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APPLICATION NOTE

Application Note AN-1081

IRUH Series of Radiation Hardened, Ultra Low Dropout Linear Voltage Regulators

By Alan Tasker, Engineering Lead, Space Products
International Rectifier HiRel Products

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Within the series there are three slightly different groups of Ultra Low Dropout linear voltage regulators. Devices listed in group 1and 2 are available in two different metal package styles, an MO-078 5-pin and an 8-pin flat pack. Devices in group 3 are available in the MO-078 package only. For the most part, the application information contained herein is applicable to devices in all three groups. However, there are some differences in construction between group types which lead to some differences in application information. These differences will be pointed out in each section as appropriate. Primary emphasis will be orientated toward Group 1, with differences in the other two groups, if any, following.

International Rectifier • 233 Kansas Street, El Segundo, CA 90245 USA

Application Note for the IRUH Series of Radiation Hardened, Ultra Low Dropout Linear Voltage Regulators

By Alan Tasker, Engineering Lead, Space Products
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Introduction

Within the series there are three slightly different groups of Ultra Low Dropout linear voltage regulators. These groups are as follows.

Group	Part #	V_{IN}	V_{OUT}	I_{OUT}	TID
1	IRUH33P183B1M	3.3V	1.8V	3A	1Mrad (Si)
	IRUH33P253B1M	3.3V	2.5V		
	IRUH33PA13B1M	3.3V	1.26 to V_{IN}-.4V		
	IRUH50PA13B1M	5V	1.26 to V_{IN}-.4V		
	IRUH50P253B1M	5V	2.5V		
	IRUH50P333B1M	5V	3.3V		
2	IRUH33PA13B20	3.3V	1.26 to V_{IN}-.4V	3A	200Krad (Si)
	IRUH33PA13B20	5V	1.26 to V_{IN}-.4V		
3	IRUH33P255B50	3.3V	2.5V	5A	500Krad (Si)
	IRUH50P335B50	5V	3.3V		

Table 1- Available Part Types

Devices listed in group 1and 2 are available in two different metal package styles, an MO-078 5-pin for through hole assembly and an 8-pin flat pack for surface mount assembly.

(see figures 1 & 2 for package dimensions and pinouts). Devices in group 3 are available in the MO-078 package only. Both package styles have a thermal resistance of 6.5 ^{o}C/W for a three amp device. There will be more information on the design tips for thermal resistance later.

