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Power over Ethernet (PoE) System based Power Device (PD) @90W using Two DC-DC converters with 6KV Surge Protection

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ABSTRACT

A 90W High power - Power over Ethernet (PoE) based Power Device (PD) is presented in this paper, which is in compliance with IEEE 802.3af/at standards. This Splitter, PD, connected to two DC-DC converters of 5V and 31V, is presented. The enhancement in Performance and Efficiency is achieved by combined features of Four-paired architecture, MOSFET active bridge, Synchronous Buck topology, without the requirement of two DC-DC converters for sharing the same load. The Surge protection of 6KV proves the depletion of common surge problems in PoE system. The designed Prototype acts as Splitter to split the Data and Power and feed them to Base band equipment mounted on Telecom towers.

Keywords- Power sourcing Equipment (PSE), Power Device, Surge Protection Devices, Synchronous Buck DC-DC Converter, Protel 99se.

1. INTRODUCTION

The Internet is becoming an essential and ubiquitous tool for communication and entertainment, alike television and the telephone. In recent years Power over Ethernet (PoE) systems continues to gain popularity in global networking market. It has greatly eased the deployment of many IP-enabled devices by like Voice over Internet Protocol (VoIP), web cameras, wireless access points, monitoring systems, sales terminals, home automations, and so on. PoE brings a host of benefits to design, implementation and long term usability of wired Ethernet Local Area Networks (LAN) to improve the Connectivity, Collaboration, Flexibility, Security and Productivity of Network devices which shows increased applications at Enterprise levels. The typical PoE is given in Fig. 1.

PoE integrates data and power on the same wires, it keeps the structured cabling safe and doesn’t interfere with concurrent network operation. The ability to provide power over same cable carrying network traffic overcomes the major limitation of adding the power outlets near the application devices or providing an extra cable carrying power which increases cost and risk. In this paper the four pair architecture of PD holding 90W with 5V/6A and 31V/2A DC-DC converters are discussed.

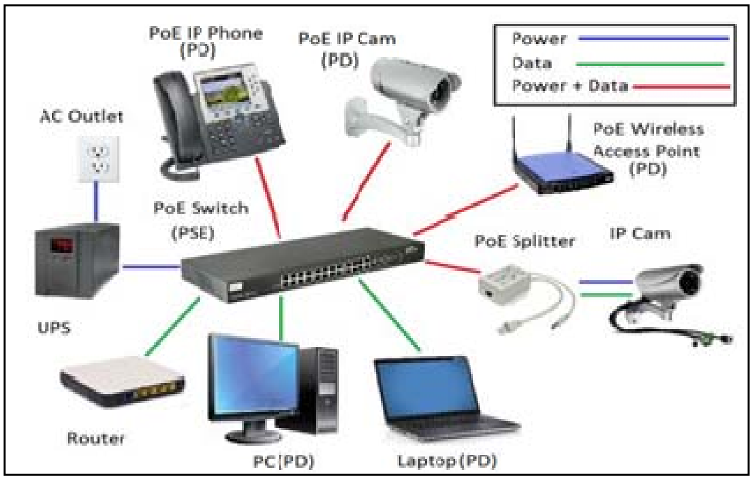

Figure 1. Typical Poe System

An End to End PoE system topology which is defined and standardized by IEEE 802.3af consists of a Power Sourcing Equipment (PSE) like a switch that provides (sources) power on the Ethernet cable together with data and a Powered Device (PD) is a device powered by a PSE and thus consumes energy. PSE also called as Injector as it injects data and power in a same cable, whereas PD is called Splitter for splitting Data and Power on the receiving end.

The Block diagram of the PoE system which is presented in this paper is given in Fig. 2. Separate Data and Power are inputs to PSE whereas its output is a Data+Power which is the input to PD through CAT5e/6e cable and RJ45 connectors. PD splits data and power at receiver end. The DC power availed at PD output can be converted to required levels for device power ups.

