications, also the capability of being used in applications requiring up to 120~140W power transmission (PSE) or 100~120W power consumption at PD site.



This article is written by:
Yung Wong, GC Network Product Manager and Robert Frost, Eu PAN Marketing Manager.