WHITE PAPER

Rejustor™ Based Voltage Regulator Compensation

1 Introduction

Most adjustable voltage regulators are controlled by a resistor divider network. Traditionally these regulators are set by fixed resistors or trim pots. Power supply tolerances are decreasing as the industry races toward increasingly lower voltage semiconductors. The industry needs a solution that is re-configurable while maintaining high-precision.

There are two key advantages to using ***Rejustors*** in voltage regulator design. The first is flexibility. Since many designs contain a mix of technologies they need several different local regulators to supply these devices. ***Rejustor*** technology provides the flexibility to design a single regulator using ***Rejustors***, then instantiating it multiple times using the ***Rejustors*** to custom configure each supply.

The second key advantage is voltage control at the load. Until now there was no "best way" to adjust a regulator so that the voltage was at the correct level at the load. If the trim resistors were positioned near the load (and far from the regulator) the feedback path would be subjected to excessive EMI which would induce noise back into the regulator. Placing the trim resistors near the source makes it difficult to measure the voltage at the load. ***Rejustors*** can be placed near the regulator, to reduce inductive noise, and they can be in-circuit adjusted[1], controlling the voltage at the source to provide the correct voltage at the load.

2 Overview

Rejustors are electrically adjustable MEMS-based micro-resistors. The resistance of ***Rejustors*** can be adjusted down at least 30% from the as-manufactured value to very high-precision. The adjustment process reversibly alters the material properties of the device and the physical change is "stored" in the material indefinitely with no external power required. The resistance can be adjusted bi-directionally many times using low-power analog signals under control of Microbridge Technologies ***Rejustor*** Calibration Tools.

There are many different ***Rejustor*** based compensation and control configurations depending upon how the ***Rejustors*** are configured in the circuit. This application highlights just a few possibilities. Custom ***Rejustor*** networks can be developed that include both fixed resistors and ***Rejustors*** in a single, integrated network.

Rejustors are used in any application that requires an adjustable (or trimmable) resistor. Sample implementations are presented for two regulators: a linear voltage regulator and a switch regulator.

Rejustors are simple but powerful circuit compensation components. They are pure resistive elements that require no-power to maintain their resistance. These resistors can be used in implementations from low-frequency sensors to high-frequency RF amplifiers. Our objective is to demonstrate the flexibility afforded by ***Rejustors*** in circuit design. Go ahead, adjust your design!

™ *Rejustor* is a trademark of Microbridge Technologies

[1] *Rejust-it* in-circuit software required for target voltage adjustment

3 *Rejustor* Control for a Linear Regulator

This ***Rejustor*** based solution uses the LM317AT[2] "***3-Terminal Adjustable Regulator***" from National Semiconductor Corporation, a work-horse for low-voltage high-current supplies. The LM317 with precise, adjustable ***Rejustors*** control can provide an output voltage range determined by the equation:

$$V_{out} = 1.25 \times (1 + \frac{R_2}{R_1}) + (I_{adj} \times R_2)$$

The specific output voltage is controlled by the Microbridge ***Rejustor*** divider connected to the ADJ pin (external fixed resistors may be required). In testing, a 4.7kΩ ***Rejustor*** 1:1 divider provided an output range from 2.2V to 3.2V from a 10V supply, with better than 0.2% accuracy with a 1kΩ load (see Appendix A). Figure 1 shows a simplified schematic representation of the ***Rejustor*** based circuit.

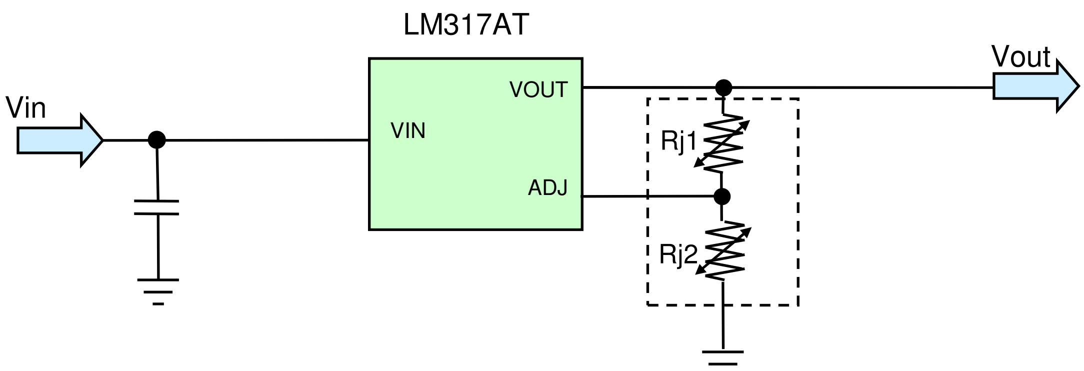

Figure 1: Adjustable Output Voltage Regulator

The voltage on the ADJ pin is 1.25V with respect to Vout. The combination of Rj1 and Rj2 adjust the regulator output voltage. As discussed, the ***Rejustors*** should be placed near the regulator although the measurement point for in-circuit calibration can be near the load. Users are cautioned to ensure that their circuit meets the appropriate minimum load current and dropout voltage design requirements, as specified in the LM317 datasheet, as well as the ***Rejustor***'s maximum dissipated power specification (in this solution, 1mW per ***Rejustor***).

