GRD Journal for Engineering | Volume 2 | Issue 6 | May 2017
ISSN: 2455-5703

Conformance Testing of Non-POE Devices in a POE Enabled Network

Chodankar Deepak P
M.E Student (Power & Energy Systems Engineering)
Department of Electrical and Electronics Engineering
Goa College of Engineering, Goa University

Abstract

Ethernet for Data transfer in Computer Networks is ubiquitous. However some recent advancements in DC Powering have enabled transporting power and data simultaneously, over the same Ethernet cables. This technique is known as Power over Ethernet (PoE). However there are few challenges though, the first and the foremost being that of operational safety of the devices which are not PoE compliant. It needs to be noted that IEEE 802.3af standard specifies a 15W of PoE power at 48Volts DC which if connected to an incompatible device, may end up damaging it, permanently. Hence it is important that a PoE Equipment is tested and confirmed that it allows for safe and reliable operation of non-compliant devices. Failure to confirm this may have a catastrophic impact on the network that could range from a network crash to an imminent fire hazard. This paper discusses important tests which need be performed to ascertain that the PoE equipment being connected in the network will allow for safe and reliable operation of incompatible or legacy network devices. A LTSPICE simulated PoE network has been considered to carry out these various tests as well as for the verification of the safety features incorporated in the PSE-PD combination and its compliance to IEEE 802.3af standard. The observations and results are tabulated and conclusions are drawn.
Keywords- POE- Power over Ethernet, MIDSPAN, ENDSPAN, Power Source Equipment, Powered Device, Unshielded Twisted Pair, Keystone, structured Cabling System

---

I. INTRODUCTION

The concept of simultaneously supply of power and data together through the same cables as the ones used for sending the signals to the devices is not a new one. Our age old POTS (Plain Old Telephone System) is a good example wherein which the telephone instruments remain ON through the power supplied through the cables and the same cables carry voice signals as well as other important resource like the ringer current.

The Power over Ethernet (POE) takes the same concept to a much higher level. At its simplest, Power over Ethernet is a technology in which the Ethernet network cables carry power and data signals together, simultaneously. The Ethernet Data Networks follow the variants of two important standards, IEEE 802.3 for Wired Ethernet [1] and IEEE 802.11 for Wireless Ethernet. Since in PoE, the power needs to be carried through the cables, the standard obviously to be followed is IEEE 802.3. The PoE too has evolved along with the developments in Ethernet and presently the ratified standard being followed for PoE include 8023af and 802.3at for low power and high power respectively, over the UTP (Unshielded Twisted Pair) cables in Category 5, Category 6 and Category 7 [6] [7] [8][9].

PoE is generally a Low Powered Network and the limitation being that of the Ethernet cables which are designed to essentially carry low level signals, albeit at high frequency [5][6][8]. Both the IEEE ratified standards take this cable limitations into account and dabble in powers up to 15.4Watts under 'af' standard while 'at' standard scales this power up to 30Watts. The currents are limited to 300mA in the former and 650mA in the latter. There is however one more standard which is a non-ratified industry announced standard called 802.3bt (likely to be ratified in 2018) which caters to 90 Watts of power using all the four pairs of the UTP cable. [10][11]

Operationally, PoE is an end to end device, i.e. the PSE (Power Sourcing Equipment) delivers the power over the Ethernet cables and PD (Powered Device) receives the power. Simultaneously high frequency data also travels on the same cables at a speed of 10/100/1000 Mbps and it does not interfere with the power being carried. There are several techniques for executing this dual task, one amongst them is "Alternative A" / "Alternative B". A 10/100 UTP LAN cable consists of 4 Pairs out which two pairs carry the Data and the other two are free. In "Process A" the Power is carried by the same pairs as Data while in "Process B" the power is carried over the spare pairs and the data moves over the other two pairs. Either of the processes serves the purpose well and reliable data along with the reliable power can get delivered to the end equipment.

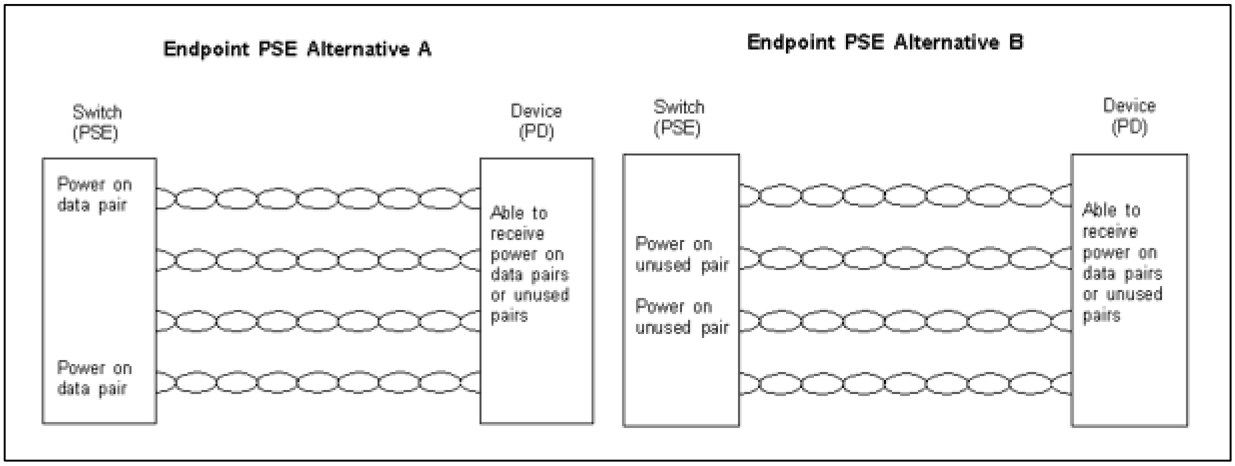

Fig. 1: Alternative A / Alternative B technique of adding power to the Ethernet cable pairs. [1]

