Application Report

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Use of an LDO as a Load Switch for Space Applications

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ABSTRACT

This application note highlights the similarities and differences of function and architecture between load switches and low-dropout (LDO) regulators. It analyzes and provides a specific configuration to use the TPS7H1101A-SP space rated low dropout linear regulator as a load switch and presents data using this configuration.

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1 Introduction

The load switch is usually used in the power path to control whether the power supply and load be connected by an external enable or disable signal. When the device is enabled via the enable pin, the pass FET turns on, thereby allowing current to flow from the input pin to the output pin, and power is passed to the downstream circuitry. Essentially, most of the load switches have the same structure, a pass FET plus a driver circuit connected to the FET's gate to turn on or turn off the pass FET.

The pass FET is the main component of the load switch, which determines the maximum input voltage and maximum load current the load switch can handle. The on-resistance of the load switch is a characteristic of the pass FET and will be used in calculating the power dissipated by the load switch [1]. The type of the pass FET determines the architecture of the load switch. A NMOS load switch requires a charge pump to bring the gate voltage above the source voltage which is usually the Vin, while the PMOS based architecture doesn't need that. However, the NMOS has a better performance when the input voltage is low.

In some advanced load switches, there are some other features, such as soft start to avoid inrush current, over-temperature shutdown, current limiting to protect device or programmable fault timer for automatic restart of the device after a fault.

A load switch has some similarities with a LDO as both make usage of a large pass transistor. However, the LDO provides regulation of the output voltage while the load switch does not. In a standard LDO application, the input voltage is larger than the regulated output voltage. In this condition, the LDO regulates normally due to the feedback loop. Even though an LDO is not originally intended or optimized to be used as a load switch, due to their similarities, the LDO could be used as a load switch. However, the LDO has to be set out of regulation mode, in other words, set it in dropout mode [4].

Figure 1 shows a basic topology comparison between an LDO and a load switch. From this figure we notice that the main difference is the feedback loop part of the LDO. When the LDO regulates, the feedback loop adjusts the Vgs value in response to changes in the output voltage. However, in this application where an LDO is being used as a load switch, the LDO is forced to be in dropout mode so that the feedback loop is not active (no regulation) and only the gate drive is present.

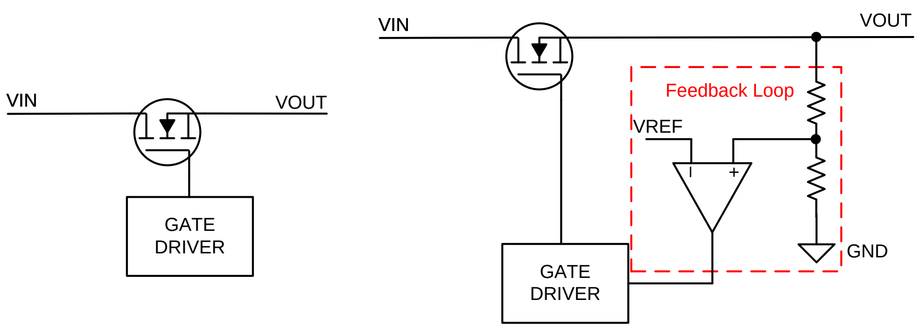

Figure 1. Typical Load Switch (left) and LDO (right) Block Diagrams

In this application note, we focus on the TPS7H1101A-SP, a space rated LDO, used as a load switch. The TPS7H1101A-SP is a very low minimum input voltage (1.5 – 7 VIN), 3-A linear regulator. Some of the features of this device are enable pin, soft start, power good, thermal shutdown, current limit and output current sensing. All these features are also applicable and desired in load switch applications.

2 Setup

The TPS7H1101SPEVM was used to test this application. Figure 2 shows a schematic of the configuration.

