Monitoring DRV3205-Q1 Die Temperature with RVSET Pin

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ABSTRACT

The DRV3205-Q1 offers a feature that allows the system designer to track the thermal behavior of the device through the RVSET pin by monitoring its voltage. This application report covers how to enable this feature on the DRV3205-Q1 and how it can be used effectively.

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1 Purpose of RVSET Thermal Voltage

The RVSET thermal voltage allows direct access to the DRV3205-Q1 die temperature without any external components. This feature allows the system designer to track the die temperature of the device when measuring the offset voltage of the current sense amplifier (CSA) of the device as the temperature varies. The CSAs for the DRV3205-Q1 device have a typical ±1-mV initial offset at room temperature with an additional ±1 mV across temperature. The true temperature of the die is typically 5°C to 10°C above the free air temperature during no load operation. System designers can monitor the RVSET voltage and calibrate the offset of the CSAs on that voltage as the device varies with temperature.

The RVSET voltage can also be used to give a baseline of the expected thermal response of the device under a given load. The DRV3205-Q1 generates heat when sourcing and sinking current to and from the gate of the external MOSFETs as well as from the operation of the integrated boost regulator. The higher the current that is required to switch the external MOSFETs the more power is dissipated, in turn creating more heat from the device. The RVSET Thermal voltage can be used to characterize the device behavior across varying loads on the device.

2 Theory of Operation

The basis of how the RVSET pin can characterize temperature from a voltage uses the simple PN junction of a diode. If a constant current is applied to a diode, then the voltage measured across that diode will vary linearly with temperature. The circuit for the RVSET thermal voltage actually uses two diodes. Figure 1 shows the circuit for the RVSET thermal voltage.

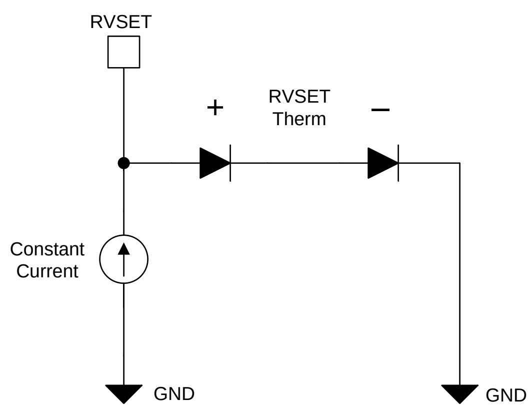

Figure 1. Simplified Circuit for RVSET Thermal Measurement

3 Accessing RVSET Thermal Voltage

The RVSET pin on the DRV3205-Q1 is primarily used to set the overvoltage and undervoltage thresholds of the VDDIO and ADREF pins on the device. These limits are determined by the value of the resistor that is connected from the RVSET pin to ground. By default, the RVSET pin is used at startup of the device and is not used again.

To access the RVSET thermal voltage, use the steps that follow:

Step 1. Power on and enable the DRV3205-Q1 device.

Step 2. Enter diagnostic mode.

Step 3. Enable bit one of the Configuration 8 register.

Step 4. Measure the voltage from the RVSET pin to ground.

4 Interpreting the RVSET Voltage

To verify the relationship between the RVSET thermal voltage and temperature, an experiment to vary the temperature of the DRV3205-Q1 and monitor how the RVSET thermal voltage responds was conducted. The DRV3205-Q1 device was placed in a configuration to force the temperature around the device. Figure 2 shows a block diagram of the setup.

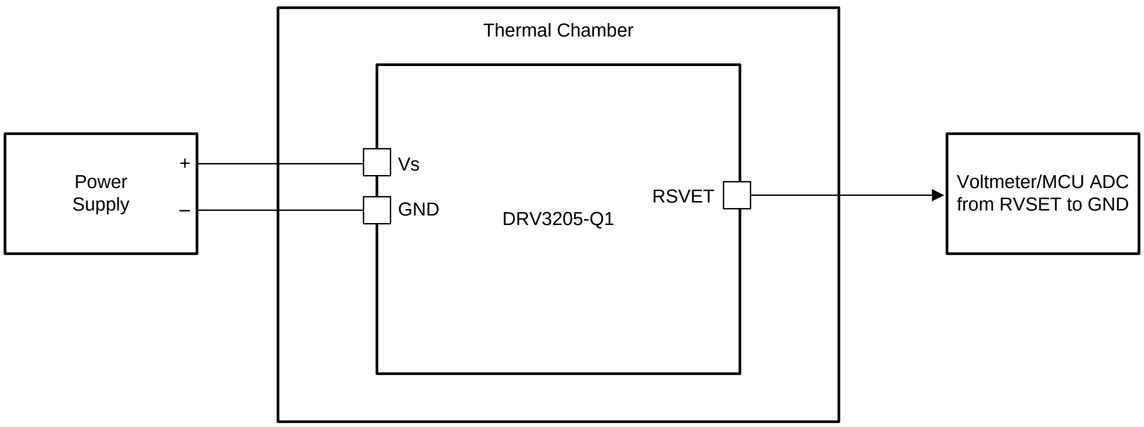

Figure 2. Block Diagram of Setup for RVSET Thermal Measurement With Necessary Pins Outlined

