

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

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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.

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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](#).

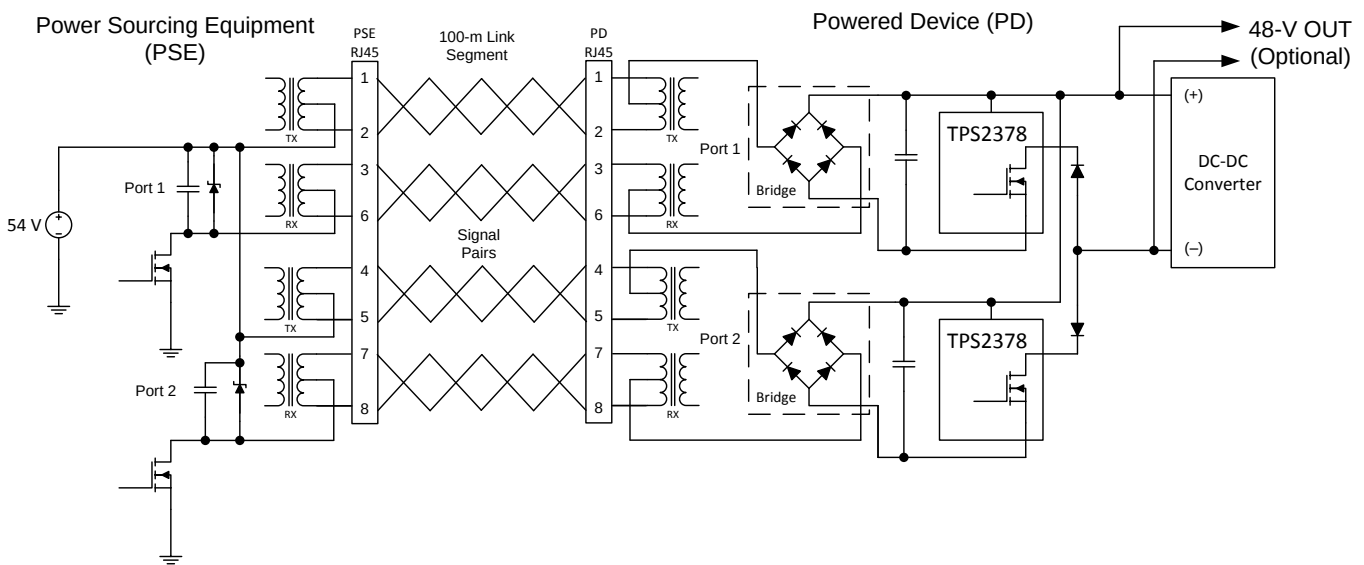


Figure 1. Top Level Block Diagram: Forced Four-Pair UPOE

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. 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.

