Keywords: Power over Ethernet, PoE, Current Sense Amplifier, Current sensing, Sense resistor, Ethernet cables, Power sourcing Equipment, Powered Device

APPLICATION NOTE 6220

40W SINGLE PORT MAX5971A CURRENT SENSING

Abstract: Many PoE power sourcing equipment (PSE) single port applications require real time knowledge of the powered device (PD) current used after startup. This application note details a method to obtain real time current monitoring and reporting of the actual current sent to the PD. It uses a MAX4080 high-side, current-sense amplifier and a current sense resistor on the PSE high-side power path.

Overview

Many Power-over-Ethernet (PoE) power sourcing equipment (PSE) single port applications require real-time knowledge of the powered device (PD) current used after startup. The MAX5971A PSE controller with an Integrated MOSFET is capable of delivering up to 40W in to a single port using endpoint or midspan modes. The MAX5971A features current foldback during startup and normal operation, an internal sense resistor for monitoring continuous overcurrent and short-circuit conditions. The MAX5971A powers down the port for continuous overstress. However, no mechanism is available for real-time monitoring and reporting of the actual current sent to the PD during normal operation.

This application note details a method to obtain real-time current monitoring and reporting of the actual current sent to the PD. It uses a MAX4080 high-side, current-sense amplifier, and a current sense resistor on the PSE high-side power path.

Current Sensing Methodology

Typical of a PSE, the MAX5971A internal MOSFET connects and disconnects the low-side negative 48V rail from the input 48V source negative low-side rail (V_{EE} typically). The MAX4080 high-side, unidirectional current-sense amplifier enables current monitoring without interfering with the low side (V_{EE} for Telecom) return currents or adding additional resistance to the low-side path. For a PoE application, this requires placing a current sense resistor high-side, ideally after the positive input 48V source rail and prior to the PSE Ethernet magnetics. Typically, circuitry associated with a high-side resistor must cope with large common-mode signals; however, the MAX4080 76V input voltage range applies independently to both supply voltage (V_{CC}) and common-mode input voltage (V_{RS+}). Additionally, the high-side current monitoring does not interfere with the low-side return current path of the load being measured or the MAX5971A IC's internal current monitoring. Refer to "application note 746" for additional information on high-side current sensing applications.

System and Ethernet Cable Delivery Resistance

The current sense resistor is typically chosen so that maximum load current develops full-scale voltage across the resistor. However, from a system perspective we also need to consider other resistance in the power path such as cabling and the PSE controller. Cabling wise, minimizing the EtherNet cabling system resistance is critical to delivering all available PSE power to the PD. Cat 5e EtherNet cabling has approximately 12.5Ω resistance per 100m (328ft). This resistance is for a single EtherNet cable with 8 wires, grouped into 4 pairs.

See **Figure 1** below detailing an Ethernet wire and a PoE power pair configuration using 2 pairs of 4 Ethernet wires.

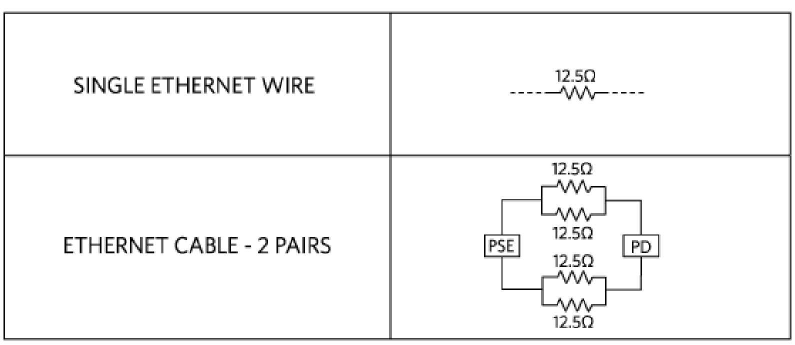

Figure 1.

Therefore the total PoE power pair loop resistance is 12.5Ω (6.25Ω + 6.25Ω) when considering the PSE supply and return lines to the PD. See Figure 1.

The MAX5971A's internal MOSFET switch has a typical and max $R_{DS(ON)}$ of 0.6Ω and 1.3Ω respectively at 85°C. Thus, from a power-loss perspective the current-sense resistor should be significantly less than these values and not add much to the overall cabling and system resistance.

From a current-sensing resistor perspective, higher resistance values allows lower currents to be accurately measured. Additionally, the sense resistor I^2R loss at high current can become significant, increase the resistor temperature and introduce measurement drift.