The RVSET voltage was recorded for various temperatures ranging from –40°C, the lowest operating point of the DRV3205-Q1 device, all the way up to the thermal shutdown of the device at approximately 190°C. Figure 3 shows that he RVSET thermal voltage is linear throughout these temperatures.

The data in Figure 3 is typical of most devices, but the slope and the offset of the line can vary slightly. Figure 4 shows the same data as Figure 3 with some possible results for multiple devices.

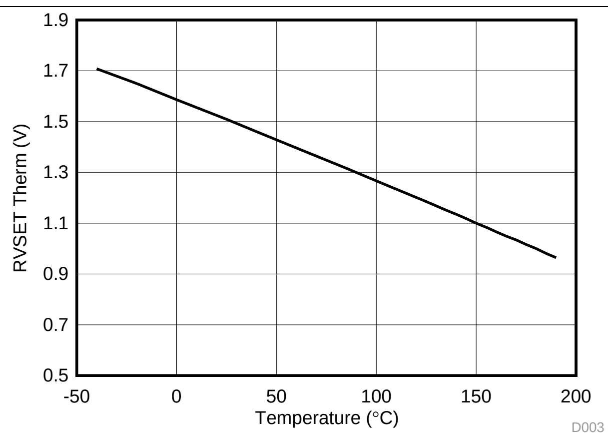

Figure 3. Characterizing RVSET Thermal versus Temperature

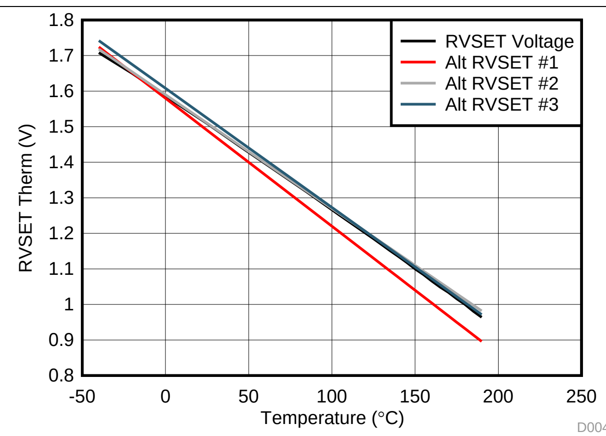

Figure 4. Data from Figure 3 With Other Possible Outcomes of RVSET Thermal Overlaid

5 RVSET Thermal for Current Sense Amplifier Offset Calibration

The RVSET thermal voltage can be used to characterize the offset voltage of the on board CSAs of the DRV3205-Q1 device. The offset voltage of the CSAs will shift across temperature, though this relationship may not be linear with respect to temperature like the RVSET thermal voltage. Figure 5 shows a schematic of the DRV3205-Q1 CSAs.