To carry power over the Ethernet simultaneously with Data is indeed an interesting and viable proposition, but it does come with its own set of challenges. Ethernet has evolved over the past four decades and it is quite fair to expect a large number of devices in operation which are not compatible with the PoE. A PoE port delivers its power at 48Volts and PoE compatible device converts this voltage to its acceptable level. A non - compatible device which has no mechanism to handle this, may get damaged severely. Hence in order to ensure the Safety of the network, of the devices connected, of the personnel and of the associated infrastructure, it is essential and important that the critical tests are performed on the PoE product (MIDSPAN or ENDSPAN) especially those covering all the various safety and operational aspects, before it is incorporated in the network.

II. POWER OVER ETHERNET – DESIGN ARCHITECTURE [4]

As has been stated earlier, Power over Ethernet is a technique in which DC Power and Data are simultaneously carried over an Ethernet cable. At the receiving end, a PoE compatible device extracts the necessary power and gets powered up. The Data signals are handled in conformance with the data handling protocols applicable to the device and the network. A typical design of PoE using Linear Technology PSE –PD combination is shown in fig 2.

As seen, this PoE design implementation is with the use of Spare Pairs of Ethernet cable. In Category 5 or Category 6 cables, the Data pairs consist of 1-2 and 3-6 while pairs 4-5 and 7-8 are unused. It is useful to pump the power over this spare unused pairs as limitations are relatively few.

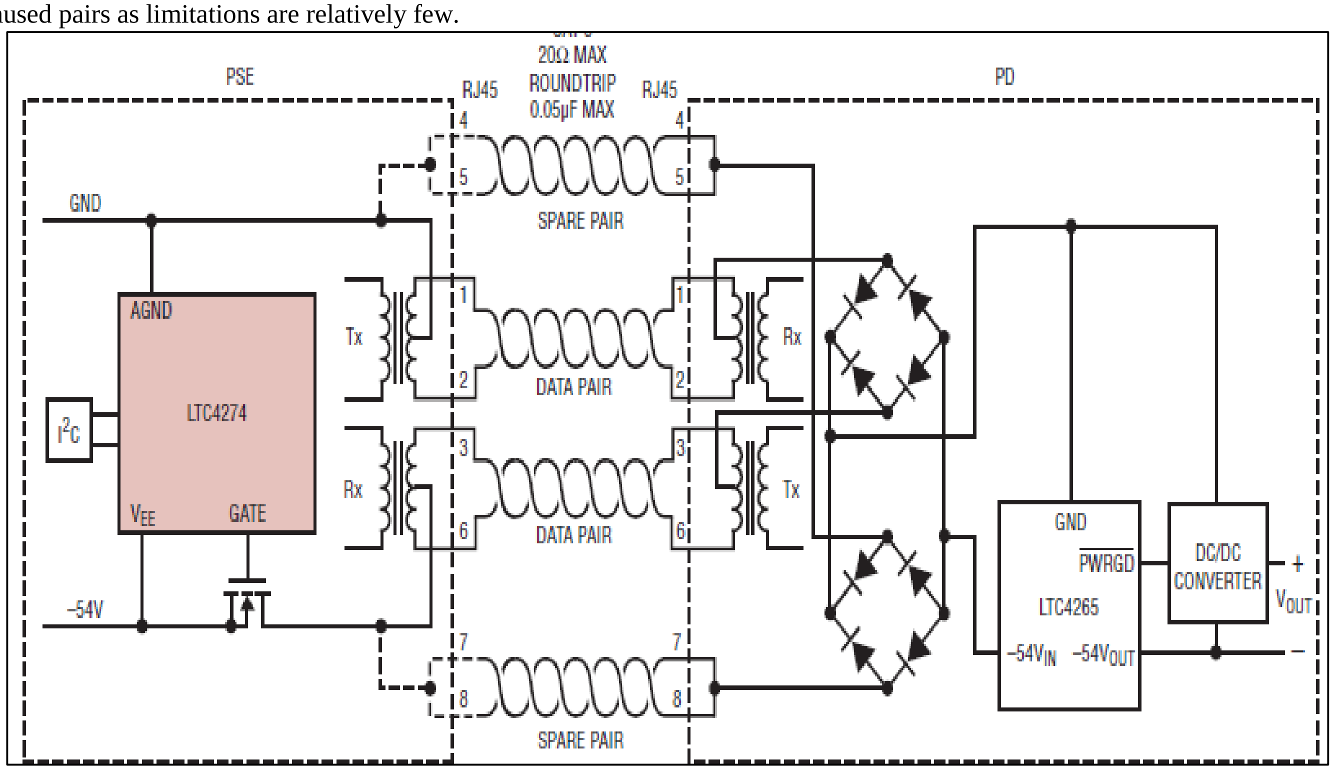

Fig. 2: PSE-PD Power over Ethernet Minimal Design [4]

The IEEE 802.3 section that deals with Power over Ethernet is the Clause No. 33 that defines the functional and electrical characteristics of the two important constituents, Power Sourcing Equipment (PSE) and Powered Device (PD) [1]. These constituents allow the connected devices to draw or supply power using the same Ethernet cable carrying the 10Base-T, 100Base-T and 1000Base-T data, simultaneously. More importantly this clause specifies the following,

1) A protocol allowing the detection of a device that requests power from a PSE
2) Methods to classify devices based on their power needs
3) A method for scaling supplied power back to the detect level when power is no longer requested or required

