International
IOR Rectifier

APPLICATION NOTE

Application Note AN-1161

DC Output Regulation of the IRUH3301xxxx

By

Michael F. Thompson & James A. Brandt

Table of Contents

Page

I. INTRODUCTION

INTERNATIONAL Rectifier would like to present this document to describe the performance of our radiation hardened IRUH3301 series of linear regulators. The output voltage produced by these hybrid devices is expected to face an increasing demand for high accuracy. The logic devices such as FPGA's and microprocessors that are the loads for these circuits continue to decrease in voltage and to narrow the allowable voltage range. Therefore, output voltage accuracy as affected by all variables such as temperature, radiation and life time is very important together with the ability to provide low output voltages (down to 1V and below). IR is pleased to discuss a new regulator family that is generally improved over our older designs, but specifically addresses the need for better accuracy and lower minimum output voltage.

The new design uses a control IC built on a Silicon On Insulator (SOI) process, which provides a very good radiation tolerant IC with respect to total dose thus improving the voltage stability versus total dose. In addition, the performance in terms of SEE is also much better. The use of an internal voltage reference with a lower voltage allows the new design to provide output voltages down to 0.8V, meeting the need for modern logic devices. This application note will follow this general outline:

--First, it will briefly describe the overall regulation tolerance and the factors that affect it.

--Second, it will review each of those factors by themselves with respect to actual data from the IRUH3301.

--Third, it will show the total DC regulation tolerance and an example of the tolerance in a typical application.

II. A SUMMARY OF THE DESIGN CHALLENGE

Operation of any linear regulator in a power electronic circuit involves many concerns for the designer. This application note covers specifically the tolerance of the DC regulation of the output voltage (the accuracy of the output voltage). As for all high reliability (hi-rel) designs, variations during life time and operational conditions are important. Logic devices that draw power from these regulators are extremely unforgiving in their requirements for input power, and the latest series of IR rad hard regulators are available to help meet those requirements.

The factors that affect the DC regulation include initial tolerance, which is measure of how accurate any given part will be when first used in its application circuit. It is important to note that initial tolerance for this product line includes the effects of line and load variation. Once this benchmark has been achieved, the effects of temperature can be considered. As the part serves its purpose in actual operation, it will suffer from the effects of aging, especially in the sometimes decades-long life of a hi-rel application. Finally, and perhaps most difficult of all, are the compound effects of radiation on the parts' accuracy. Radiation is specified by the effects of Total Ionizing Dose (TID) and also the effects of different dose rates (Extremely Low Dose Rate Sensitivity - ELDRS). Each of the factors just mentioned will be separately examined in the following sections.

III. INITIAL TOLERANCE

The initial tolerance of the IRUH3301 is rated to +/-1.5% at room temperature (please see datasheets available at www.irf.com for the latest specification information on this part). This initial performance is checked after assembly before it is sealed, at the start of burn-in, during burn-in, and after burn-in for a total of 4x verification and screening. An example of the results found after assembly are shown in Figure III-1. Any outliers are screened out during testing. All initial tolerances on active components are checked at the wafer level and component lots are also verified (on a sample basis) during element evaluation.

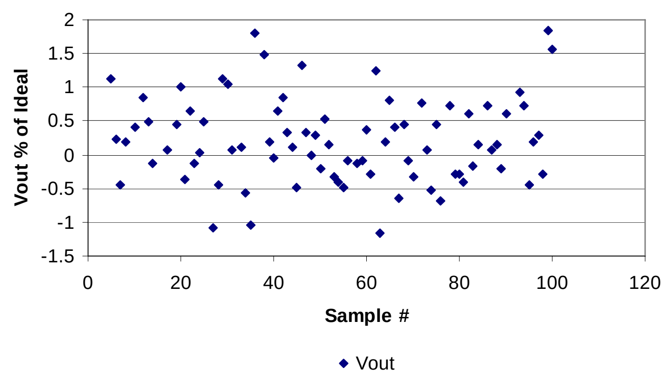

Figure III-1: Tolerance of the output voltage as expressed as a percentage of the ideal output voltage of the hybrid device. This figure shows the variance in initial output voltage of the IRUH3301 hybrid.

IV. TEMPERATURE VARIATIONS

The next effect to be examined is temperature. The extremes of temperature are specified (again as per the datasheets) to +/-1.5% over the full device temperature range of -55 degrees Celsius to +125 degrees Celsius. This percentage is exclusive of the initial tolerance; see Table I for the separate tolerances for each effect (initial, temperature, radiation, etc.). Data for the performance of the control IC for temperature variation is shown in Figure IV-1; in final test, all component variations will be covered by checking for +/-3% (initial plus temperature) tolerance of the IRUH3301. Any part that does not meet this requirement would be screened out, of course. The majority of the temperature variation is typically the result of the regulator IC performance. All internal resistor(s) in the voltage setting resistor divider have a

Temperature Coefficient of Resistance (TCR) maximum of 25ppm/°C; the typical values would run 1/10th of this.

