Application Report
SLVA625A–November 2013–Revised June 2016

Dual TPS2378 PD for 51-W High Power-Four Pair PoE

Eric Wright

ABSTRACT

This application report discusses a high-power four-pair solution for Power-over-Ethernet (PoE) applications requiring power in excess as defined in the current IEEE 802.3at standard. Specifically, this report provides a dual TPS2378-based, forced four-pair solution providing 45 W to the load.

Contents

List of Figures

List of Tables

1 Introduction

The TPS2378 device is an IEEE 802.3at compliant, Type 2 PoE Powered Device (PD) controller. TPS2378 supports use with high power auxiliary adapters and provides startup control for the DC-DC converter. The TPS2378 device can be arranged in a dual fashion to support high-power, four-pair operation at 51 W at the input RJ45 connector which therefore enables Cisco System's Universal Power Over Ethernet (UPOE™) concept.

There are two basic forms of UPOE. One is based on Link Layer Discovery Protocol (LLDP) which is through the Ethernet data path. The other form is forced using circuit hardware only. In both forms, the power sourcing equipment (PSE) proceeds by detecting, classifying, and ramping up voltage to one pair set according to the IEEE 802.3at standard. The method used at the PD (LLDP or forced) determines how the operating voltage is applied to the second pair set. The focus of this application report is on a forced four-pair PD as shown in Figure 1.

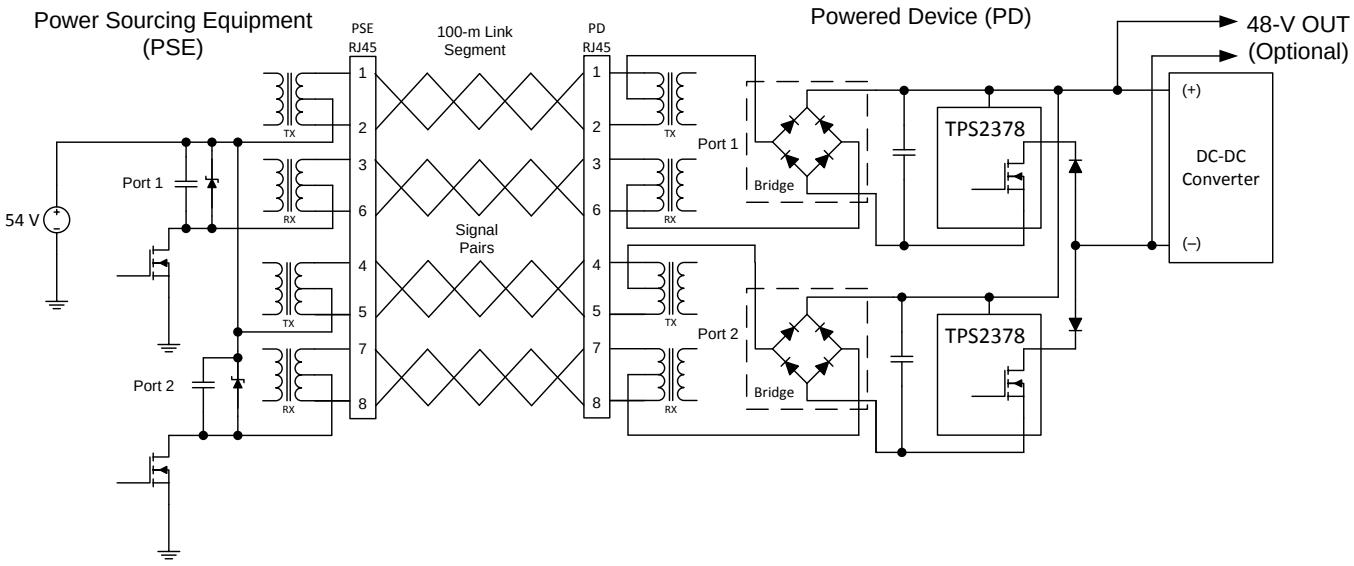

Figure 1. Top Level Block Diagram: Forced Four-Pair UPOE

A key concept of the forced design is that it prevents reverse biasing of the bridge on the second PSE port pair by using the additional PD controller series diodes. This concept allows for normal detection and classification on the second PSE port while the first pair set is powered. The PD must not exceed the power consumption requirements for standard Type 2 PDs until the second pair set is powered.