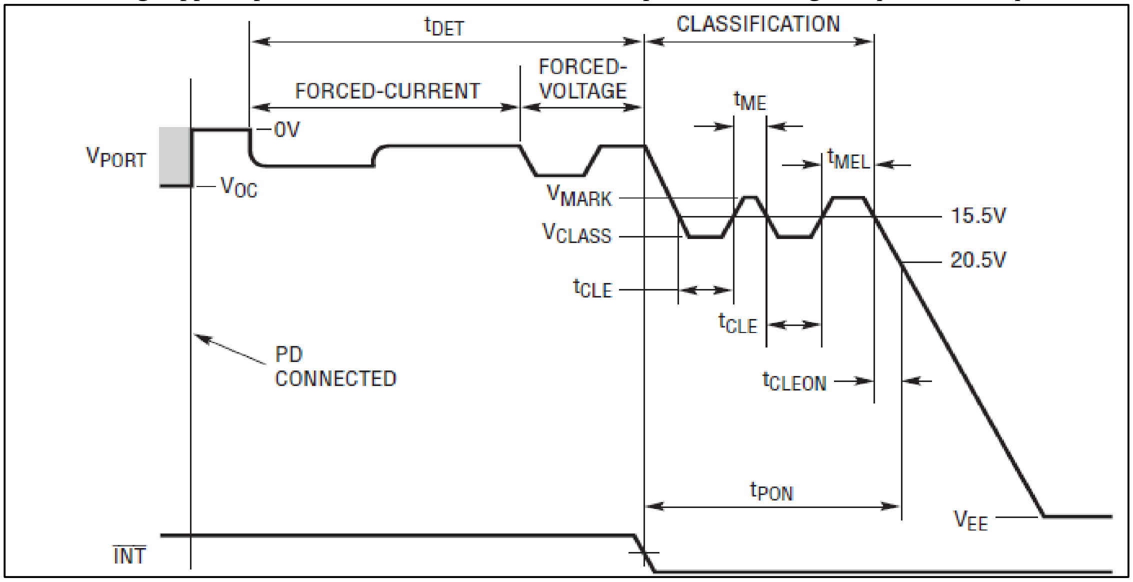

Fig. 3: Waveform showing detection and classification stages of connected PD device [4]

A PoE connection takes the following steps when initiating Power: [1] [2]

1) Detection - A pulse is injected to check the powered device (PD) for the correct signature resistance range between 15–33 kΩ. At this the voltage needs to be between 2V to 10V.
2) Classification – At this stage the power drawn by the resistor helps detect which class the device belongs. For this the voltage needs to be between 14.5-20.5 Volts
3) Start-up - The powered device starts up when the voltage reaches greater than 42 V
4) Normal operation - Supply power to device when the range is between 36-57 V

Given the large number of legacy devices (both IEEE 802.3 and other types of devices) that could be connected to a 100 Ω balanced cabling system, and the possible consequences of applying power to such devices, the protocol to distinguish compatible devices and non-compatible devices is important to prevent damage to non-compatible devices.

III. POWER OVER ETHERNET – THE MINIMAL SYSTEM IMPLEMENTATION

The PoE Minimal System Implementation is shown in the following figure Fig 4. The schematic shows a Minimal System Implementation of PoE using LTC 4274 as PSE (Power Source Equipment) and LTC 4265 as PD (Powered Device).

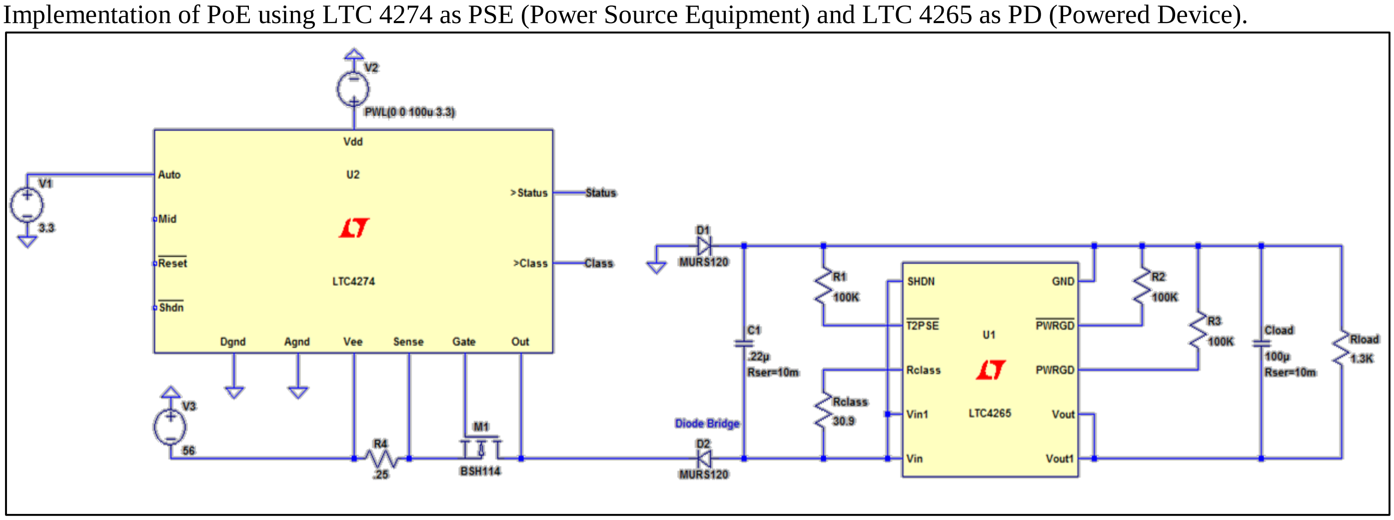

Fig. 4: Minimal PoE implementation using PSE /PD combination. [2] [3]

This PoE implementation is with the minimum number of external components yet displays all the necessary characteristics of a full-fledged system. With the AUTO pin tied High (3.3V), the PSE LTC 4274 operates in Auto Mode. This means majority of the operations are performed without the need of an external processor. R_4 is a current sense resistor while M_1 is a MOSFET for power control and delivery. Applied PoE voltage V3 is 56V while V_4 is PSE chip supply of 3.3V. The pins Mid (Midspan), Reset and Shdn (Shutdown) are left unconnected.