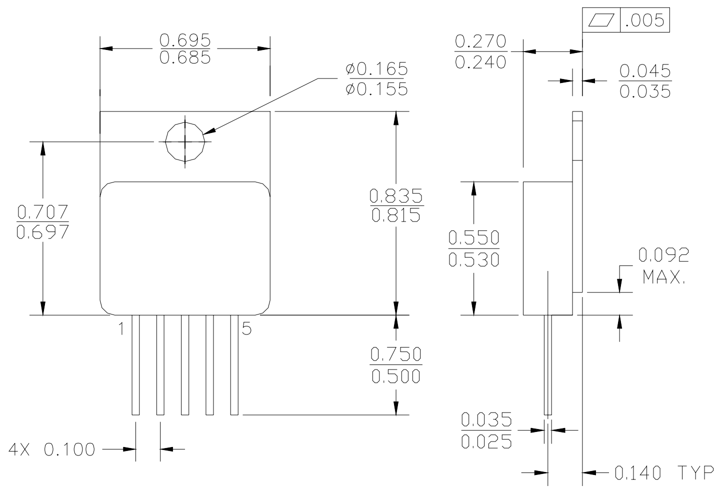


Figure 1 - MO-078 package

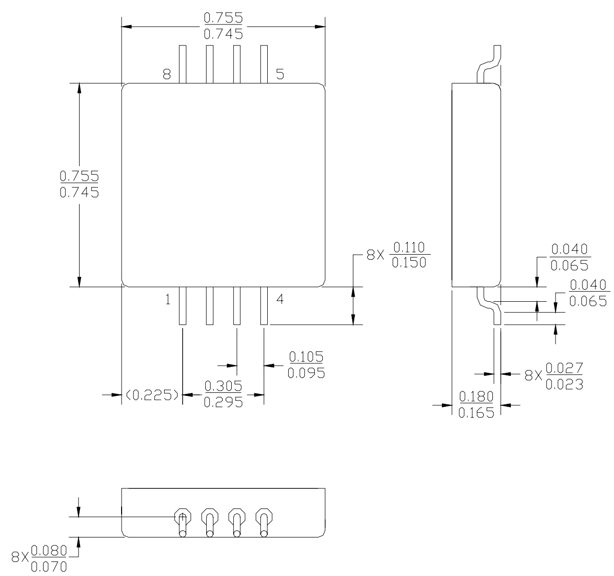


Figure 2 - Flat Pack

Features

- Characterized for use in a radiation environment
- 400 mV dropout Voltage
- Fixed and adjustable types
- 3 Amp and 5 Amp output current types
- Shutdown function allows power sequencing
- Fast transient response
- Overload protected
- Low noise
- Thermal shutdown
- Internal components derated per IR internal design criteria

Performance

Within the series there are three slightly different groups of Ultra Low Dropout linear voltage regulators. Some of these are fixed input/fixed output types, while the others are fixed input/variable output types. Output Voltage accuracy is guaranteed to be within ±5% over line, load, temperature, and radiation.

Radiation Hardness

These devices have demonstrated total ionizing dose (TID) radiation hardness up to 1.0 MRad (Si). Testing was performed in accordance with Mil-Std-883, Method 1019.6, condition A. After exposure to radiation, Vout remained within ±5% of its specified value with stable operation. As a result these parts can be used in the most severe radiation environments such as deep space.

These devices have been characterized under Low dose irradiation for enhanced low dose rate sensitivity (ELDRS) effect. Testing was performed in accordance with Method 1019.6, condition D. The devices are rated at 500Krad (Si) at low dose rate of 0.100 Rad (Si)/sec".

The complete reports of all radiation testing are available on the IR website at:

http://www.irf.com/product-info/hi-rel/radrpt.html

Dropout Characteristics

The input voltage range is specified for each device on the data sheet. Devices will continue to operate to a dropout Voltage of 400 mV. For example Vin must be greater than Vout plus 400mv.

The adjustable types will hold full specifications at full output current with V_{out} adjusted to be the specified V_{in} minus 400 mV. The LDO regulator when operated below full current will allow even lower dropout levels.

Short Circuit Protection

Short circuit protection is provided by means of a delayed over current latch function. Output current is limited at turn on during the charging of the output capacitors. If current doesn't drop to 3 amps or less within 10 ms, an over current latch is activated, shutting off the output. Reset of this latch is described in the below paragraph. The off state is defined as Vout= 0.0 V ± 0.1V

Shutdown Pin Operation

A shutdown pin is provided so that the regulator may be switched on and off by a 5.0 volt logic signals. The source current is typically 200ua. This signal will also reset the over current latch function as described above, so that turn-on will be attempted when this pin is again brought low. Input threshold is guaranteed to be 1.0V min and 1.6V max. Shutdown/reset is affected by bringing this pin higher in voltage than the threshold. If not needed, the pin should be grounded. Above 2.0 Volts, this pin has a resistive dynamic input impedance of 20K Ohms.

Thermal Shutdown

Thermal shutdown occurs when the internal temperature of the semiconductors reaches a junction temperature of 150^{o}C.

Transient Response

Response to an increase/decrease in load current is very fast. A load condition increases from 0.2 Amp to 3 Amp, settles to within 10 mV in less than 3 μS.

Thermal Characteristics

Thermal resistance from Junction to case (Theta j-c) is 6.5^{o}C/W for the 3 Amp series, 2.5^{o}C/W for the 5 Amp series, and 8.5^{o}C/W for the 3 Amp series rated at 200KRad (Si). Most of the dissipation occurs in the output stage, i.e. (V_{in}-V_{out}) x I_{load}. Care must be taken to ensure proper heat sinking so that the internal junction temperature does not exceed program derating guidelines. The maximum allowed junction temperature of the internal pass transistor is 200^{o}C. However, for derating purposes, and because of proximity to other components, we choose to allow only a maximum of 150 ^{o}C T_j.

In addition to the above thermal restrictions, there is a specified maximum operating case temperature of 125^{o}C.