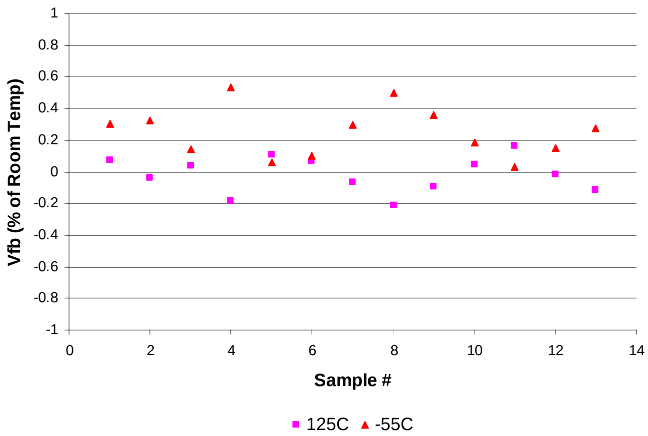

Figure IV-1: Tolerance of the output voltage over the rated temperature range of the part as expressed as a percentage of the output voltage at 25 degrees Celsius. This shows the temperature variation of the output voltage regulation of the control IC only.

V. Life

In subjecting the IRUH3301 to life testing (aging) per MIL-STD-883 [1], Method 1005, the results shown in Figure V-1 were achieved. The goal for our design is +/- 1%. The majority of this will be caused by aging in the regulator IC. The regulator IC has a design targeted aging limit of 1%. The resistors have a qualification maximum of +/- 0.5% over 2000 hrs of life testing with typical values again around 1/10th of this.

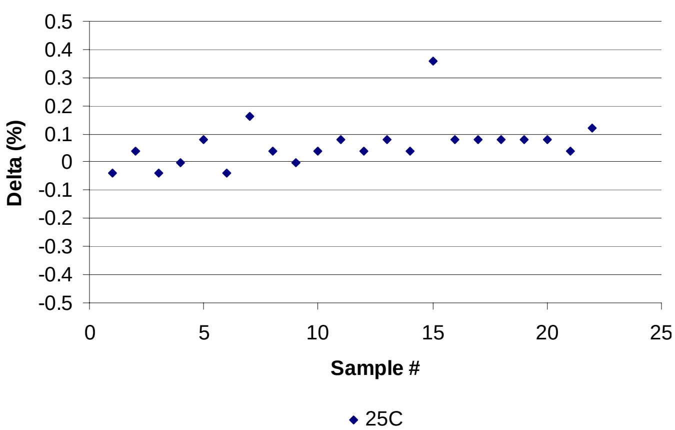

Figure V-1: Life test data for the IRUH3301.

VI. Radiation: TID

The test method used as a guide in the development of the Test Plan for TID testing was MIL-STD-883 [1], Method 1019 Ionizing Radiation, Condition A. This method establishes the basic requirements for the performance and execution of the tests. The effects of TID are shown in Figure VI-1. Per the standard, to rate the IRUH at 300kRad TID as per the datasheet, we have to test to 50% higher (hence the 500krad level shown). Our limit for TID effects is +0.5% to -2%. This performance is tested on a sample basis for every wafer lot. During our last testing (results are available on the web at URL http://www.irf.com/product-info/hi-rel/gsion-iruh3301.pdf), the dose rate was 50 to 300Rad (Si) per second.

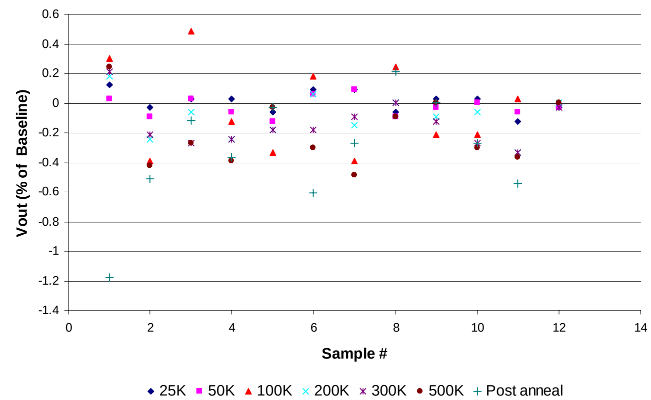

Figure VI-1: Tolerance of the output voltage as affected by TID exposure in RADs. In this graph, samples #1-5 are biased with 50mA load with 6.8Vin, samples # 6-11 are in circuit with 0Vin, and sample 12 is the control (no radiation).