The PD LTC 4265 is driven by the output of PSE. D1-D2 form a bridge while V_{out} delivers the required power into the Load.

The Circuit action is quite elaborate. Once the PSE is Powered ON, it goes through the detection stage wherein it detects whether the connected device is a valid PD or not. In case it is not, then PSE does not connect the power. If the valid PD gets detected, PSE connects the PoE voltage (56V in this case) to PD which in turn powers up the load. In case the Load gets disconnected or shorted, the Power Delivery to the PD stops. Similarly there are defined limits of the upper voltage and under voltage cut offs.

IV. POWER OVER ETHERNET – TEST SIMULATIONS AND RESULTS

Any device connected to the PoE network goes through Detection and Classification stages before the DC Power is applied to the device. In case the device fails at the Detection Stage, the PSE does not apply the power to the device. However in case the device passes the detection stage then the PSE carries out the Classification Test and then applies the required power. Further if the valid device is disconnected from the network midway through its operation, PSE immediately withdraws the DC power thus safeguarding the port in case a non-PoE device gets connected at the same port.

These all important functionalities, features and operational specifications of the PoE circuit need to be verified and their adherence to the IEEE 802.3 Standard need to be confirmed. As stated earlier, this circuit is tested by simulating the requisite test cases and the observations/results are compared with the expected results. If the results match within the given tolerance band, then the PoE device is confirmed to be working satisfactorily and its conformance with the IEEE 802.3 stands verified.

Ethernet has been in existence since 40 years while PoE has been relatively a recent addition to the network. It is quite likely that in any Ethernet network, majority of the devices are non-PoE compliant. Hence the first and the foremost priority in any PoE network will be to protect and safeguard the use of these PoE non-compliant products. There are certain measures which are in place in a

PSE-PD combination network which ensure safety and reliable operation of legacy products.

A. Test Case 1: Detection and Classification of valid signature resistance [2]

To avoid damaging network devices that were not designed to tolerate DC voltage, a PSE must determine whether the connected device is a real PD before applying power.

The IEEE specification requires that a valid PD have a typical common-mode resistance of 25k at any port voltage below 10V. The PSE must accept resistances that fall between 19k and 26.5k, and it must reject resistances above 33k or below 15k. The PSE may choose to accept or reject resistances in the undefined areas between the must-accept and must reject ranges. In particular, the PSE must reject standard computer network ports, many of which have 150Ω common-mode termination resistors that will be damaged if power is applied to them.

Fig 5 below shows graphically the process of detection and classification of a valid PD device and subsequently application of DC voltage to the device.

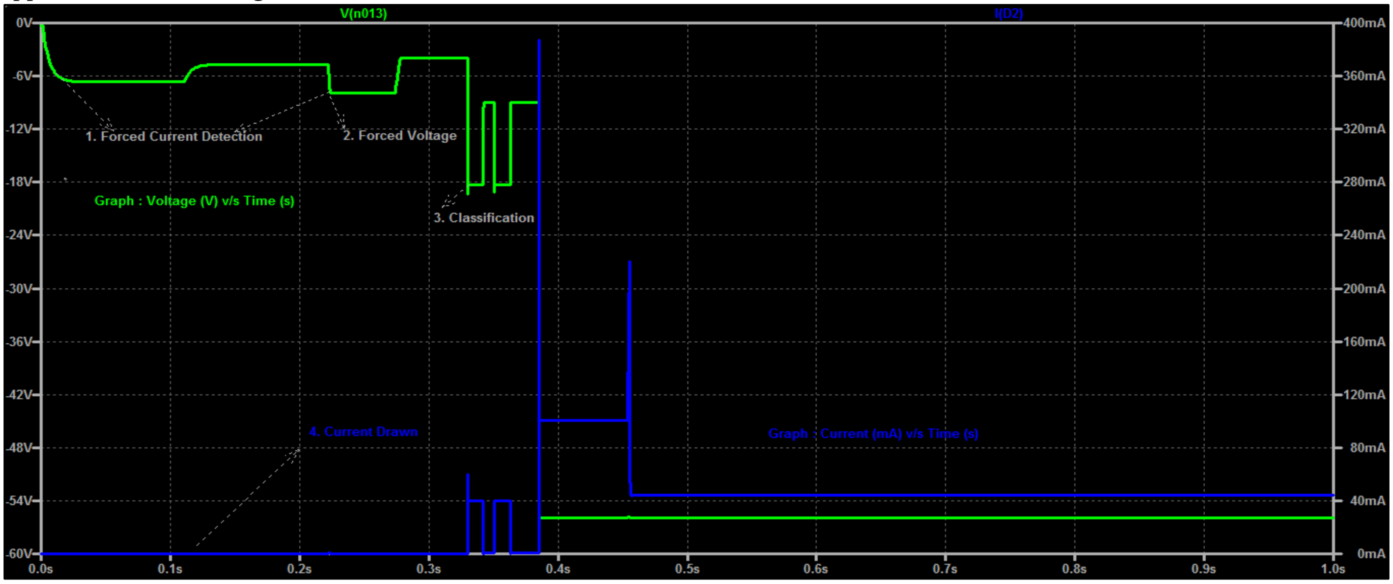

Fig. 5: Detection and Classification for PSE-PD combination [2] [3]

