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Source Measurement Unit (SMU) Instruments Simplify Characterizing a Linear Voltage Regulator's DC Performance

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Linear voltage regulators (LVRs) are essential elements of power management systems. They provide the constant voltage rails required by any electronic circuit designed to operate at specific DC levels. A properly designed voltage regulator will maintain the specified output voltage continuously, regardless of changes in the input voltage or load current.

The two main types of LVRs, conventional and low dropout (LDO), function on the same principle, but an LDO LVR requires a lower input voltage in excess of the output voltage to operate than a conventional type does, thereby reducing the amount of power needed to operate it. As a result, low dropout regulators are better suited for battery-powered electronics and portable handheld communication devices.

This article discusses how to characterize some common DC electrical characteristics of LVRs, including line regulation, load regulation, dropout voltage and quiescent current. These parameters are applicable to qualifying both conventional and LDO LVRs for specific applications.

Testing an LVR requires a variable power source for the input side and a variable load for the output side. Source Measurement Unit (SMU) instruments are excellent candidates for these applications because voltage and current measurements must be made on both sides of the regulator. One SMU instrument can act as a power source on the input side; a second SMU instrument on the output side can act as a load. A growing number of test equipment vendors have begun offering system-level SMU instruments that house multiple SMU instrument channels in a single enclosure. For applications like these, a dual-channel SMU instrument like Keithley's Model 2602A System SourceMeter® instrument (***Figure 1***), could serve as an economical substitute for two separate SMU instruments.

Configuring an LVR Characterization System

As illustrated in ***Figure 2***, SMU_1 is connected to the input side of the regulator and is configured to source voltage and measure current (SVMI). The voltage sourced is the desired input voltage(s) applied to the regulator. The compliance, or the current limit, is set to a value higher than the maximum output current of the voltage regulator in order to account for the LVR's current consumption.

SMU_2 is connected to the output side of the regulator. It also sources voltage and measures current (SVMI). However, the voltage is configured as a fixed value that's lower than the expected output voltage of the regulator. SMU_2 automatically switches to sinking, or drawing, current from the regulator, thereby acting as a load. The compliance current, or the current limit, is set to the desired load current. Given that an SMU instrument operates on the principles of range, it is important to ensure that SMU_2's voltage range encompasses the expected output voltage of the regulator to ensure the regulator output voltage is measured correctly.

LVRs may require external capacitors to ensure stable operation of the voltage

Figure 1. Series 2600A Dual-Channel System SourceMeter instruments.

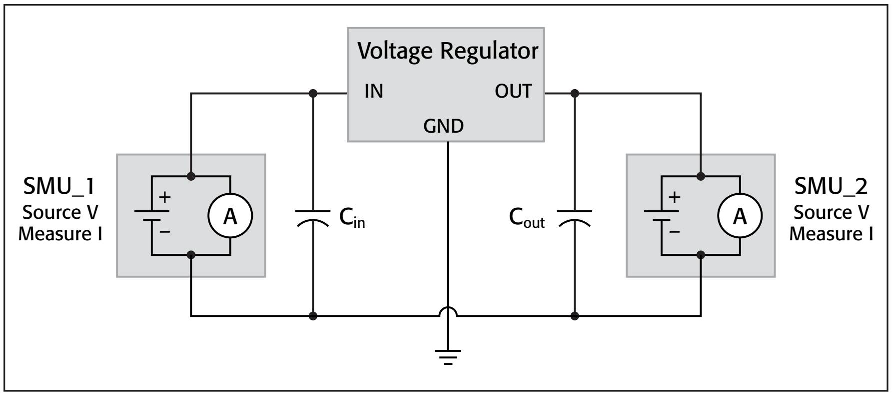

Figure 2. Block diagram of LVR test using two SMU instruments.

regulators. These are usually bypass capacitors to ground, indicated as C_{in} and C_{out} in ***Figure 2***, added on the input and output terminals. Large capacitors at these terminals can cause the SMU instruments to be unstable at small current ranges. Some SMU instruments may offer advanced modes of operation to improve stability in cases of large capacitive loading. Alternatively, adding a series resistor or back-to-back parallel diodes will also improve stability.

The use of heat sinking is another important consideration when characterizing LVRs. An LVR's parameters are temperature sensitive and overheating a packaged regulator will produce unintended damage. Therefore, heat must be removed from the device appropriately, taking power dissipation and the ambient temperature at the intended operating conditions into account.