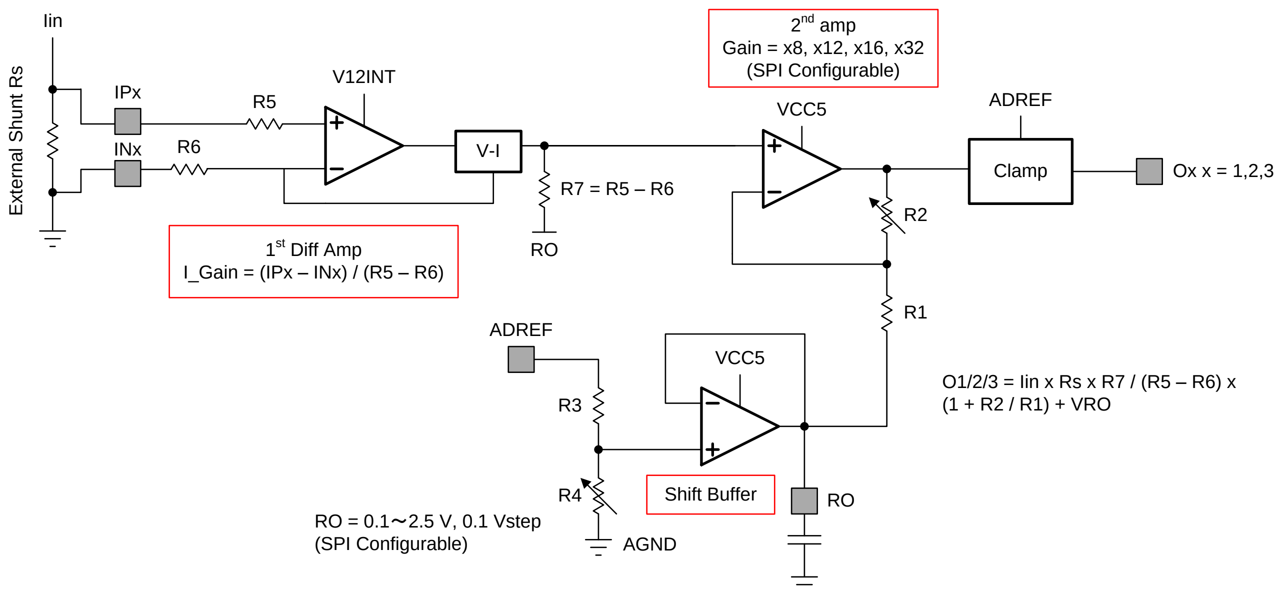

Figure 5. DRV3205-Q1 Current Shunt Amplifier Schematic

The DRV3205-Q1 device has three current sense amplifiers. The three pins that are of concern for CSA offset voltage measurement are the IPX, INX, and OX pins. To measure the offset voltage for the CSAs, the IPX and INx pins must be shorted to a common voltage while the voltage at the output of the amplifier, OX pin, is measured.

The way this configuration is done across temperature is by using a similar setup as mentioned previously where the temperature of the device is forced in a thermal chamber, but instead of only monitoring the RVSET thermal voltage, the offset voltage of the CSA is monitored as well. Figure 6 shows a block diagram of the typical setup for this measurement.

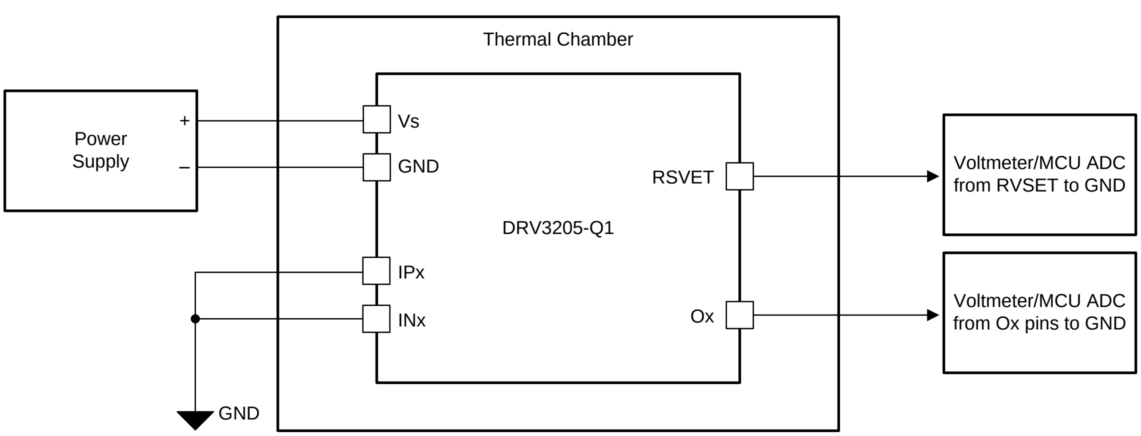

Figure 6. Typical CSA Offset Characterization Setup With Necessary Pins Outlined

Figure 6 shows that the IPX and INX pins are shorted to a common voltage of zero and the RVSET and OX pin voltages are measured as the temperature is forced on the device. To characterize the CSA offset, the device will typically be forced to three temperatures, 25°C, –40°C, and 125°C. The RVSET voltage and the offset of the CSAs are then recorded with a voltmeter or an ADC on an MCU. This process is repeated for all three CSAs on the device. The offset of the CSAs are then characterized versus the RVSET thermal voltage at the forced temperatures. Because this relationship is not always linear, a general function may need to be computed to determine the relationship between the CSA offset voltage and the RVSET thermal voltage.

When a function for the offset voltage is determined with respect to the RVSET voltage it can be programmed inside the MCU that is used in tandem with the DRV3205-Q1. Figure 7 shows a high level diagram of a typical application of the RVSET thermal voltage for the device.