2 Requirements

The PD solution requirements shown in Table 1 reflect the following system level assumptions shown in Figure 1.

- Dual IEEE 802.3at type 2 PSE ports (each port uses two signal pairs) delivering power to the PD over a single Ethernet cable.
- PSE output power (at PSE RJ45 connector): 30 W maximum for each port or 60 W maximum for both ports.
- PSE output voltage (at PSE RJ45 connector): 50 V minimum for each port.
- Link segment (Ethernet cabling): Each port modeled as 12.5 Ω maximum DC pair loop resistance for the 100-m Ethernet link segment.

Table 1. Requirements Summary

Parameter	Limit
PD input power	51 W
PD input voltage	42.5 V

Table 1. Requirements Summary (continued)

Parameter	Limit
Load power requirement	45 W
Converter efficiency	> 88%
Pair current (max for both)	1.2 A
Converter output voltage	19 V
Converter output current	2.9 A

2.1 Criteria

The high-power solution meets the following basic criteria:

- Current sharing between both pair sets provides at least 51 W available at the PD power interface (PI).

NOTE: Inadequate current sharing can result in port turn-off, erratic behavior (PSE or PD) or other negative results. Erratic behavior occurs because of current-limit onset or inadequate PD input voltage on the pair set carrying the higher current. Saturation of data transformers is another concern of inadequate current sharing.

- Avoids data transformer saturation through the use of magnetic components compatible with IEEE 802.3at standard (minimum). Based on the current sharing balance, higher current data transformers may be required.
- No overheating in the PD circuitry.
- A high efficiency DC-DC converter is required to maximize the power available to the load.

2.2 Importance of PD Efficiency and Current Sharing

The maximum ensured PD input power is 51 W with the PD input voltage as low as 42.5 V because of the cable impedance excluding of the effect of current imbalance between pairs. As a consequence, the PD output power is limited by efficiency which includes a bridge, a return switch, and a DC-DC converter. The required output power imposes an efficiency requirement on the PD.

In order to ensure reliable system level operation, a worst case PD efficiency analysis is required. The worst case efficiency includes the input bridge, the PD front-end return switch, any additional series diode, the PoE data transformers, and the efficiency of the DC-DC converter stage.

With *passive* current sharing, any impedance difference through each power feed and return impacts the current imbalance between each pair set. Passive current sharing requires that the PSE provide power through a single cable and from a common voltage source to minimize the impedance difference.

In some cases, the use of a standard or a Schottky bridge with negative temperature coefficient, impairs sharing when the Ethernet link segment is short. To minimize this effect, diode characteristics must match with good temperature matching along with good PCB thermal management.

In summary, the PD architecture and efficiency must carefully be selected to meet the maximum output power requirement.

3 Reference Design Description

Figure 2, Figure 3, and Figure 4 show a dual-TPS2378, high-power, four-pair reference design (TPS2378EVM-602). For the BOM, refer to the user's guide for the EVM (SLVUAG7). Dual-TPS2378 PD controllers are used in Figure 3 to OR both pair sets together. Each TPS2378 device provides a typical current limit of 1 A. With PD input power of 51 W at 42.5 V minimum, the total pair set current is 1.2 A or 600 mA, assuming equal current sharing for both.