LVR Parameters to be Characterized

SMU instruments are well-suited for characterizing a variety of LVR parameters, including line regulation, load regulation, dropout voltage, and quiescent current.

Line regulation

Line regulation testing characterizes an LVR's ability to maintain the specified output voltage as the input voltage changes under a constant load condition. Typically, the output voltage is expected to vary less than 100mV. The power dissipation should be carefully monitored to reduce the effect of temperature change on the device.

In a line regulation test, SMU_1 is configured to sweep the input voltage within the maximum allowed input voltage of the regulator. SMU_2 is configured to source a fixed voltage less than the expected output voltage of the regulator, allowing SMU_2 to sink current. The compliance current is set to the desired constant load condition.

Figure 3 illustrates a typical measurement taken in a line regulation test sweeping Vin from 8V to 20V with the compliance current set to 5mA, 500mA and 1A.

Depending on the size of the bypass capacitor on the input side, a delay may be required to allow sufficient time for charging the capacitor prior to continuing the sweep.

Load regulation

A load regulation test measures the LVR's ability to maintain the specified output voltage as the load current varies under a constant input voltage. Typically, the output voltage is expected to vary less than 100mV. As high load currents can change the operating temperature of the device, it is important to remove heat from the device so the measurement is taken under a constant temperature condition.

In the load regulation test, SMU_1 is configured to a fixed input voltage. SMU_2 is configured to source a fixed voltage less than the expected output voltage of the regulator, allowing SMU_2 to operate in current sink mode. Compliance current should be varied to reflect the desired load current levels. ***Figure 4*** illustrates a typical measurement of V_{out} vs. I_{load}, where I_{out} varies from 0A to 0.95A at V_{in} levels of 8V, 15V, and 20V.

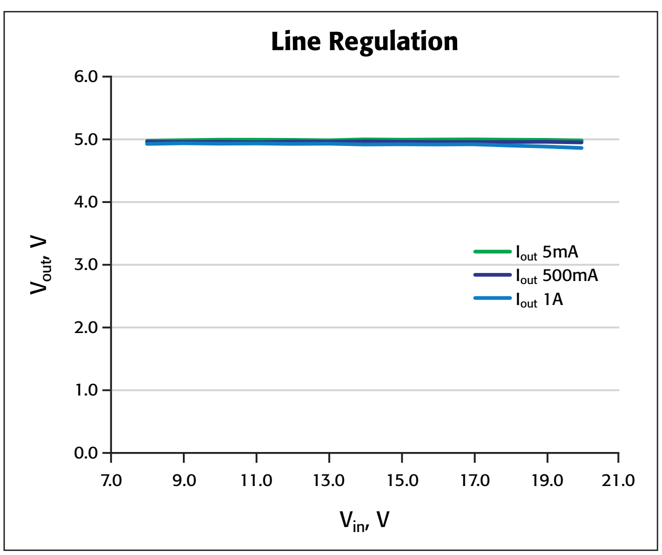

Figure 3. Plot of LM340 line regulation.

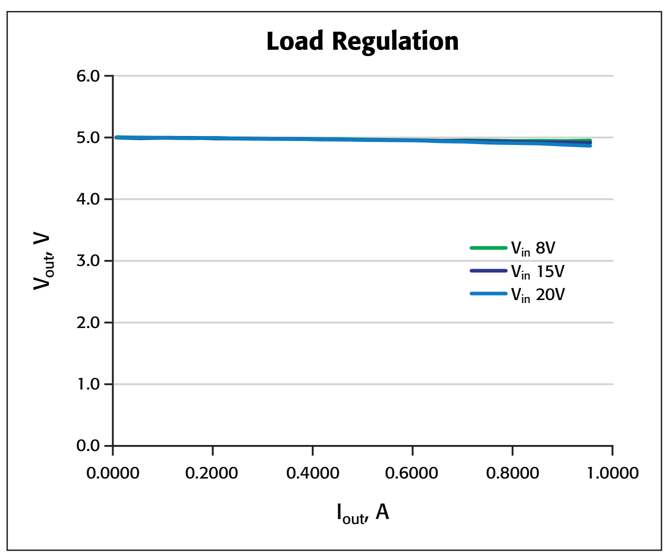

Figure 4. Plot of LM340 load regulation.