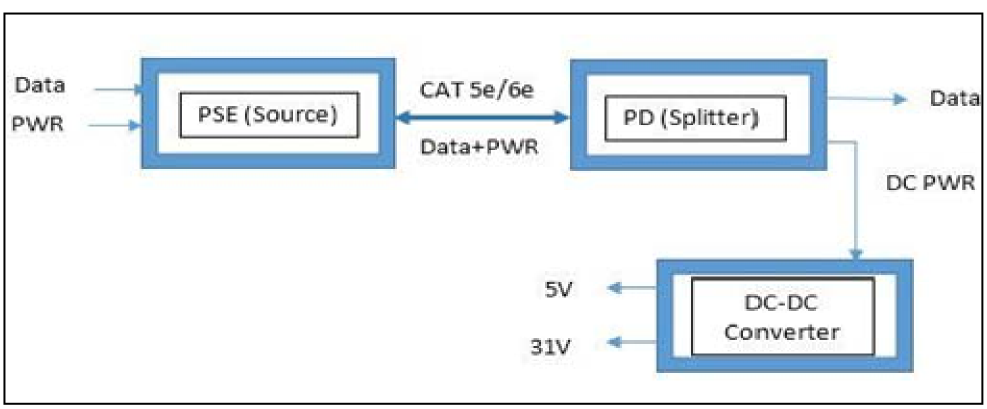

Figure 2. Block Diagram Of Presented Circuit

2. BACKGROUND

In a typical Two pair PoE system, only 20W power can be delivered from power sourcing equipment (PSE) to power device (PD) to distant loads [1]. To get more power from PSE, the use of four pair architechture with two DC DC converters [2].The Polarity protection to PSE and PD is provided by Diode Active Bridge[1],[2]. Meanwhile Four pair architechture proved higher power for the same PSE. Input current balance control method and using of two DC-DC converters sharing the common load instead of one DC-DC converter improves performance of PD[3]. Following the paper[4], Selection of converter topology for higher efficiency also marked the importance. Compared to Flyback, Active-Clamp Forward and Forward Flyback topology, Synchronous Buck converter topology prover higher conversion efficiency [5]. As the installation of PD is in remote areas, surge protection will be mandatory. The PSE and PD may both affected from Lightening Surges and faults, the use of Gas Discharge Tubes (GDT) and Transient Current Suppressor (TCS) devices will minimise the surge that affects to system[6],[7]. Taking all above modification history of PD, For considering a higher efficiency, 90W PD with Four pair architecture and Active MOSFET bridge with Synchronous Buck converter topology is selected.

3. PROTOTYPE DEVELOPMENT

A Prototype 90W LTPoE++ Class IV PD with two DC-DC converters of considerable higher efficiency is built to admit the better performance.

Protel 99se tool supports for both drawing schematics and PCB routing.

PD Controller of LT4275 package supports IEEE-802.3af (Type1,PoE), IEEE-802.3at (Type2,PoE+) and LTPoE++ adding more power levels upto 90W is chosen as per required power rating, which controls and co-ordinates all components of PD equipment. LT4275 provides Resistance Signature of 25kΩ during detection of PD from PSE. The Schematic of PD controller is given in Fig. 3 and Fig.4 [Appendix A],[Appendix B].

LT4275 controller has inbuilt Overtemperature protection. The higher surges upto 6KV can be mitigated using TVS diodes, GDT’s in Schematics Fig. 5. The Auxilliary power supply of threshold 6.3V is included in the design when power from PSE is not available.

For powering the base band equipments of Telecom tower, the power from PD should be modulated to required Powers. As all the designs are tested by Linear Technology Corporation, the same are modified and used in this paper.

A 55-57V range of PD output is modified to 5V and 31V Regulated Supply carrying maximum currents of 6A and 2A respectively. The 5V regulated supply powers the top station controller card on board and 31V supply for RF card.