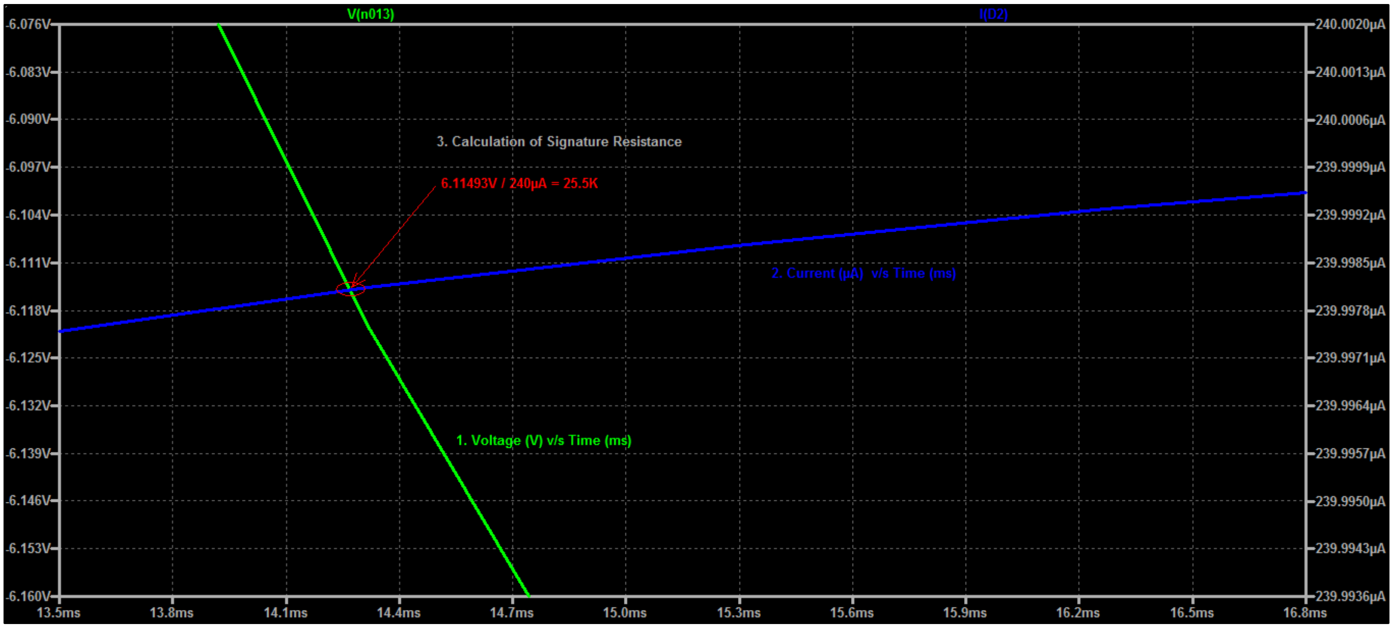

Fig. 6: Calculation of signature resistance V/I

1) Detection of valid resistance goes through two stages i) Forced Current ii) Forced Voltage. The waveform Fig 6 shows the current being drawn during the Forced Current event. The voltage measured is 6.11 V and current is about 240µA as can be seen from Fig 6. This gives us the value of signature resistance as 25K which is within the limits of a valid PD. Thus detection of a valid PD is successful after the event 1.
2) The next stage is of Forced Voltage. The process is similar to forced current and is carried out to eliminate any likelihood of false detection. The voltage range and the current observed are approximately equal to those observed during the forced current tests. Thus detection of a valid PD is successful at the 2nd stage.
3) Classification Test Pulse is injected and corresponding current is observed. The product of the voltage (18.3V) and Current (41mA)