Choosing the high-side sense resistor requires balancing power-loss constraints, accuracy and temperature-introduced drift. For this application, the sense resistance was chosen at less than 20% of the MAX5971A MOSFET typical resistance;thus, a 0.100Ω sense value was selected. The MAX4080 provides an analog voltage output proportional to the load current flowing through the high-side sense resistor. As a result, a 1A maximum current, an analog voltage range of 0V-6V and maximum MAX4080 V_{OUT} voltage of 6V was selected.

The MAX4080 gain needed to yield a maximum 6V output voltage (V_{OUT}) required for the application is:

$$A_V = V_{OUT}/V_{SENSE} = 6V/0.100V = 60V/V$$

Where V_{SENSE} is the full-scale sense voltage (1A × 0.100Ω) and A_V is required MAX4080 gain of 60V/V.

The sense resistor power dissipation, P_{SENSE} is as follows:

$$P_{SENSE} = I_{LOADMAX}{}^2 \times R_{SENSE} = 1A^2 \times 0.100\Omega = 0.1W$$

Where $I_{LOADMAX}$ is the maximum load current and R_{SENSE} is the sense resistor value.

Refer to the MAX4080 IC data sheet "Choosing the Sense Resistor" section for additional information.

PSE and Current Sense Configuration and PD Connection

A MAX5971A evaluation kit was configured for midspan operation and the controller's overcurrent threshold and current limit were configured for the desired Class 0-4 power level operation. Refer to the MAX5971A data sheet powered device classification (PD classification) section for more information and **Table 1** for configuring the controller.

Table 1. MAX5971A Current Limit ILIM1 and ILIM2 Configuration.

IC CLASSIFICATION	ILM1 PIN (JUL1)	ILM2 PIN (JUL2)	OVERCURRENT Threshold (mA)	CURRENT LIMIT (mA)
Class 0-Class 4	Not installed	Not installed	Class 5 disabled	Class 5 disabled
CLASS 5	Installed	Not installed	748	850
CLASS 5	Not installed	Installed	792	900
CLASS 5	Installed	Installed	836	950

Referring to the MAX5971A evaluation kit data sheet, page 5 and Tables 4 and 5, Jumper JU4 and resistors R5-R8 were configured for midspan on the EV kit. Resistor R7 was replaced with a 0.100Ω1% 1206 case-size surface-mount resistor for current sensing on the high-side positive rail (GND of MAX5971A evaluation kit).

A 16-gauge wire was utilized to connect the MAX5971A PSE evaluation kit V_{EE} 2-hole pad to a MAX4080 evaluation kit GND 2-hole pad. Another 16-gauge wire was utilized to connect the MAX5971A PSE evaluation kit GND 2-hole pad to the MAX4080 evaluation kit V_{CC} 2-hole pad.

Sense resistor R1 on the MAX4080 evaluation kit was removed and 24-gauge twisted pair wires were soldered to the MAX4080 and MAX5971A evaluation kits as follows. One red wire of the 24-gauge twisted pair wires was connected to the MAX5971A PSE evaluation kit resistor R7 GND side and the other end of the red wire to the MAX4080 evaluation kit V_{SENSE}+ 2-hole pad. The black wire of the #24 gauge twisted pair wires was connected to the MAX5971A PSE evaluation kit resistor R7 VC3 side and the other end of the black wire to the MAX4080 evaluation kit V_{SENSE-} 2-hole pad. See **Figure 2** for both of the ev kit's connections.