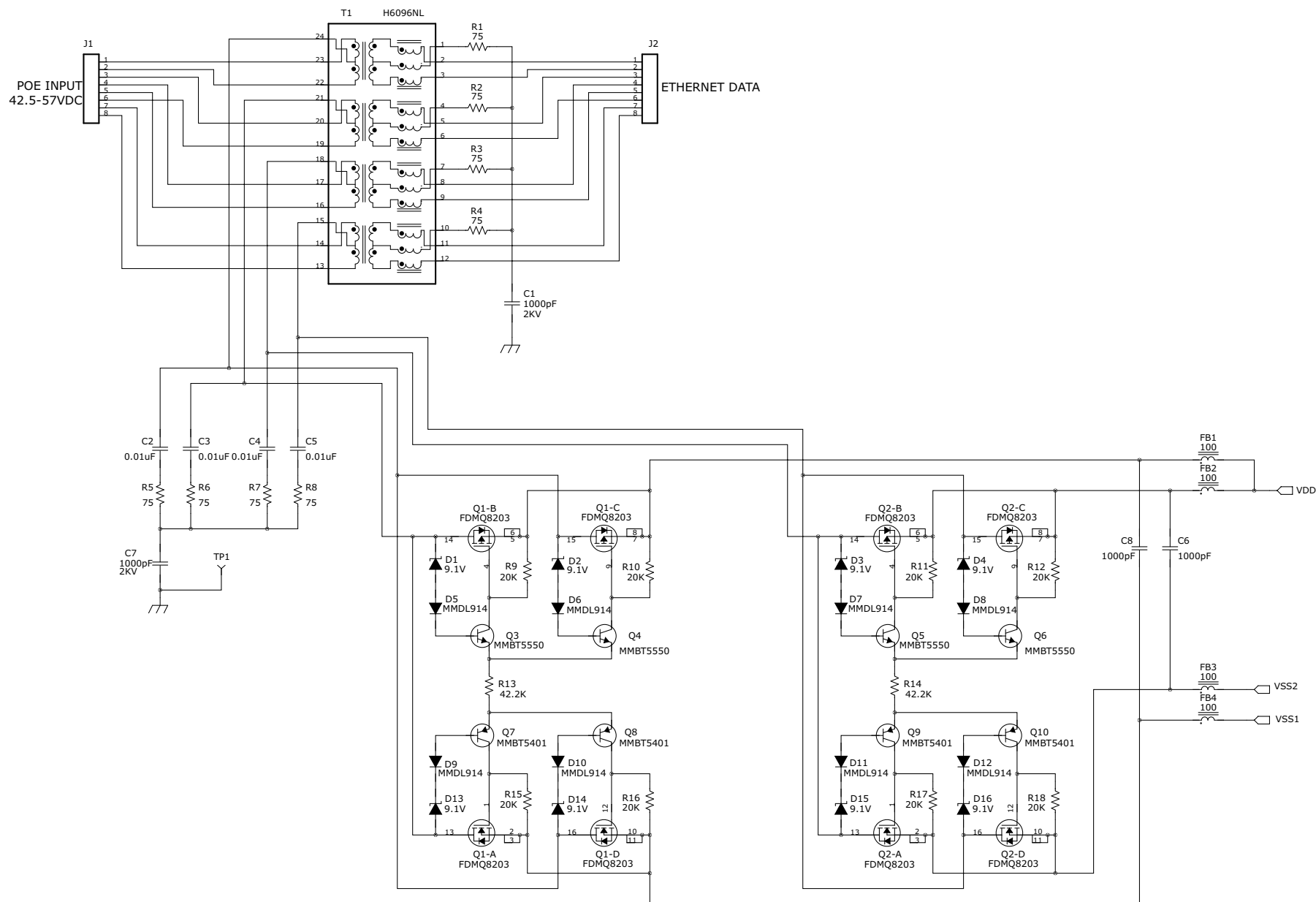


Figure 2. Schematic Diagram: Ethernet Power Input and High-Efficiency MOSFET Bridge