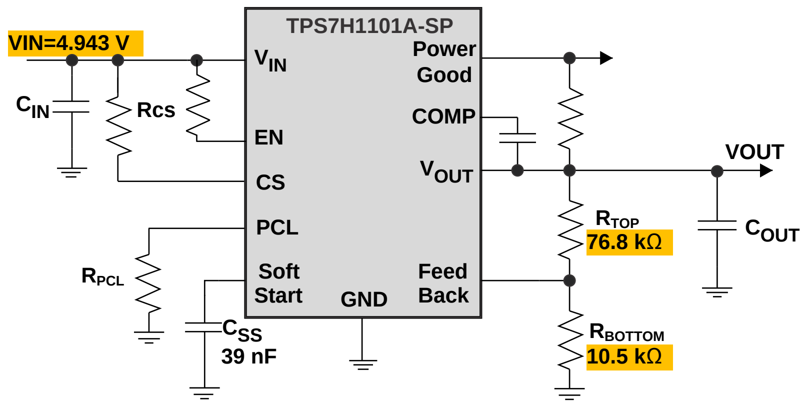

Figure 2. EVM Modifications Used to Test the TPS7H1101A-SP as a Load Switch

In normal operation of LDO, the desired output voltage is calculated using Equation 1 where the typical value for VFB = 0.605 V. In this case, VIN – VOUT > VDROP_MAX allows the LDO to regulate normally.

$$V_{OUT\_IDEAL} = \frac{(R_{TOP} + R_{BOTTOM}) \times V_{FB}}{R_{BOTTOM}} \tag{1}$$

As mentioned earlier, to be used as a load switch, the LDO needs to be set in dropout mode and there are 2 options for this. The first option as mentioned in the E2E post [4] is to connect the feedback pin to ground. The downside of this option is that the soft start feature of this device is no longer present as the feedback is not able to track the reference voltage. The second option is to set the ideal output of the LDO slightly larger than the input voltage to stop the feedback loop from taking over but still allowing the feedback to track the reference at startup or when the LDO is enabled. A typical dropout value for the TPS7H1101A-SP is 210 mV at a 3-A load and therefore, setting the input voltage 50 mV lower than the output voltage would work for this purpose.

For this particular test, the feedback resistors shown in Figure 2 provide a VOUT = 5.03 V theoretically, while the measured VOUT value is actually 4.993 V. Therefore, in order to set the LDO in dropout mode, the input voltage is set to 4.943 V (50 mV below the measured output voltage). This way the LDO will operate as a load switch without feedback loop.

3 Results

Due to their typical different applications, load switches usually have lower FET on-resistance than LDOs. For this specific application of the TPS7H1101A-SP, the dropout and load step measurements can help us evaluate the on-resistance. As mentioned above, the soft start function is high desired in load switches to minimize inrush current so it will be tested for this specific application as well. The results of these tests follow.

3.1 Dropout Test

The curves in Figure 3 show the dropout voltage of the pass MOSFET as a function of the load current across temperature. The slope of the curves is the R_{DS_ON} as shown in Figure 4. It can be observed how the maximum R_{DS_ON} is 90 mΩ under worst conditions. A thermal stream was used for the temperature measurements and an electronic load was used for the dropout voltage measurements.

