Steady-State Characteristics of Voltage Regulators

Part I: Linear Regulators

This document will guide you through the measurement of the steady-state characteristics of two voltage regulators: the L7805CV and the TPS7250. Both are linear series regulators with fixed, 5V output.

The objective of this lab is to extrapolate the following steady-state characteristics of the regulators:

1) Line regulation $\frac{\Delta V_O}{\Delta V_I}$
2) Load regulation $\frac{\Delta V_O}{\Delta I_O}$
3) Efficiency $\eta = \frac{P_O}{P_I}$

These parameters will be calculated using voltage/current data obtained through an automated test rig specifically designed to test power converters at different operating conditions.

1. Devices under test

The L7805CV, manufactured by ST Microelectronics, is a 3-terminal linear regulator with a fixed output of 5V and a maximum output current of 1.5A. Please refer to the datasheet for the detailed electrical characteristics.

The pinout of the IC is shown in Figure 1. Note that the tab of the package, attached to the heatsink without any kind of electrical insulation, is internally connected to pin 2 (GND).

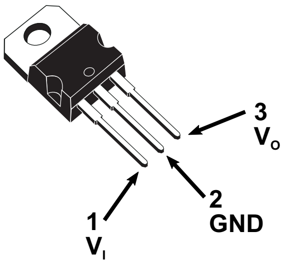

Figure 1. TO-220 pinout of the L7805CV.

The TPS7250 is a low drop-out (LDO) linear regulator manufactured by Texas Instruments; the device has a fixed output of 5V, and delivers up to 250mA of load current. Unlike the L7805CV, this device provides a separate feedback pin for sensing the output voltage (though it is locally tied to the output on the ASLK board). Please refer to the datasheet for the electrical characteristics.

2. Test instrumentation

The test rig is composed of an electronic load (Keysight N3300A) and a bench power supply (Keithley 2260B-80-13), both having remote control and measurement capabilities. The instruments are interfaced and controlled by a MATLAB script running on a host computer.

This setup allows you to perform automatic load (output current) and line (input voltage) sweeps. The script stores the input / output voltage and current measurements in a CSV (Comma-Separated Values) file.

3. Measurements to be performed

3.1. L7805CV

The L7805CV can source a maximum of 1.5A; however, the actual maximum output current is ultimately limited by the amount of power that can be safely dissipated on the pass element without overheating the component: as the drop-out voltage (V_I-V_O) increases, the maximum output current decreases (there is a plot illustrating this behavior inside the datasheet). In order to remain within the thermal specifications of the device, perform load sweeps between 25mA and 500mA maximum. Choosing a suitable number of intermediate points is left to the reader. Repeat the load sweeps with V_I=7V, 8V, 10V and 25V.

The line and load regulation measurements will be performed separately, using the same procedure but a limited set of operating points, please refer to the L7805CV datasheet for the nominal test conditions.

The L7805CV includes a thermal protection circuitry. If you experience the output voltage dropping to 0 during the measurements, the regulator has probably shut down due to overheating.

3.2. TPS7250

The TPS7250 is a lower power regulator than the L7805CV; hence you will perform the load sweeps between 50mA and 250mA. Choosing a suitable number of intermediate current steps is left to the reader. Repeat the load sweeps with V_I=5.5V, 6V, 7V and 10V.

The line and load regulation measurements will be performed separately, using the same procedure but a limited set of operating points, please refer to the TPS7250 datasheet for the nominal test conditions.

The TPS7250 is rated for an input voltage up to 10V. This device is easily damaged: increasing the input voltage above 10V will quickly destroy the IC.

There are a couple of reasons why the data acquired during the efficiency sweeps are not useful to measure the regulation parameters. Firstly, as noted in the component datasheets, regulation performance ought to be measured with a pulse-testing technique to maintain a nominal junction temperature of 25° (in our case, however, thermal effects are neglected). Secondly, the test conditions specify a set of operating points that may be problematic or unsafe to use with the parametric sweep procedure, as their combination exceeds the thermal rating of the devices (this is true for the L7805CV).

Because of the limitations of the electronic load and power supply, the minimum load current cannot be as low as the test conditions adopted in the datasheets, therefore preventing an exact verification of the electrical characteristics published by the manufacturers.

4. Material checklist

- 1 Analog System Lab Kit (ASLK).
- 1 L7805CV device in TO-220 package mounted on a DIP-8 socket.
- Wires.
- 1 Bench power supply (Keithley 2260B-80-13).
- 1 Electronic load (Keysight N3300A case with N3302A module).

5. Test circuit for the L7805CV

The L7805CV comes already soldered to a DIP-8 socket that is pin-to-pin compatible with the ASLK circuit used for the TPS7250. Just replace the TPS7250 IC with the L7805CV assembly (remember to plug it in with the notches aligned). Do not remove or untighten the heatsink.

6. Test circuit for the TPS7250

The TPS7250 comes already mounted on the ASLK board; the circuit schematic is shown in Figure 2. A few steps are needed to prepare the ASLK board for this lab experiment:

1) Remove jumper JP3 (the LDO is used to power the DACs).
2) Move jumper JP6 (connect V_{IN} to the screw terminal CN3).
3) Move jumper JP7 to the "ON" position.