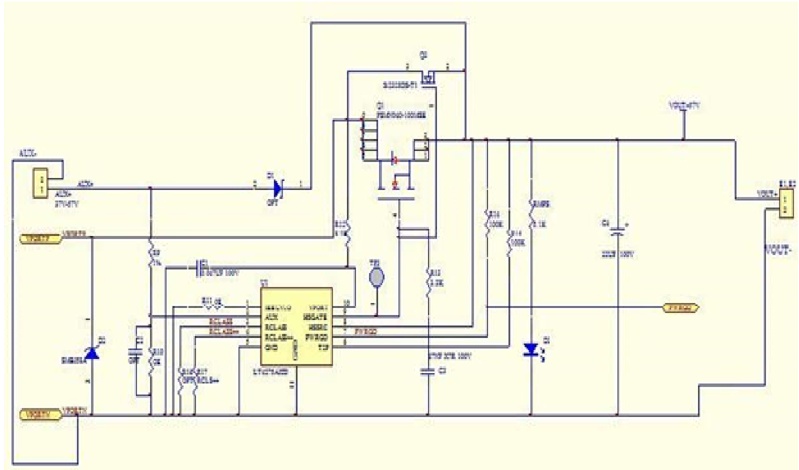

Figure 3. Pd Schematics1

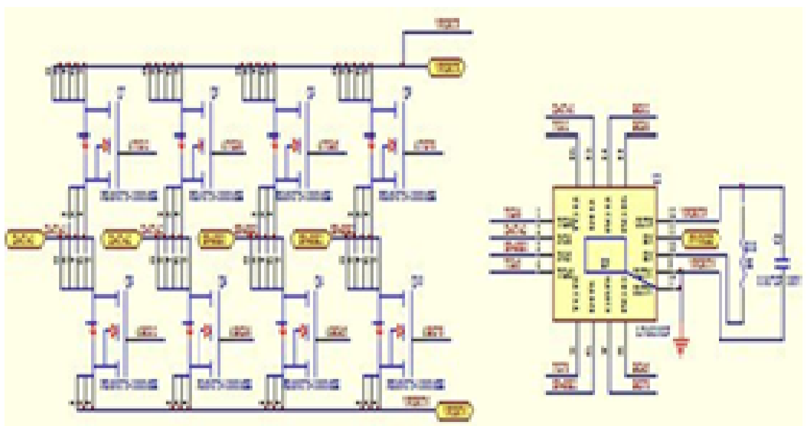

Figure 4. PD SCHEMATICS2.

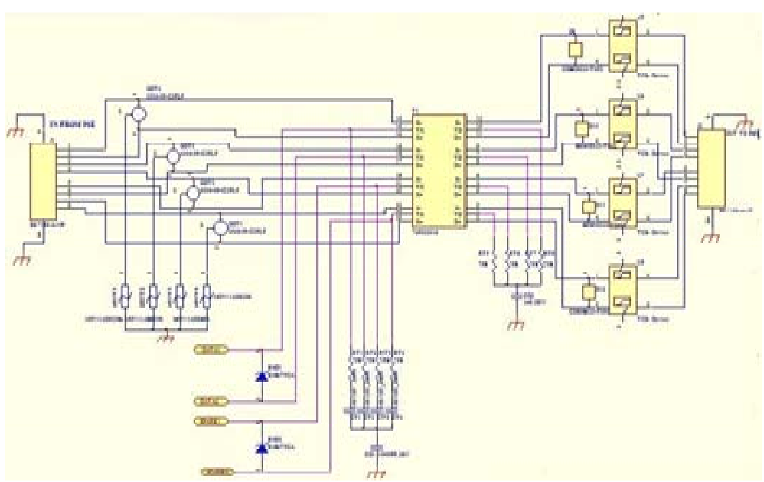

Figure 5. Surge Protection And Data Transformer Schematics.

i. 5V Regulator Controller

LT3812EFE-5#PBF Regulator Controller is chosen for design, which opts Synchronous Buck Converter topology with Current feedback from output. As the design demands for lower duty cycle without transformer (considering weight and component count issues) the regulator provides On time for MOSFETs less than 100ns. The chip also features output overvoltage protection input undervoltage lockout and extremely fast response supporting the requirements. For V_{in}=12V to 60V, V_{out}=5V±5%, $I_{out(max)}$=6A, F=250KHz. Few design calculations for 5V regulator are mentioned below.