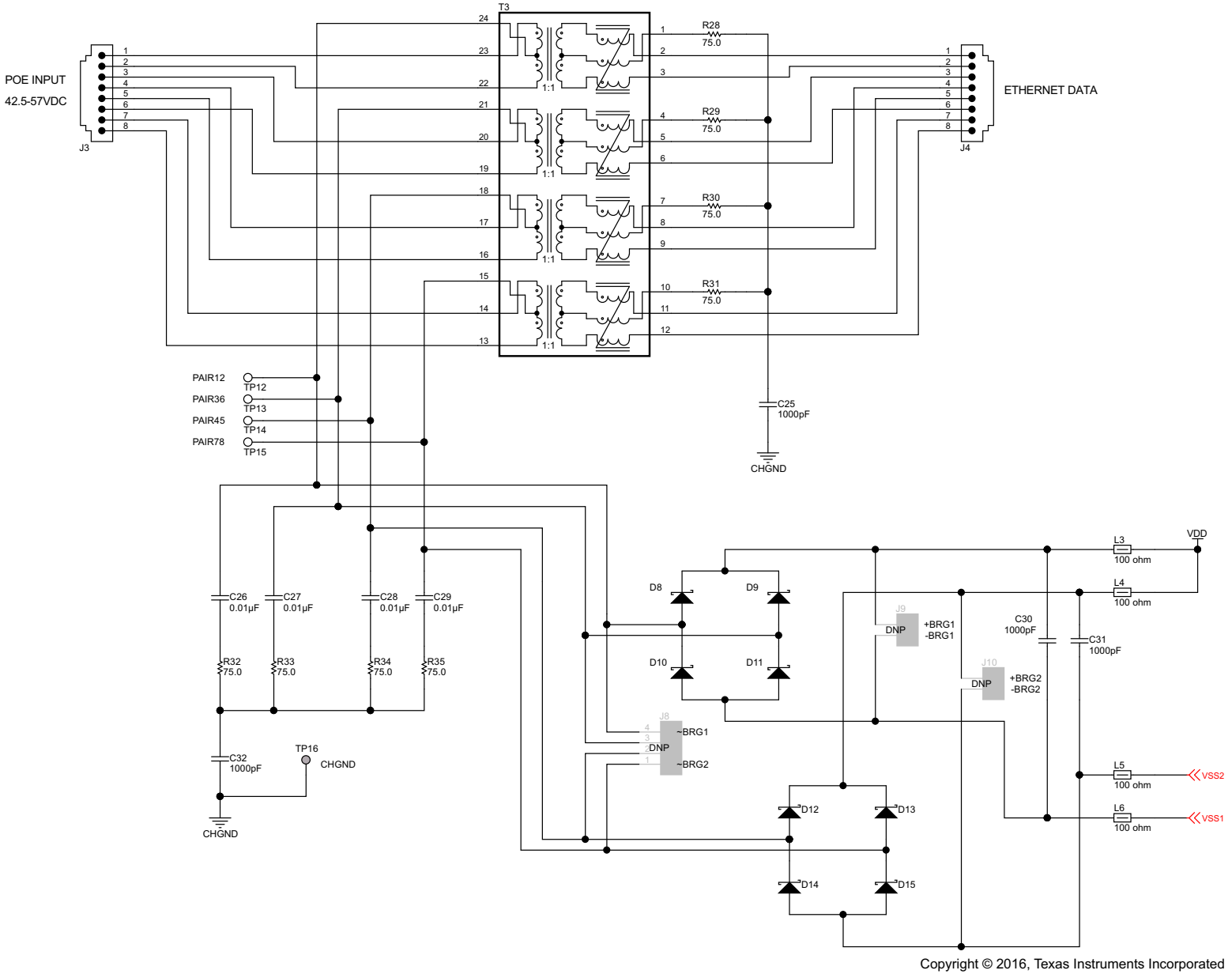

Figure 2. Schematic Diagram: Ethernet Power Input and Diode Bridge

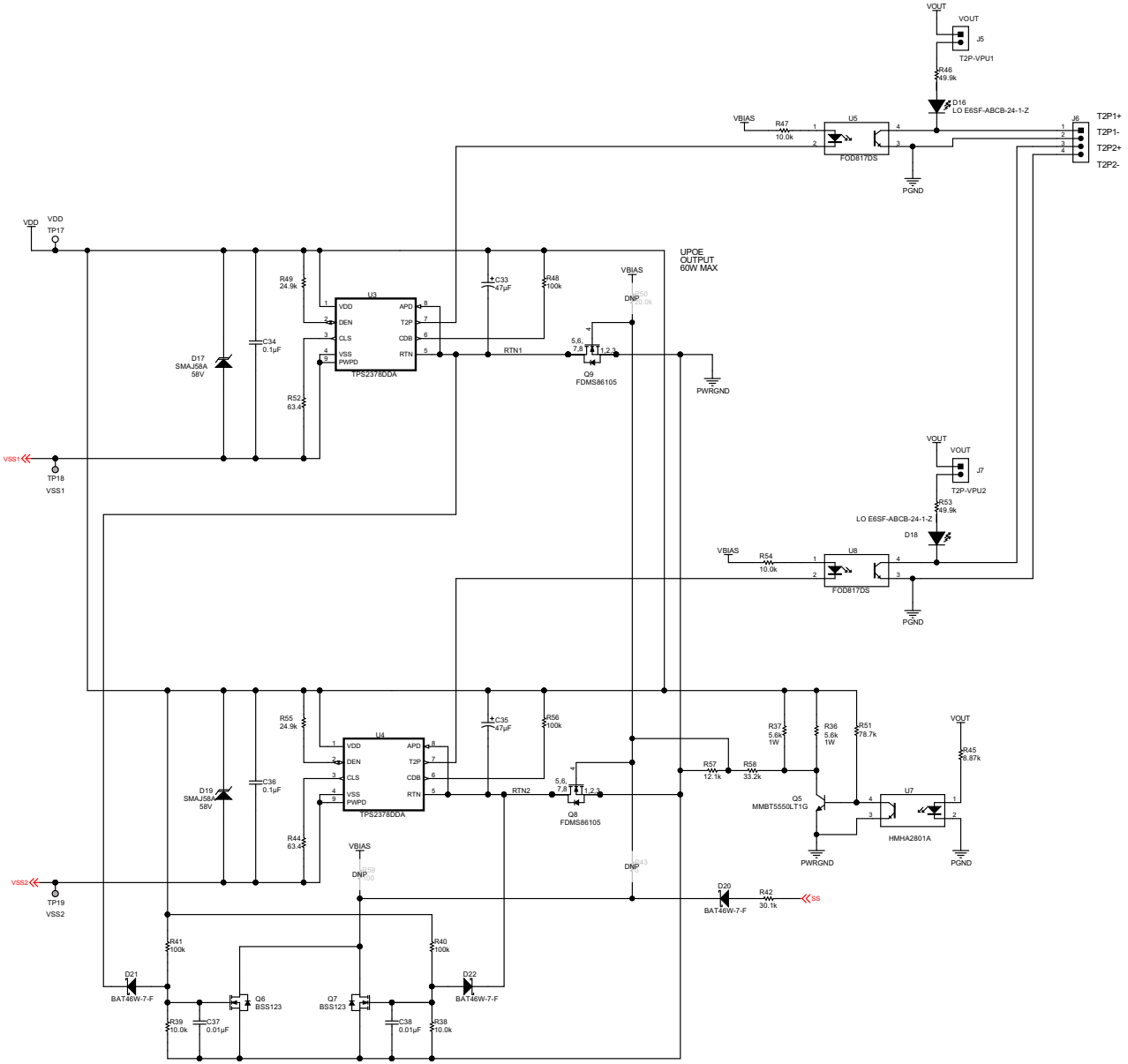

Figure 3. Schematic Diagram: Dual TPS2378, ON Control, and MPS

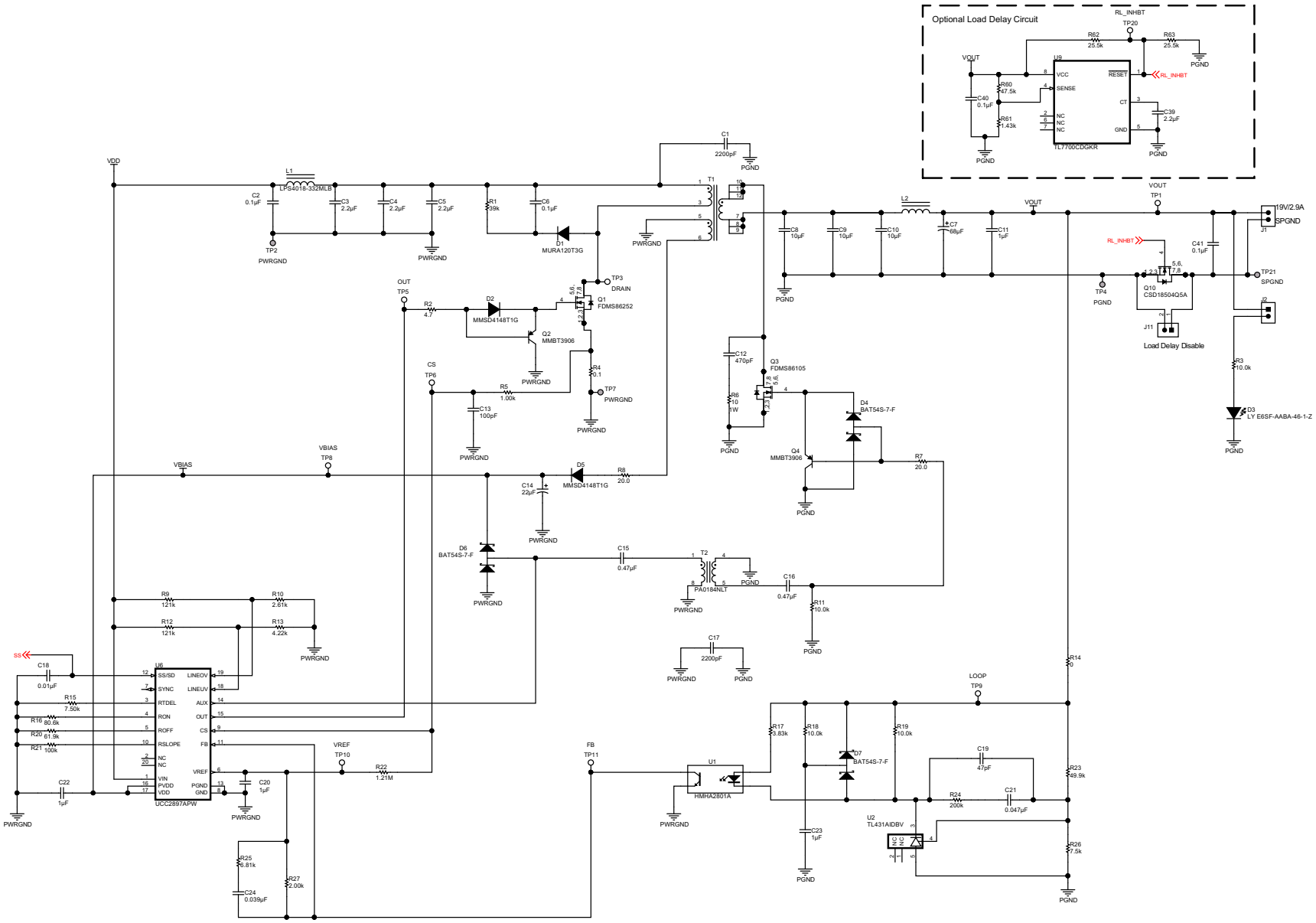

Figure 4. Schematic Diagram: High Power DC-DC Converter

Detection and classification occurs on either pair set independently because of the body diodes in the ORing MOSFETs (Q8 and Q9) in the RTN side of each TPS2378 device. If each TPS2378 RTN pin was connected together, the first powered pair set backs the bias of the diode bridges of the second pair set. In this case, the second pair set does not undergo detection and classification.

In addition to Q8 and Q9, there are two required circuits to ensure that the following must occur. Figure 3 shows these circuits.