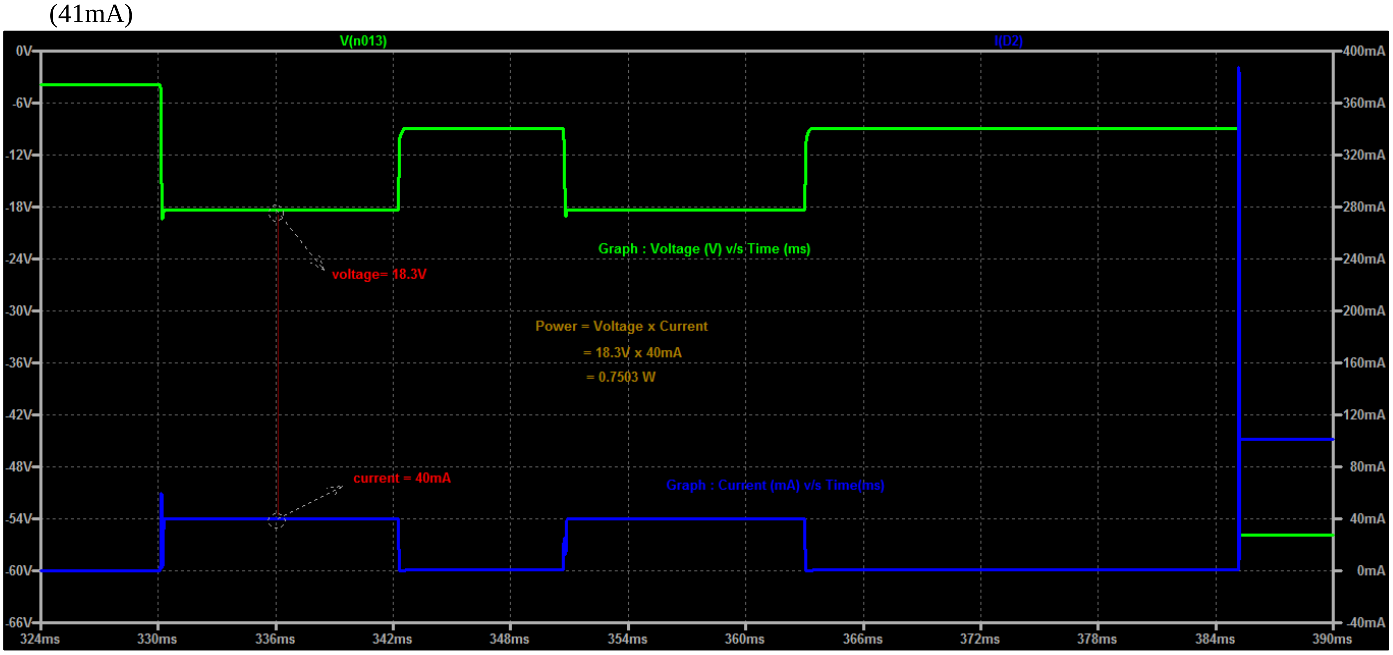

Fig. 7: Classification Waveform for PSE-PD combination

Power = Voltage x Current
= 18.3V x 41mA
= 0.7503 W

B. Test Case 2: Connecting A Legacy Non-Compliant Device to the Poe Network. [1]

When a non-compliant device is connected to the PSE, it is expected that no DC voltage shall be applied to this device nor any current shall be drawn.

Fig 7 shows the PSE with a non-PoE load connected. Ideally the load shall not draw any current nor shall any DC voltage be applied to the load, lest any damage occurs to the device.

As is observed graphically, Fig 8 shows a voltage swing of 0 to 330mV which well within the limits of a network device. Similarly Fig 9 shows the current waveform at the load wherein we observe a swing of 0 to 240µA which is also well within the tolerance band. Thus we infer that a legacy device may safely be connected to the PoE network.