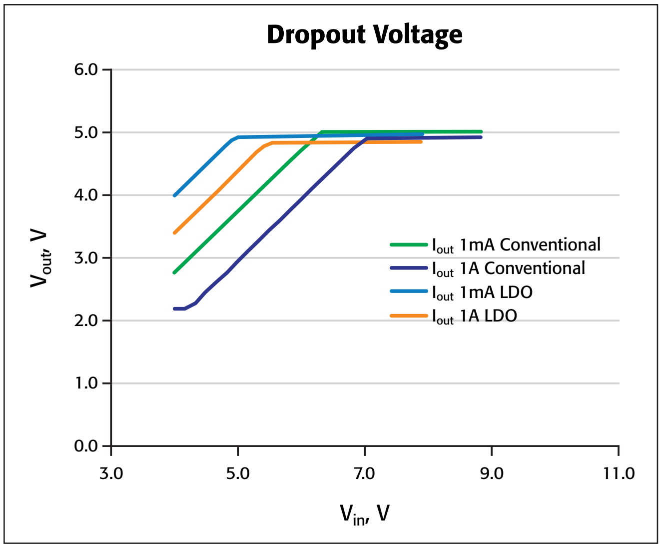

Figure 5. Plot of LM340 dropout voltage.

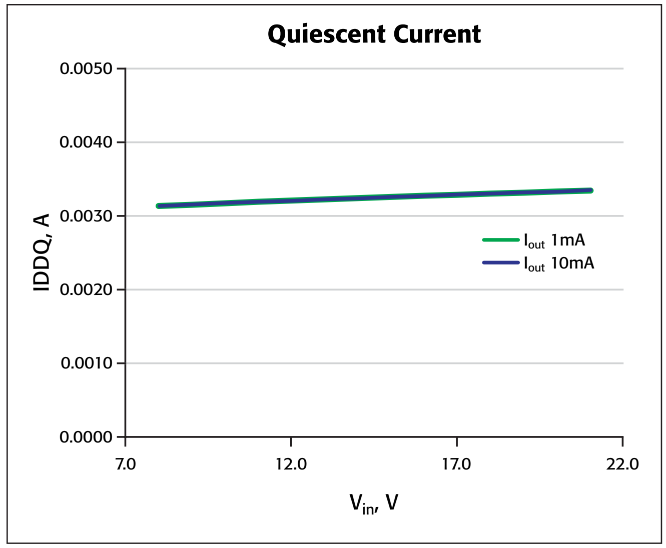

Figure 6. Plot of LM340 quiescent current.

Dropout voltage

An LVR's dropout voltage specifies the minimum input voltage in excess of the output voltage necessary to achieve the specified output voltage. For an LVR, the input voltage must always be higher than the output voltage. LDO regulators operate at a smaller input and output voltage differential than conventional LVRs. This characteristic is important in battery-powered applications, where current efficiency and low power consumption are critical.

The dropout voltage test employs SMU_1 to sweep the input voltage of the regulator; SMU_2 is configured to source a fixed voltage less than the expected output voltage of the regulator in order to draw current. The compliance current is set to the desired constant load condition. Voltage measurements taken on both the input and output sides during the sweep will show the LVR's characteristic dropout voltage. ***Figure 5*** illustrates the typical dropout voltage at Iout set to 5mA and 1. The LDO regulator's output voltage drops out at close to 5V; in contrast, the conventional regulator's output voltage drops out at 6V or higher.

Quiescent current (IDDQ)

Quiescent current is the difference between the input current and the output current of a voltage regulator. This is the current used to operate the regulator that is not delivered to the load. Quiescent current is normally specified at no-load or very small load conditions. Much as with dropout voltage, maintaining control over this parameter is critical in battery-powered applications.

The quiescent current test setup involves setting SMU_1 to sweep the input voltage of the regulator. SMU_2 is configured to source a fixed voltage less than the expected output voltage of the regulator to operate in sink mode. The compliance current is set to the desired constant load condition. The differences in current measurements taken on the input and output sides at different load conditions will indicate the LVR's quiescent current characteristics. ***Figure 6*** shows a typical quiescent current measurement at Iout levels of 1mA and 10mA.

Conclusion

SMU instruments offer a wide variety of advantages for LVR DC characterization, including their flexibility in sourcing either voltage or current while measuring both voltage and current. They can operate as a precision power supply or a variable load with accurate measurement capabilities. They are good all-around "workhorse" additions to many researchers' and engineers' toolboxes. KEITHLEY

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