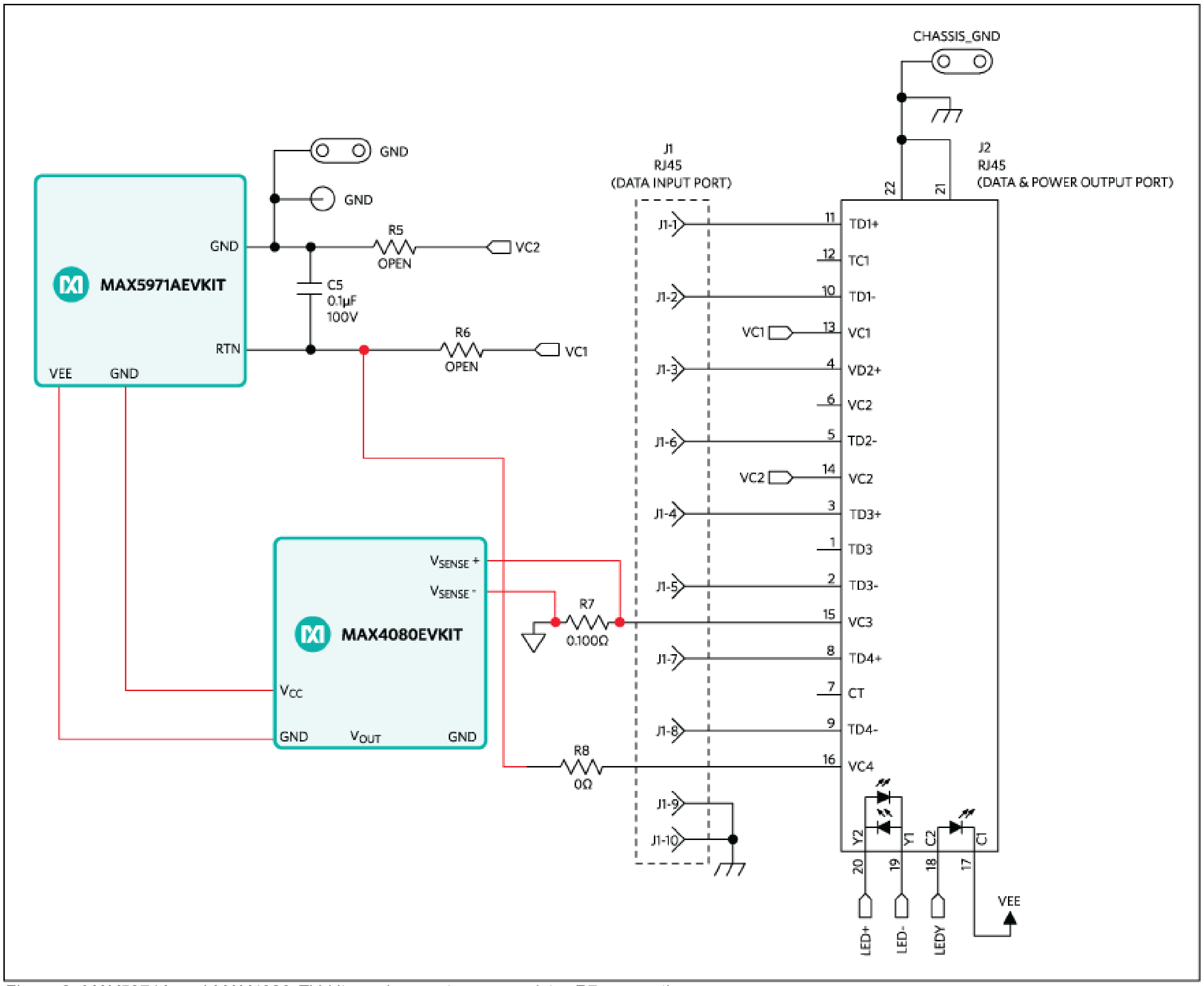

Figure 2. MAX5971A and MAX4080 EV kits and current sense resistor R7 connections.

A seven-foot (2.1m) Cat 6 Ethernet cable was used to connect the MAX5971A PSE Ethernet RJ45 output port to the RJ45 input port on a 22W high power PD, a MAX5969B EV kit. The ev kit's PD controller's raw 48V output (V_{DD} and R_{TN}) was connected to an HP6060B electronic load + and – input terminals.

Lab Verification

Test data was taken at various PD current loading for PSE MAX5971A input voltages of 57V, 48V, and 40V input rails. Refer to the "6220_PSE_MAX5971A_CurrentSense_appnote_data" excel spread sheet for the 57V, 48V, and 40V cases data. The test data demonstrates the MAX4080 current measurements at various power and voltage levels. The minor differences between the PSE-MIDSPAN Iin_mid currents (PSE input) versus the I_PD currents (R7 current sense resistor) are the MAX5971A and MAX4080 circuits' operational and supply currents (6mA-11mA). The PD current Iout_pd also correlates well with the MAX4080 current measurements and differences are due to the PD DC-DC converter switching and supply currents (7mA-10mA). Refer to the Excel spreadsheet for the respective data.

Transient load testing at a PSE input voltage of 48V was done next. The Ethernet cable was replaced with a 3ft (0.91m) Cat 6 Ethernet cable with the blue/white pair 1 exposed to measure PD current. The MAX5969B PD's minimum loading and quiescent current is about 7mA-10mA when measured at the Ethernet cable, at 48V. Test data for DC loading of 100mA and transient current of 600mA at a Frequency of 20Hz and duty cycles of 10%, 20% and 50% was taken using an oscilloscope. Channel 1 was the MAX4080 EV kit V_{OUT} signal and channel 2 was the Ethernet cable (Blue/white, pair 1) measured current feeding the MAX5969B EV kit input. For the channel 1, dividing the RMS or AMPL voltages by 6 yields the respective measured current. Channel 2 is the measured current to the MAX5969B EV kit input. Refer to Appendix A **Figures 3-5** demonstrating transient current loading for the respective scope shots. Current data for both channels correlate to within 2 significant digits.