4 *Rejustor* Control for a Switching Regulator

This ***Rejustor*** based solution uses the TPS61028[3] "**96% Efficient Synchronous boost Converter with 1.5A Switch**". This high-efficient regulator is a step-up dc-dc converter optimized for battery-powered portable applications. The TPS61028 provides an adjustable output voltage range from 1.8V to 5.5V from a supply as low as 0.9V. The specific output voltage range is controlled by the Microbridge ***Rejustor*** divider connected to the FB pins. The TPS6102x family of regulators provides many advanced features, the details of which are beyond the scope of this document.

In this application, the ***Rejustor*** Divider defines the output voltage. A high efficiency switching regulator was chosen to provide flexibility on the input side of the regulator without compromising overall power consumption for this solution. Figure 2 shows a simplified schematic representation of the ***Rejustor*** based circuit.

[2] LM317 is a product of National Semiconductor Corp.
[3] TPS61028 is a product of Texas Instruments Inc.

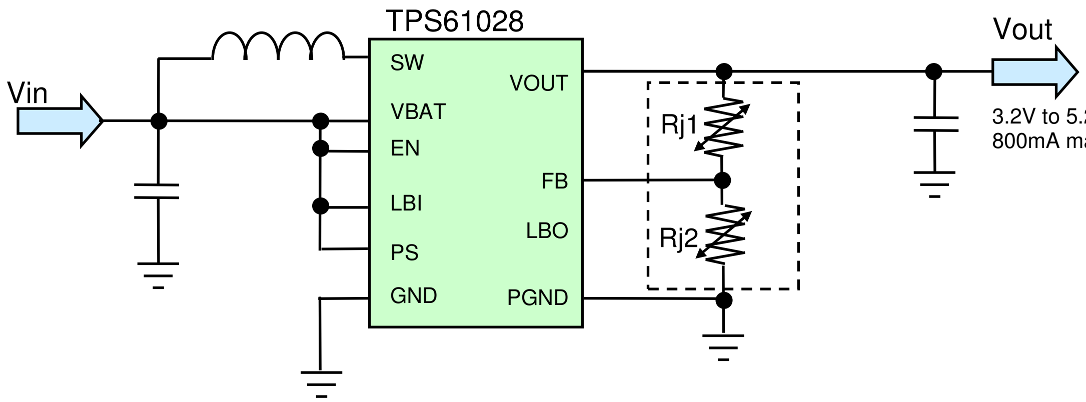

Figure 2: Concept Adjustable Output Voltage Regulator

The ***Rejustor*** divider combination used for this application should be high-resistance to provide a high-impedance load to the FB pin on the regulator. As discussed, the ***Rejustors*** should be placed near the regulator although the measurement point for in-circuit adjustment should be observed near the load.

5 Summary

These examples describe practical circuits for regulated voltage using either a linear or a switching regulator. These single implementations can be designed, tested and manufactured prior to determining the output voltage requirement for each discrete design. ***Rejustors*** enable this capability while improving precision and flexibility over existing methods.

Using ***Rejustors*** for these applications reduces design cycle-time since generic units are produced then configured to meet each specific application. Raw material and finished goods inventory are reduced as a result of design flexibility.

As a passive device, the ***Rejustor*** is ideally suited for this application since no boot-up sequence is required. Using ***Rejustors*** that haven't been adjusted doesn't harm the voltage regulator since the ***Rejustor*** is always a resistor. Following adjustment, the regulator design will hold its target voltage with no noticeable drift over time. In addition, the regulator can be re-adjusted at any time using ***Rejustor*** Calibration Tools.

Being able to perform simple analog electronic adjustment changes the competitive game. The ***Rejustor*** is more than just a resistor and Microbridge is a company committed to adjustment and compensation technologies.

We have focused on just a few of the many applications for small, precision adjustment using the ***Rejustor***. Adjust your design!

6 Appendix A

The following data was collected in testing the circuit shown in Figure 1 using a 4.7kΩ ***Rejustor*** 1:1 divider, with a 10V supply, a 0.1μF input bypass capacitor and a 1kΩ load.

Rj1		Rj2		Vout			
Value (Ω)	% Downtrim	Value (Ω)	% Downtrim	Expected (V)	Observed (V)	% Up/Down	% Error
4700	0%	4700	0%	2.735	2.679	0.00%	2.05%
4230	10%	4700	0%	2.874	2.873	7.24%	0.03%
3995	15%	4700	0%	2.956	2.957	10.38%	0.05%
3760	20%	4700	0%	3.048	3.048	13.77%	0.02%
3525	25%	4700	0%	3.152	3.153	17.69%	0.04%
3290	30%	4700	0%	3.271	3.270	22.06%	0.02%
4700	0%	4700	0%	2.735	2.704	0.00%	1.13%
4700	0%	4230	10%	2.587	2.588	4.29%	0.06%
4700	0%	3995	15%	2.512	2.515	6.99%	0.11%
4700	0%	3760	20%	2.438	2.442	9.69%	0.16%
4700	0%	3525	25%	2.364	2.367	12.46%	0.14%
4700	0%	3290	30%	2.290	2.292	15.24%	0.11%
4700	0%	3055	35%	2.215	2.218	17.97%	0.12%

Table 1: Output Voltage Range As A Function Of *Rejustor* Trim (1:1 Divider)