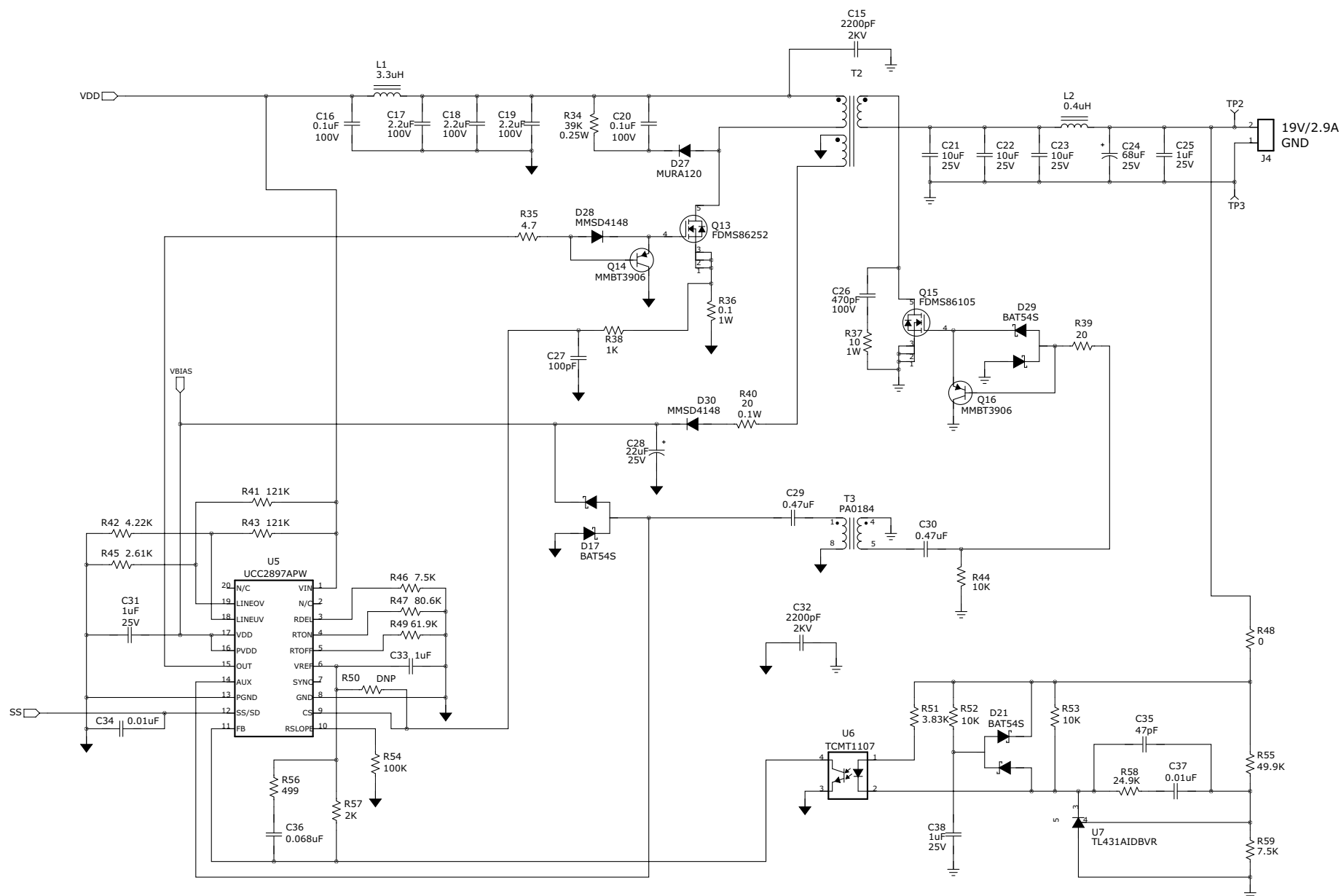


Figure 4. Schematic Diagram: High Power DC-DC Converter

Detection and classification occurs on either pair set independently because of the body diodes in the ORing MOSFETs (Q18 and Q19) 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 Q18 and Q19, 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 Q11 and Q12 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 Q11 or Q12 remains ON until the respective TPS2378 RTN pin falls to a sufficient level. When both Q11 and Q12 are OFF, then UCDB releases and is pulled up to VBIAS by R65. When UCDB is released the ORing MOSFETs, Q18 and Q19, turn on which shorts out the respective body diodes and further reduces the ORing loss. Diode D19 blocks the VBIAS voltage from affecting the UCC2897A SS pin. R29 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 (T2P) hardware detection circuitry is also available for each TPS2378 device. Each T2P pin on the respective TPS2378 is connected to J4 through optocouplers. The optocoupler outputs are configured such that when both T2P signals are active (active low) each optocoupler is ON. Through wire AND'ing the optocouplers together, a single T2P 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 T2, transistors Q13 and Q15, input capacitor C16-C19, output capacitors C21-C23, and L2, C24, and C25 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 R34, capacitor C20, and diode D27. The secondary-side snubbing is provided by resistor R37 and capacitor C26.

The operating current for the UCC2897A device is provided through the self-biasing components R40, D30, and C28/C31.

Resistor R38 and capacitor C37 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. C27 and C30 must be returned directly to the IC ground.

The primary-side controller functions are supported by external circuitry such as resistors R4/R45, R42/R32, and R46, R47, R49, and R54. Capacitor C34 programs the soft-start time.

The primary side gate-drive circuitry is composed of the phasing network, R35, Q14, and D28. The secondary-side synchronous rectifier gate-drive circuitry is composed of D17, C29, T3, C30, R44, R39, D29, and Q16.

The resistor-divider network, R55 and R49, comprises the voltage-sense feedback loop with R48 providing a 50- Ω injection point for small-signal control-loop analysis. Feedback components R58 and C37 provide the necessary gain and pole to stabilize the control loop. R51 provides bias current to optocoupler U6, and secondary-side error-amplifier and voltage-reference U7. R57 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. R56 and C36 provide a compensation zero.

R52 and C38 provide secondary-side soft start. D21 helps ensure that C38 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](#)

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