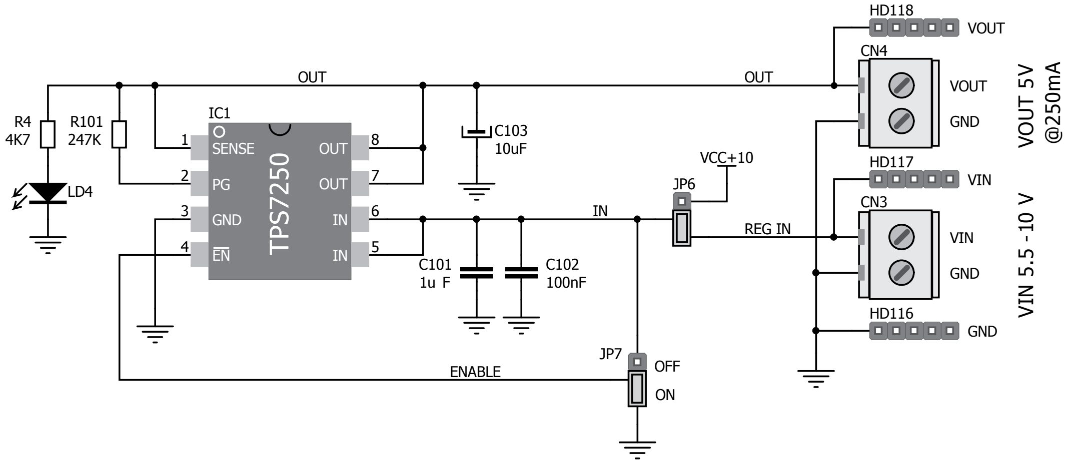

Figure 2. TPS7250 circuit schematic; the same circuit is used for the L7805CV (reproduced from the ASLK manual).

7. Test setup

Connect the device under test (the ASLK board) according to the drawing of Figure 3 (start with the L7805CV). Proceed with the tests as explained in the following section.

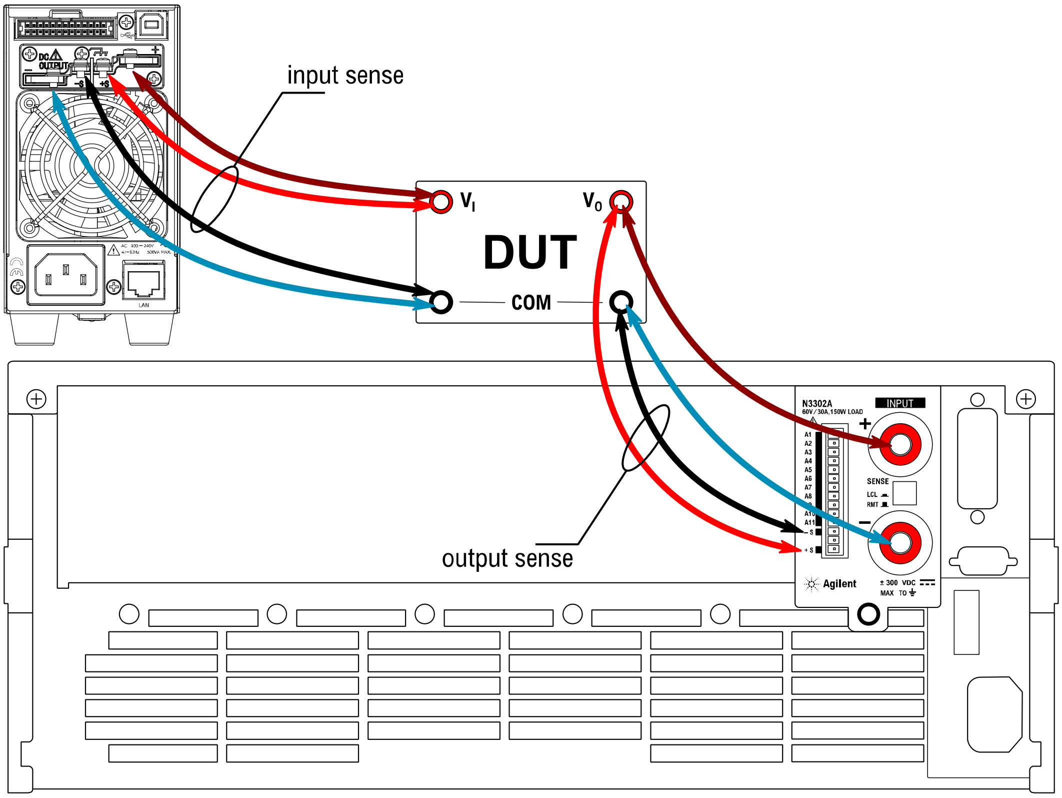

Figure 3. Simplified drawing of the measurement setup.

8. Test procedure

Switch on the electronic load and the power supply.

Launch the MATLAB script and follow the on screen instructions. The script will ask the user for a list of input voltages and load currents in the form of a CSV file. Please have this file ready before starting the measurements.

The software will prompt you to save the data when the measurements are done. Remember to use meaningful filenames!

Perform all the measurements stated in section 3.1 for the L7805CV.

After testing the first regulator disconnect the IC and connect the other one. If the control script was interrupted mid-run, you should manually disable the electronic load first, before disabling the power supply. After you have connected the new device you can execute the script again.

Perform all the measurements stated in section 3.2 for the TPS7250.

9. Laboratory report

The report concerning this laboratory unit will be graded and is due at the end of the course. Such report should cover at least the following points:

- Brief summary of the laboratory exercise.
- Line regulation, load regulation and efficiency plots for both devices, calculated from the measurements.
- Analysis of the results and explanation of how they were obtained.
- Brief comparison of the two devices.
- Comparison of your results with the manufacturers' data as presented in the datasheets, if applicable.
- Benefits and limitations of the adopted measurement setup.

Please note that the line and load regulation figures reported in the datasheets are expressed in mV, i.e. the absolute difference between the minimum and maximum regulated output voltage. Please be aware that the datasheets include the electrical characteristics of many regulators, make sure you are using the correct ones!