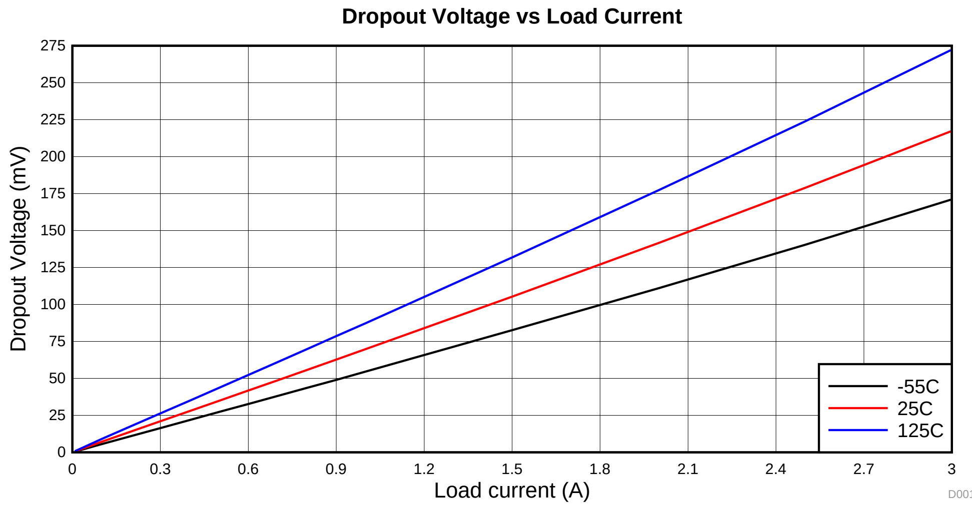

Figure 3. Dropout Voltage Measurements Across Load and Temperature

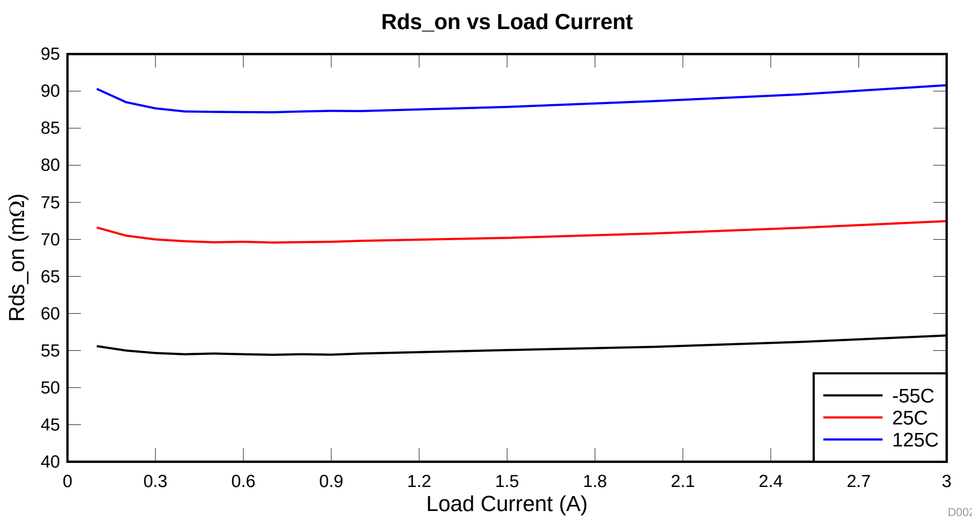

Figure 4. On-State Resistance Across Load and Temperature

From Figure 4, it can be concluded that the fairly linear behavior of the MOSFET R_{DS_ON} indicates how the device is behaving like a resistor as intended.

3.2 Load Step Response

A resistive load was used to perform load step testing. Figure 5 shows a 3-A load step response performed at room temperature. It can be observed that the dropout is about 200 mV agreeing with the 25°C curve shown in Figure 5.