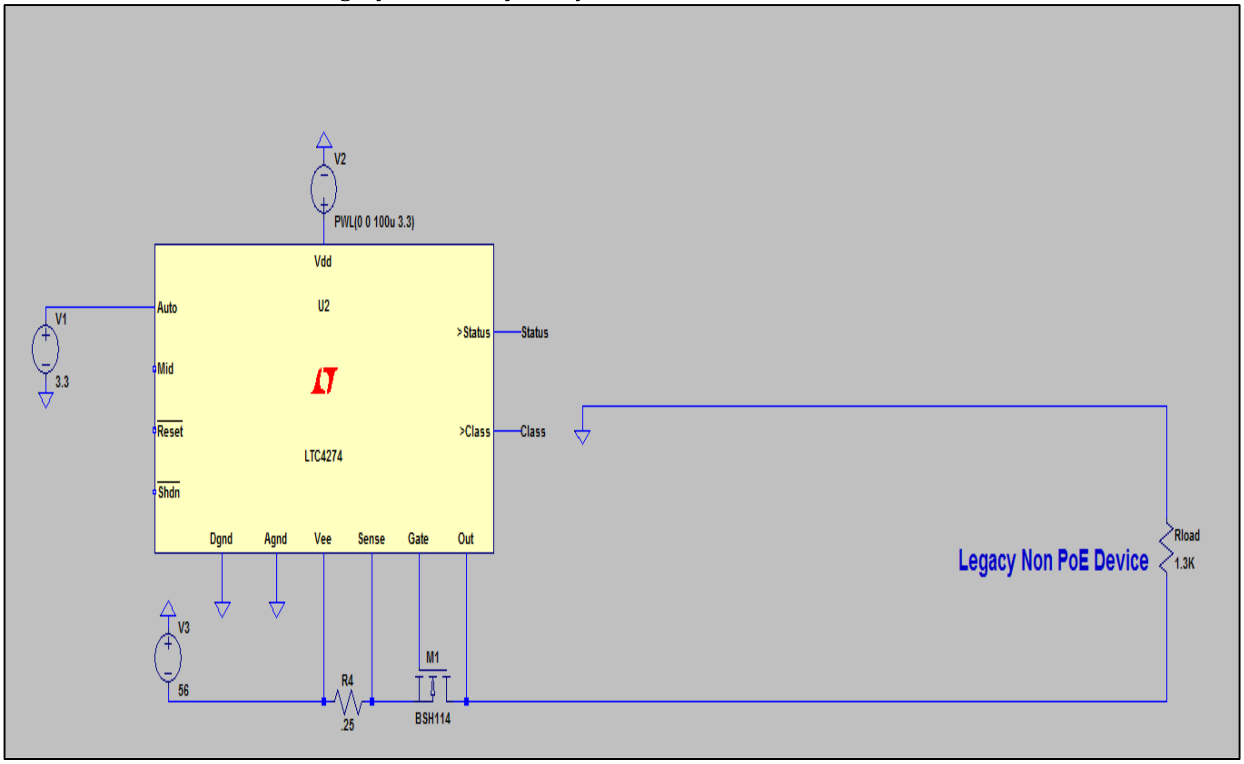

Fig. 8: PSE with Legacy device connected

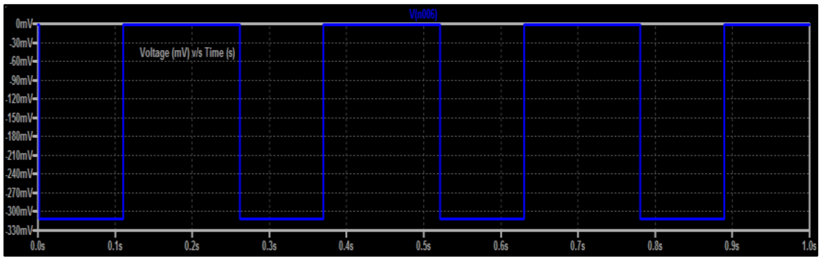

Fig. 9: Voltage waveform at the load

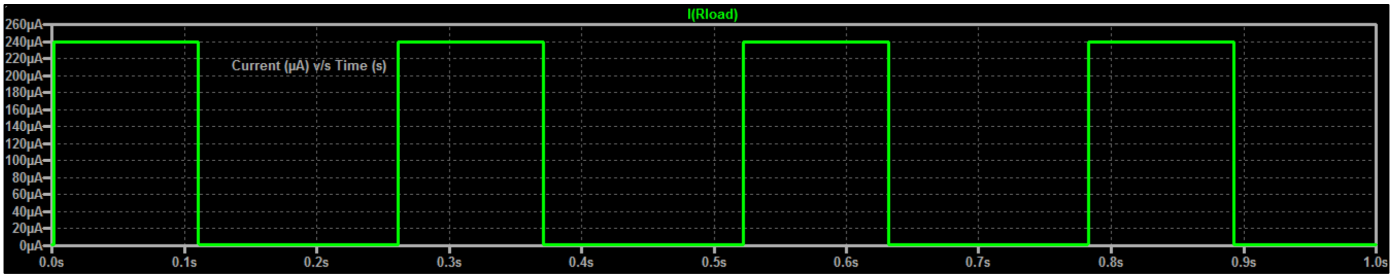

Fig. 10: Current waveform at the load [4]

It can be seen from the above that once the PD is removed from the circuit, PSE stops delivering power to the end device, thus safeguarding the use of legacy devices which are not wired to receive high DC voltage or current.

C. Test Case 3: Disconnecting the Non-Compliant Device and Reconnecting It to the Poe Network.

In Fig 7, as the circuit gets into operation, the load is disconnected. It is expected that the voltage at the open terminals will shoot to the level of PSE open circuit voltage which is about 56 V. However once the load gets reconnected, the PSE output shall fall to the near zero level.

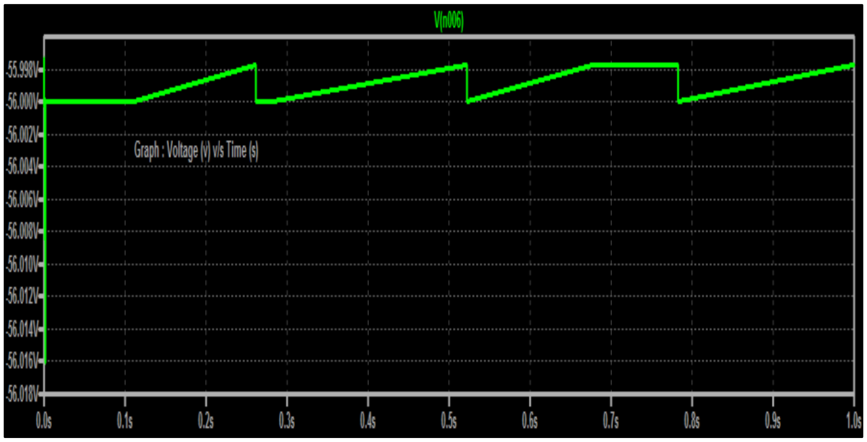

Fig. 11: Voltage waveform when load is disconnected

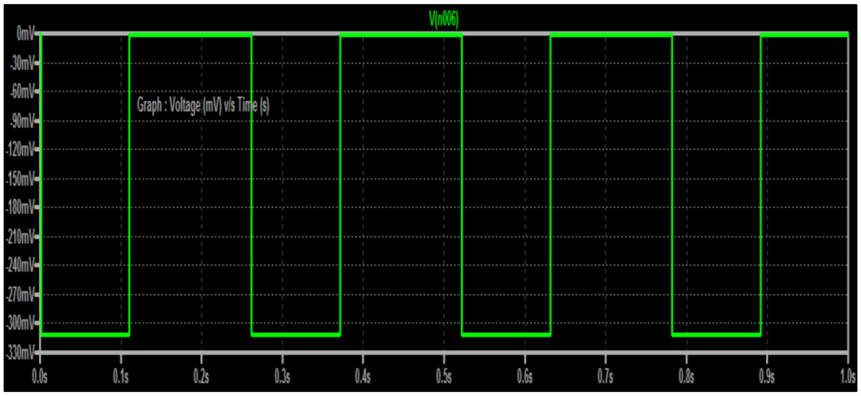

Fig. 12: Voltage waveform when load is reconnected

It is observed from Fig 11 that once the load is disconnected the PSE starts delivering its DC voltage at the Load Terminals. However when the Load is reconnected, the voltage level at the terminals falls back to near zero, i.e. about 240µV, as seen in Fig 12. This confirms that in a PoE network, it is safe to disconnect and reconnect a non-PoE device without causing any damage to it.

D. Test Case 4 : The Non-Compliant device is Short circuited

When the Load is short circuited, the PSE shall not deliver any excessive current to the device. Ideally the short circuit current at the device terminals shall be zero.