The timing resistor is calculated by,

$$F = \frac{V_{out}}{2.4V * R_{on} * 76pF} ...Hz \tag{1}$$

Hence, Ron=110kΩ, For Ripple ΔIL (Inductor current) =40% at maximum V_{in},

$$L = \frac{V_{out}}{F * \Delta I_L * I_{out}} \left[1 - \frac{V_{out}}{V_{in}}\right] ....H \tag{2}$$

Hence L=7.6µH. Choose 7.7µH inductor for ripple variation from 25%to 40% over input supply range.

The two N-Channel, Low RDSon MOSFETs - Si7850DP are chosen.

Output Capacitors are chosen for low ESR of 0.018Ω for minimal output voltage changes due to Inductor ripple current and load steps.

The ripple voltage will be,

$$\Delta V_{out}(\text{Ripple}) = \Delta I_L(\max) * ESR = 6A * 0.018\Omega = 108mV. \tag{3}$$

An optional 10µF ceramic capacitor is included at output to minimize effect of ESL in output ripple.

The Schematic of 5V regulator is given in Fig. 6 [Appendix C].

ii. 31V Regulator Controller

LT8620EMSE#PBF-ND is an output voltage controlled low output voltage ripple regulator controller for 31V/2A supply. It features Low EMI and Internal compensation to the design, supporting lower component count.

For V_{in}=5.5V to 65V, V_{out}=31V, I_{out}(max)=2A,V_{sw}(bot)=0.15, V_{sw} (top)=0.3, V_{in}=65, The frequency of operation is calculated as,

$$F = \frac{V_{out} + V_{SW}(bot)}{T_{on}(\min) * (V_{in} - V_{sw}(top) + V_{sw}(bot))} ....Hz \quad (4)$$

Yields F=2MHz. The value of timing resistor R_t is,

$$R_t = \frac{46.5}{F} - 5.2....\Omega \quad (5)$$

Hence R_t=18.2kΩ. Soft start capacitor of C=0.1μF is connected across soft start pin to ground. Boost capacitor of C=0.1μF provide drive voltage higher than input voltage.

For feedback resistors, taking one of Resistor R1=1MΩ, other resistor R2 is calculated,

$$R_1 = R_2 \left[\frac{V_{out}}{0.970} - 1 \right] ...\Omega \quad (6)$$

Yielding R2=32.3kΩ≈33kΩ. Output Inductor is calculated as,

$$L = \frac{V_{out} + V_{sw}(bot)}{F} ....H \quad (7)$$

Yielding L=22μH. Schematics of 31V regulator is given in the Fig. 7 [Appendix D].

The Figure 9 Shows PoE PSE and Figure 8 Shows the presented PD.

4. EXPERIMENTAL VERIFICATION AND RESULTS

Working of PD is determined by complete PoE system which includes PSE, PD, Converters, Data and Power.Setup for test run is done according to block diagram in Fig. 2.

Data can be a Local Area Network (LAN) cables which run towards input of PSE. An Domestic AC input of 230V is suffice for the operation of PSE and hence the PD.The PSE module RT2009V1 PSE consists of AC-DC Rectifier converting available AC supply to 55V to 57V at the input of PSE along with PSE module. The output RJ45 jack of PSE is connected to PD and output RJ45 jack of PD is tested for data by connecting it to devices like PCs, VoIP cameras etc. On power up, PSE detects classifies and powers up the PD, under normal operation. PD provides Data and 55V to 57V DC power as outputs.