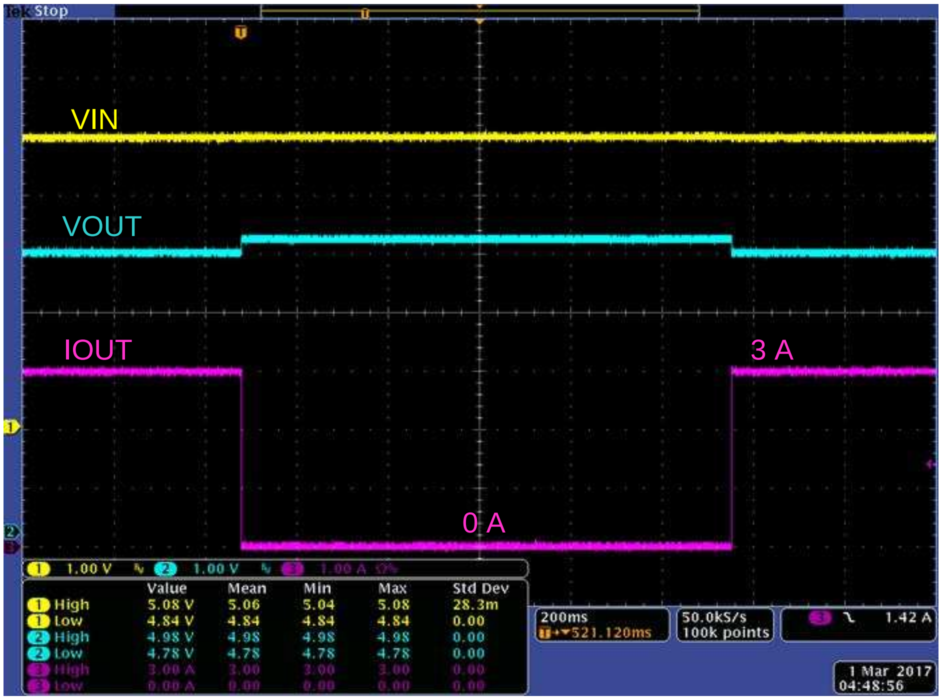

Figure 5. 3-A Step Response

3.3 Soft Start

A very important feature in load switches is the soft start capability to avoid large inrush currents. Figure 6 and Figure 7 show the soft start function of the LDO as load switch at room temperature. The soft start capacitor size is 39 nF, which corresponds to a theoretical soft start time of about 9.4 ms based on Equation 2 where the typical values of I_{SS} and V_{FB} are 2.5 µA and 0.605 V.

$$\mathbf{t_{ss}} = \frac{\mathbf{C_{ss} \times I_{ss}}}{\mathbf{V_{FB}}} \tag{2}$$

Figure 6. Soft Start Behavior With No Load

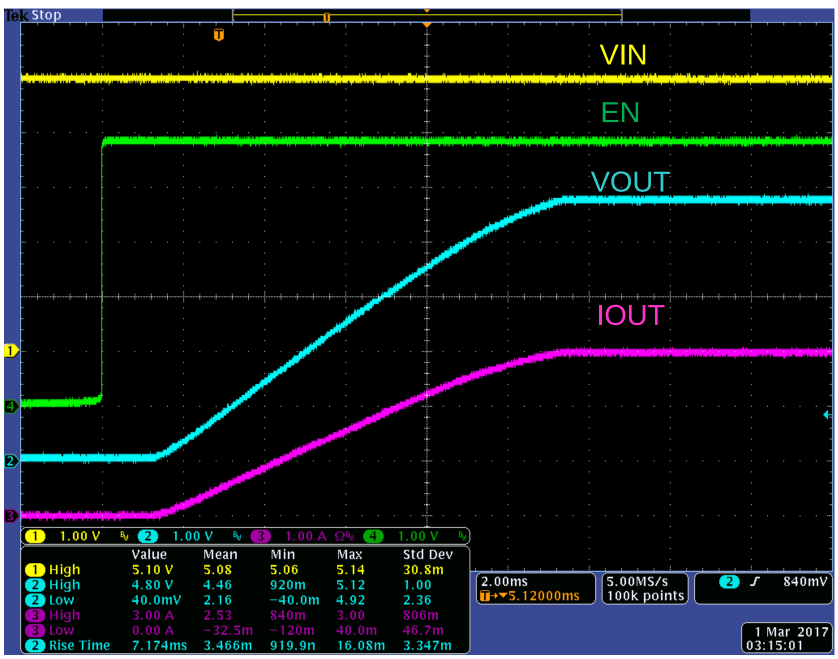

Figure 7. Soft Start Behavior With a 3-A Load

As mentioned earlier, grounding the feedback pin would not allow the LDO as a load switch to use the soft start feature. Figure 8 below shows how the soft start of about 7.2 ms in Figure 7 is no longer present if the feedback pin is grounded.