Conclusion

For PoE end applications requiring real time current monitoring after startup and reporting from a 40W single port PSE, the MAX5971A PSE controller with Integrated MOSFET and a MAX4080 high-side current-sense amplifier is an excellent cost-effective simple solution. This method avoids changing the 48V low-side rail resistance and accurately measures real time current used by the PD during operation.

Appendix

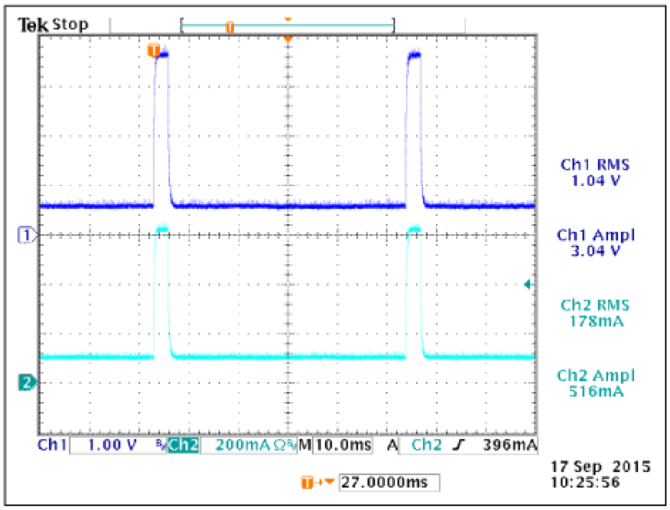

Figure 3. 100mA DC and 600mA transient current loading at 20Hz, 10% duty cycle.

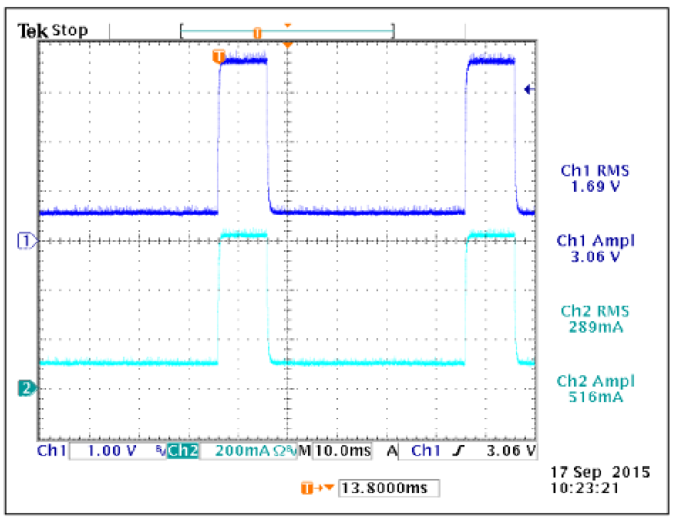

Figure 4. 100mA DC and 600mA transient current loading at 20Hz, 20% duty cycle.

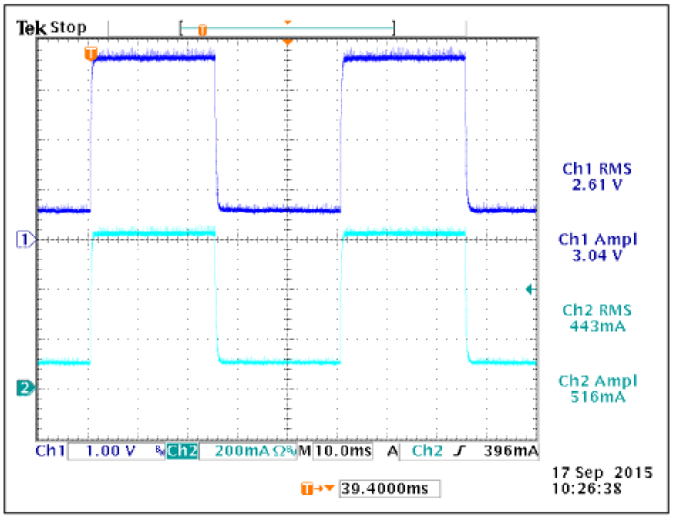

Figure 5. 100mA DC and 600mA transient current loading at 20Hz, 50% duty cycle.

Related Parts		
MAX4080	76V, High-Side, Current-Sense Amplifiers with Voltage Output	Free Samples
MAX5969B	IEEE 802.3af/at-Compliant, Powered Device Interface Controllers with Integrated Power MOSFET	Free Samples
MAX5969BEVKIT	Evaluation Kit for the MAX5969A and MAX5969B	
MAX5971A	Single-Port, 40W, IEEE 802.3af/at PSE Controller with Integrated MOSFET	Free Samples
MAX5971AEVKIT	Evaluation Kit for the MAX5971A	

More Information
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