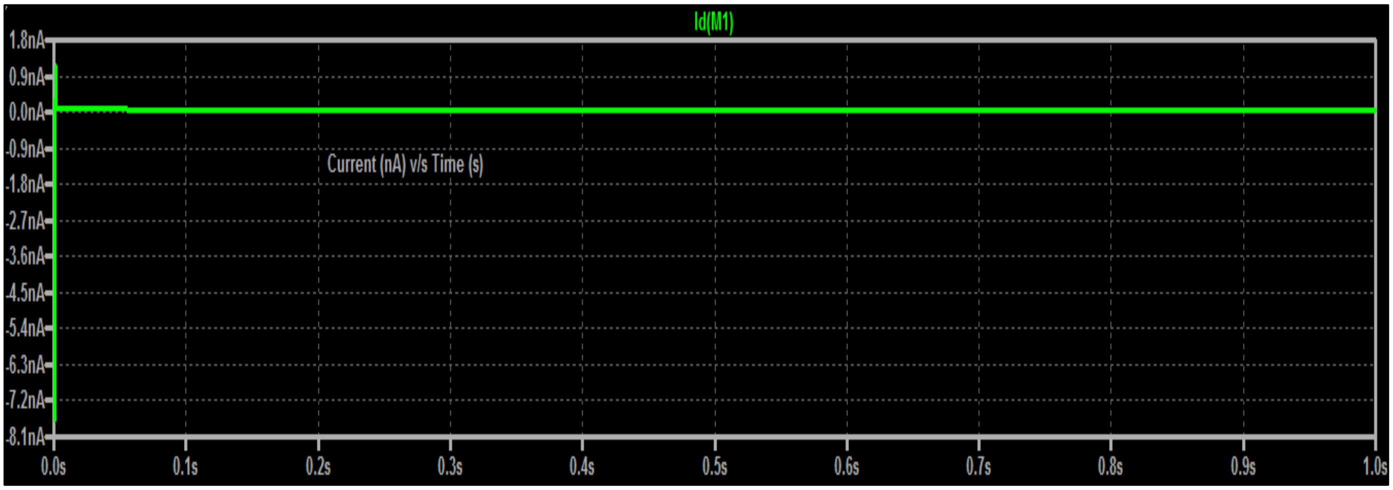

Fig. 12: Current waveform at the load terminals when load is short circuited

Fig 12 above shows the current being drawn by the device when it gets short circuited. It may be observed that the current is of Nano Ampere range and it is safe for the device.

The results and the observations above have been tabulated below in table 1.

Table 1: Tabulated Results of Test cases

Test Case 1 : Detection and Classification of valid signature resistance			
Test	*Specifications*	*Observation*	*Inference*
Measurement of Signature Resistance	*19K to 26.5K*	*25K*	*Valid Signature resistance hence the PD is valid*
Classification of the device	*Power Range for PD under 802.3af :0.44W to 12.95W*	*0.75W*	*Class 0 PD Device classified.*
Test Case 2 : Connecting a legacy Non-Compliant device to the PoE network.			
Measurement of voltage at the load terminals	*0mV to 500mV*	*Swing between 0mV to 320mV*	*Non-compliant device is safe when connected to the PoE network*
Measurement of Current at the load terminals	*0μA to 500 μA*	*Swing between 0μA to 240 μA*	*Non-compliant device is safe when connected to the PoE network*
Test Case 3: Disconnecting the non-compliant device and reconnecting it to the PoE network.			
Measurement of voltage at the load terminals after disconnecting the non-compliant device	*Shall be equal to the PSE terminal voltage*	*Load Terminal voltage = PSE terminal voltage = 56V*	*Load Terminal voltage is in sync with PSE voltage*
Measurement of voltage at the load terminals after reconnecting the non-compliant device	*0mV to 500mV swing*	*0mV to 300 mV swing*	*Once the load is reconnected, the terminal voltage falls back to 300mV. This confirms that there is no impact on the load terminals even after reconnecting the disconnected load. Device operates safely.*
Test Case 4 : The Non-Compliant device is Short circuited :			
Measurement of current upon short circuiting the load	*The short circuit Load current shall be close to Zero amps*	*The short circuit current is observed to be zero amps*	*The non-compliant device remains safe despite the short circuit occurring across the terminals*

V. CONCLUSION

After carrying out comprehensive test cases on the simulated network, it is observed that the PoE network operates safely and guards the safety of the non- compliant devices connected to it.

In all, this simulated PoE network has been submitted to FOUR critical test cases and the results have been tabulated in table no. 1. The PoE network has successfully passed all the tests carried out by connecting a PoE compliant load and PoE non-compliant loads. In both the cases, the network has satisfactorily responded to all the tests.

Hence it may be concluded that the above simulated PoE network containing PSE-PD is safe for use with the legacy PoE non-compliant products.

REFERENCES

[1] IEEE Std 802.3-2015 IEEE Standard for Ethernet- (Approved 3rd Sep, 2015 by IEEE SA Standard Board) Section TWO, Subsection 33 – Data Terminal Equipment (DTE) Power via Media Dependent Interface (MDI)
[2] Linear Technology LTC 4274 A/C Single PoE/PSE Controller, LT 0715 Rev D 2011
[3] Linear Technology LTC 4265 IEEE 802.3 at High Power PD Interface Controller With 2-event classification Recognition LT0714 Rev B
[4] Linear Technology LTSPICE IV User Guide – 2011
[5] WP_Shieldadv Advantages of using Shielded Cabling Systems to Power Remote Network Devices Rev B 6/13.
[6] ISO/IEC 11801, "Information Technology" Generic Cabling for Customer Premises – 2002.
[7] Valerie Maguire WP-DeMystifying Cable De-Mystifying Cabling Specifications From 5e to 7a – Rev F 5/11
[8] ISO/IEC TR 29125 "Information technology – Telecommunication Cabling Requirements for Remote Powering of terminal Equipment "2010.
[9] Siemon White Paper - Zone Cabling and Coverage Area Planning Guide-2015
[10] Cisco White Paper – Cisco Digital Building Solution
[11] Design Lights Consortium White Paper – PoE Lighting Systems