This performance is much better than with our previous part, which could vary up to 6% at 500k Rad (Si) with our old control IC. Published reports on radiation performance of the IRUH3301 series are available on the IR web site [2] [3] [4] [5], and of course any reports published after the release of this application note can be found on the IR Hi-Rel web site's radiation reports page where these existing documents can be found.

VII. Radiation: ELDRS

The test method used as a guide in the development of the Test Plan was MIL-STD-883 [1], Method 1019 Ionizing Radiation per Condition D. This method establishes the basic requirements for the performance and execution of the tests. The effects of ELDRS are shown in Figure VII-1. Again, these meet the specified limits in the datasheet of +0.5%/-2%.

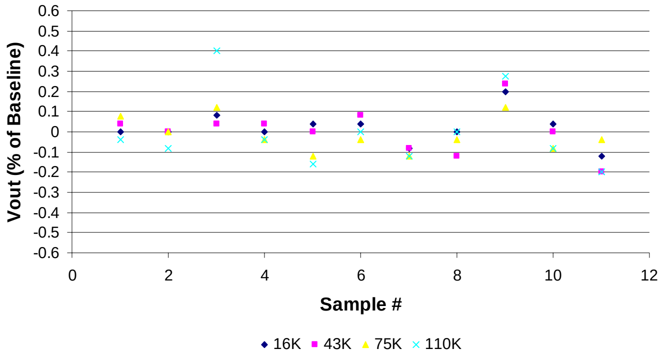

Figure VII-1: Tolerance of the output voltage as affected by ELDRS exposure. In this graph, samples #1-5 are biased with 50mA load with 6.8Vin, samples # 6-10 are in circuit with 0Vin, and sample 11 is the control (no radiation)

VIII. RSS Summation and a Typical Application

The previous sections have shown the worst case tolerances as affected by initial tolerance, temperature, radiation, and MIL-STD-883 tests for aging. To summarize these results, the Root Sum Square (RSS) method provides a total of +2.4/-3.1% total (see Table I). The RSS method is simply a mathematical method whereby the individual factors are squared and then a square root is taken of the sum of those squares.

Factor	Minimum	Maximum
Initial	-1.5%	+1.5%
Temperature	-1.5%	+1.5%
Radiation	-2.0%	+0.5%
Aging	-1.0%	+1.0%
RSS TOTAL	**-3.1%**	**+2.4%**

Table I: Summary of Tolerances due to Various Effects on the IRUH3301

IX. Conclusion and Upcoming Improvements

IR believes these test results show that the IRUH series has an improved output regulation performance of +/-3%. This is an improvement over the previous family which had an accuracy of approximately +8 to -4%.

References

[1] MIL-STD-883 revision G, published 28 February 2006 by the Department of Defense, United States of America, Defense Supply Center of Columbus, available online at the URL http://www.everyspec.com/.
[2] IRUH3301 Series Total Ionizing Dose Test Report, http://www.irf.com/product-info/hi-rel/gsion-iruh3301.pdf
[3] IRUH3301 Series ELDRS Test Report, http://www.irf.com/product-info/hi-rel/gseld-iruh3301.pdf
[4] IRUH3301 Series Single-Event Test Report, http://www.irf.com/product-info/hi-rel/gsseeiruh3301.pdf
[5] IRUH3301 Series Neutron Test Report, http://www.irf.com/product-info/hi-rel/gsnt-iruh3301.pdf

Michael F. Thompson (IEEE M'05–SM'07) became a Member (M) of IEEE in 2005, and a Senior Member (SM) in 2007. Born in Pittsburgh, PA in 1972, the author received a Bachelor of Science degree from the University of Pennsylvania in Philadelphia, PA, USA in 1994, and a Master of Science degree (with a specialty in power electronics and controls) from the State University of New York in 1998.

He has worked for Lockheed Martin and Northrop Grumman. His design experience covers AC-DC, DC-AC, DC-DC power conversion at power levels that range from milliwatts to megawatts. He is familiar with the construction and characteristics of energy storage devices and the complexities of digital controls for power systems. Low noise output ripple designs and distributed power systems are of interest to him. He is presently working for International Rectifier as the Hi-Rel Field Application Engineer for the Eastern United States and is based out of his office in Maryland.

James A. Brandt (IEEE M'02) became a Member (M) of IEEE in 2002. Born in Toms River NJ in 1971, the author received a Bachelor of Music (with a specialty in Sound Recording Technology) from the University of Massachusetts Lowell in Lowell, MA, USA in 1995. More recently he has received BSEE and MSEE degrees from the University of New Hampshire in Durham, NH, USA in 2005 and 2008 respectively.

He completed his MSEE thesis work at MIT's Lincoln Labs designing a biasing IC in support of a Micro-Electro-Mechanical-System (MEMS) micro switch development effort. Analog system and IC design are of interest to him. He is presently working for International Rectifier as a Design Engineer in the Hi-Rel facility in Leominster Massachusetts.