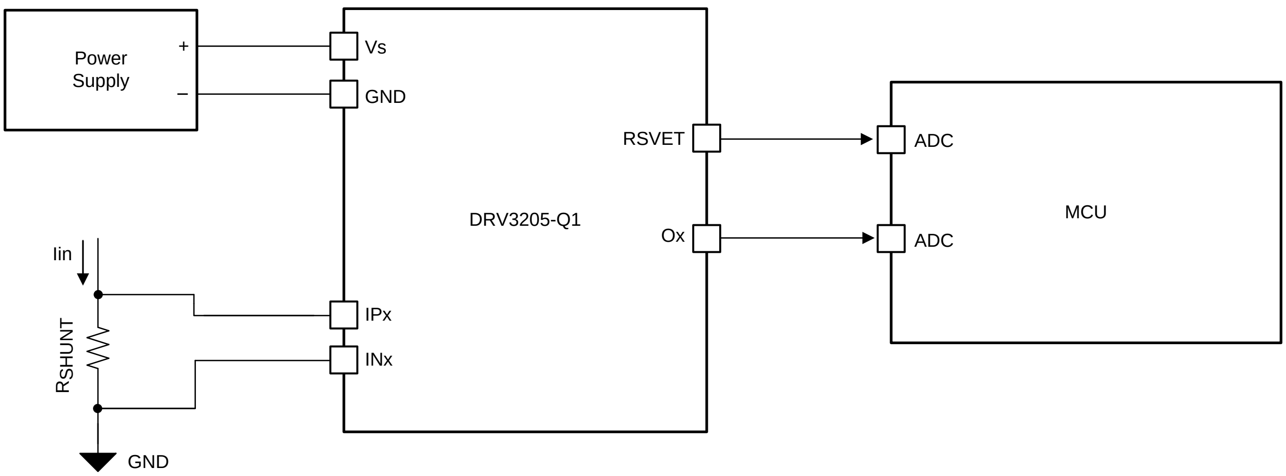

Figure 7. RVSET Thermal Implementation in System for CSA Calibration

The RVSET voltage is applied to an ADC on the MCU and is constantly sampled. The offset voltage for each CSA is calculated by the function that is programmed inside of the MCU, and when the offset for each amplifier is calculated, it will be subtracted from the measured value of the OX pin. This process helps improve the performance of the CSAs across temperature by essentially removing the offset voltage through feedback from RVSET pin on the device.

6 RVSET Thermal Across Varying Loads

The RVSET thermal voltage will change as the average current needed to drive the external MOSFETs changes. This current drives the external MOSFETs, and is supplied from the boost converter on the DRV3205-Q1. The average current that is required from the device depends on the size of the gate charge of the external MOSFETs (Q_G), the number of MOSFETs, and the switching frequency (f_{SW}). Use Equation 1 to calculate the average current (I_{avg}).

$$I_{avg} = Q_G \times \text{No. of MOSFETs} \times f_{SW} \quad (1)$$

The RVSET thermal voltage can be monitored to set a baseline of expected thermal behavior on the device. Figure 8 shows how the RVSET thermal responds to a varying load on the boost converter.

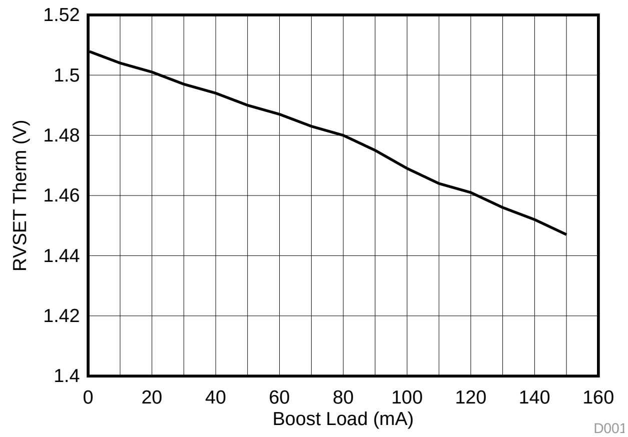

Figure 8. RVSET Thermal as Boost Load Varies

Figure 8 shows that as the load on the boost is increased, the RVSET thermal voltage steadily decreases which would imply a gradual increase in temperature with increasing load. The system designer can characterize the RVSET thermal across varying loads, which allows them to set a baseline of expected thermal behavior of the device.

7 Conclusion

The RVSET thermal function on the DRV3205-Q1 is very useful for monitoring thermal performance of the device. This feature gives a sense of the die temperature of the part without any external devices which can be used to calibrate the onboard CSAs and set an expected level of the thermal performance of the DRV3205-Q1. This feature comes at no additional cost to the customer and has no impact on board space. Just simply enable the feature in the configuration registers and monitor the voltage on the RVSET pin.

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