(a) The converter does not start until both TPS2378 circuits are powered.

(b) The maintain power signature (MPS) remains presented to each PSE port until the converter is powered.

The converter disable circuit holds off converter startup by holding the DC-DC controller soft-start pin low until both TPS2378 RTN pins are low. The Q6 and Q7 circuits provide this function through a wire *OR* connection of their drains, respectively. The gates of each monitor the TPS2378 RTN pin (the drain connection of the TPS2378 internal MOSFET) and Q6 or Q7 remains ON until the respective TPS2378 RTN pin falls to a sufficient level. When both Q6 and Q7 are OFF, then SS releases. When UCDB is released, VOUT ramps up and current flows through U7 and releases Q5; the ORing MOSFETs, Q8 and Q9, turn on which shorts out the respective body diodes and further reduces the ORing loss. Diode D20 blocks any voltage from affecting the UCC2897A SS pin. R42 can be chosen at the discretion of the user.

The MPS circuit detects when the DC-DC converter output voltage is OFF. The MPS circuit then applies the minimum DC load to the PSE ports to allow the ports to remain powered until the converter draws power. When VOUT is OFF, then U8 transistor is also OFF which allows Q17 to turn ON and loads the ports with current greater than 10 mA. When VOUT is ON, then the U8 transistor turns ON and turns OFF Q17 which removes the MPS load and the additional loss element.

Type 2 PSE (T1P) hardware detection circuitry is also available for each TPS2378 device. Each T1P pin on the respective TPS2378 is connected to J4 through optocouplers. The optocoupler outputs are configured such that when both T1P signals are active (active low) each optocoupler is ON. Through wire *AND'ing* the optocouplers together, a single T1P signal is used to alert downstream loads that 51 W is available.

For additional information on the TPS2378 device, see the TPS2378 datasheet (SLVSB99).

3.1 DC-DC Converter

This section provides a short description of the circuit elements.

The following circuit elements form the power stage of the converter: transformer T1, transistors Q1 and Q3, input capacitor C2, output capacitor C10, and L2, C7, and C11 which provide additional ripple filtering. The power resistor, R36, senses the primary-switch current and converts this current into a voltage to be sensed by the primary-side controller feedback-comparator.

The primary-side voltage clamp comprises of resistor R1, capacitor C6, and diode D1. The secondary-side snubbing is provided by resistor R6 and capacitor C12.

The operating current for the UCC2897A device is provided through the self-biasing components R8, D5, and C22.

Resistor R5 and capacitor C13 filter out leading-edge current spikes which are caused by the reverse recovery of the rectifier, equivalent capacitive loading on the secondary, and parasitic circuit inductances.

Capacitor C18 programs the soft-start time.

The primary side gate-drive circuitry is composed of the phasing network, R2, Q2, and D2. The secondary-side synchronous rectifier gate-drive circuitry is composed of D6, C15, T2, C16, R11, R7, D4, and Q4.

The resistor-divider network, R23 and R26, comprises the voltage-sense feedback loop with R14 providing a 50-Ω injection point for small-signal control-loop analysis. Feedback components R24 and C21 provide the necessary gain and pole to stabilize the control loop. R17 provides bias current to optocoupler U1, and secondary-side error-amplifier and voltage-reference U2. R27 provides the proper offset for the voltage-feedback signal to be summed with the current-sense signal and the slope compensation at the FB pin of the UCC2897A device. R25 and C24 provide a compensation zero.

R18 and C23 provide secondary-side soft start. D7 helps ensure that C23 is discharged when the supply shuts down.

4 Conclusion

In conclusion, this application report provides a means to force four-pair PoE operation using only a limited amount of additional circuitry. This forced four-pair method allows for exploration of high-power PoE operation without implementation of LLDP software.

5 References

1. TPS2378 Data Sheet, SLVSB99
2. TPS2378EVM-105 User's Guide, SLVU682
3. TPS2378EVM-602 User's Guide, SLVUAG7

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (November 2013) to A Revision **Page**

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265