Powergood indicator on PSE indicates regulated voltage from PSE Power supply and Powergood indicator on PD indicates satisfactory detection, classification and power up of PD.Powergood indicator on 5V and 31V regulator supplies denotes output voltages within tolerance levels. The test Results are given below,

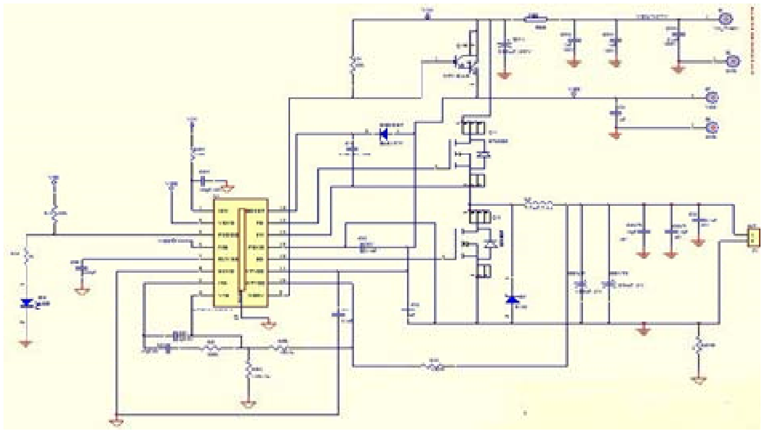

Figure 6. 5v/6a Schematics

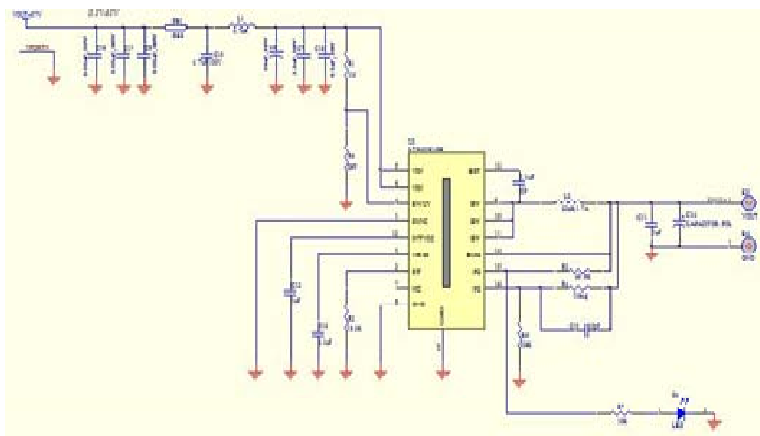

Figure 7. 31v/2a Dc-Dc Converter Schematics

Figure 8. PCB OF POE PD DEVICE.

Figure 9. Pcb Of Poe Pse Device.

TABLE 1

TEST RESULTS FOR PD

Sl. No	PD	PSE device	Output voltage across PD (V)	Data Status	Status of module
1	Presented Resonous PD	Resonous PSE	56.5	Yes Speed= 1Gbps	Working
2	Presented Resonous PD	Linear demoPSE	55(for input 55V) 56.5(for input 56.5V) 57(for input 57V)	Yes Speed= 1Gbps	Working

i. Performance of PD along with 5V and 31V Regulated Supplies

With the existing setup, connect the Ferrite bead Resistor at input of 5V and 31V regulator. Performance of PD along with 5V and 31V converters is verified and tabulated as in Table. 2.and Table. 3 respectively.

As Output of PD is 56.5V when connected to 5V and 31V and hence the same can be used to calculate the efficiency of system.

Table. 2. Test Results For 5v Regulator Supply.

Sl. No.	Load (Ω)	Input current(A)	Output Voltage (V)	Output current (A)
1	0	100m	5.10	-
2	10	55m	5.10	520m
3	8	87m	5.09	610m
4	4	155m	5.09	1.2

5	2	360m	5.09	2.616

Table. 3 Test Results Of Pd For 31v Supply.

Sl. No.	Input current (A)	Load (Ω)	Output voltage (V)	Output current (A)	Effici-ency
1	100m	0	31.0	-	-
2	300m	60	30.0	490m	85.34
3	440m	40	30.0	743m	88.87
4	560m	31	30.0	943m	88.62

5. CONCLUSION

From the above experimental results it can be concluded that the presented PoE based PD works satisfactorily with DC DC converters connected to loads proving higher efficiency and less human interference once the load is connected. This fairly compact, less component count and less cost. PD proves the better choice for higher power apllication and enhanced performance.

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APPENDIX

Here are some of the manuals and data sheets to be referred to understand Presented project.

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