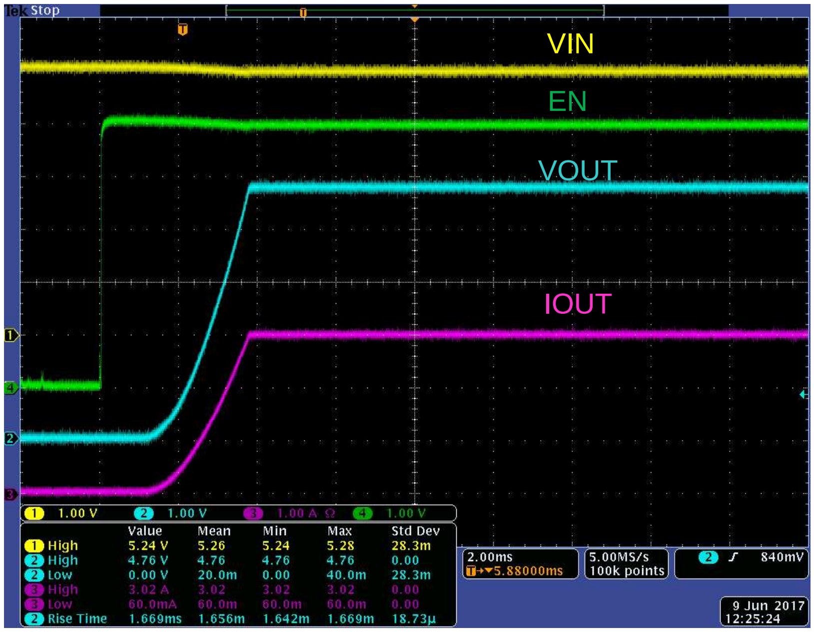

Figure 8. Lack of Soft Start Behavior at 3 A Load with FB Pin Grounded

4 Current Limit

Another important feature of load switches is the current limit feature. The TPS7H1101A-SP offers this feature and when used as load switch the feature can be used. In addition to current limit, the TPS7H1101A-SP offers current foldback. This feature takes place once current limit is triggered and remains there while the output starts drooping. After the output voltage falls below an internal threshold value, the output current will foldback to approximately half the programmed current limit as described in the TPS7H1101A-SP data sheet. At this point, the output of the LDO, or load switch in this case, will collapse to a few hundred mV. Figure 9 below shows this application with a programmed current limit of about 4 A. The current foldback (about 2 A) and the output reaching ground can be observed as well. This is a very important protection feature of the LDO as a load switch.

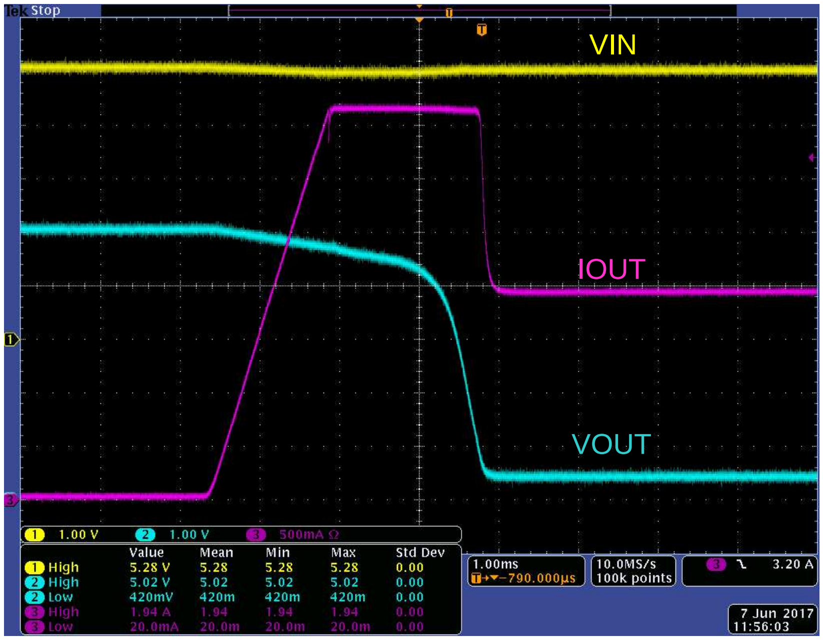

Figure 9. Current Limit Test. The Device Was Programmed With a Current Limit of About 4 A. Current Foldback Feature Can Be Observed

5 Conclusions

This application note has successfully demonstrated how to use the TPS7H1101A-SP as a load switch and presented testing data for critical parameters and features of a typical load switch. Ideally, a device designed merely for load switch applications would be able to provide lower R_{DS_ON} as well as additional features. However, this application note intends to highlight an additional usage of the TPS7H1101A-SP that could be useful for certain applications.

6 References

(1) *Basics of Load Switches*, SLVA652

(2) *Understanding Low Drop Out (LDO) Regulators*, SLUP239

(3) TPS7H1101A-SP Data Sheet, SLVSDW6

(4) "How to use an LDO as a load switch", E2E Post

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