Example 1- With the above in mind, a 5 Volt to 2.5 Volt regulator supplying 2 Amps dissipates about (5V-2.5V) x (2A) = 5 Watts. At 6.5^{o}C/W, there would be a temperature rise of 6.5^{o}C/W x 5 W = 32.5 degrees ^{o}C. If program derating guidelines dictate a maximum junction temperature of 100^{o} C, then the case must be held to no more than 100^{o} – 32.5^{o} = 67.5^{o}C.

Example 2- If we use the same electrical requirements as in the above example, but mandate a maximum case temperature of 120^{o}C, we would have to cut back on output current. This is because 120^{o}C T_{case} + 32.5^{o}C rise is greater than the maximum allowed T_j of 150^{o}C. An output current of 1.8 Amps would be the maximum allowed. Since I x V x Θ_{jc} = 30^{o}C, then I = 30 / (V x Θ_{jc}) = 30 / (2.5 x 6.5) = 1.846 Amps max for a 30 degree rise.

Adjustable Types

The adjustable types require an external resistor in order to set the output Voltage. The formula for V_{out} as a function of this resistor is $V_{out} = V_{ref}$ x (1+R_{adj}/1000) Volts. V_{ref} is specified to be 1.265 Volts. The internal reference will have some tolerance, as will the internal 1000 Ohm resistor and the external Voltage adjust resistor. These tolerances are the main contributors to output voltage variations, both unit-to-unit and over temperature and time. The following table lists the standard 1% resistor value that is the closest to the calculated value of several common output Voltages.

out (V)	R_{adj} (Ω)		V_{out} (V)	R_{adj} (Ω)
1.5	187		3.3	1620
1.8	422		3.5	1760
2.0	576		3.8	2000
2.2	732		4.0	2150
2.5	976		4.5	2550
2.8	1210		5.0	2940
3.0	1370			

Table 2 - Commonly Available 1% resistor values for various output Voltages

Application Circuit

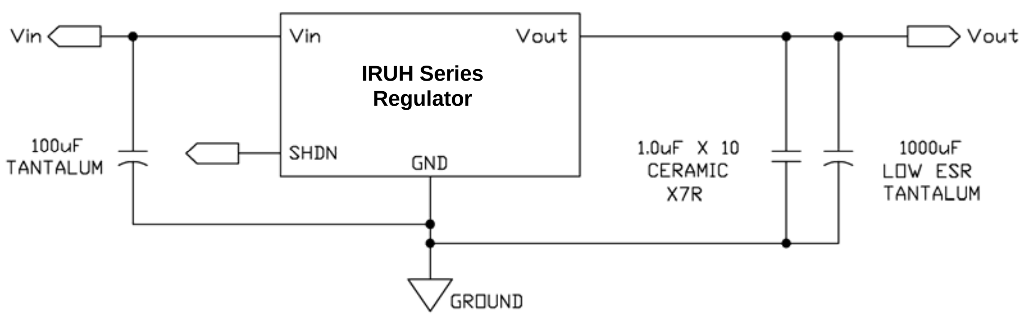
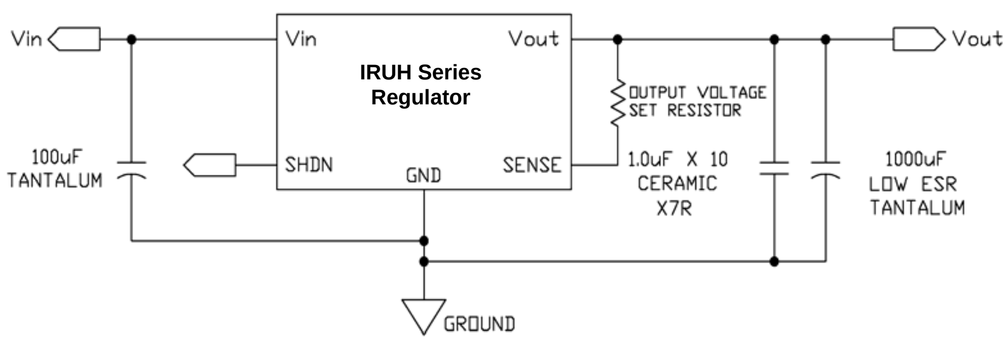


Figure 3 - Fixed 3 Amp Regulator



$V_{out} = V_{ref} \times (1+R_{adj}/1000)$, with Vref~1.265 Volts

Figure 4 - Adjustable 3 Amp Regulator

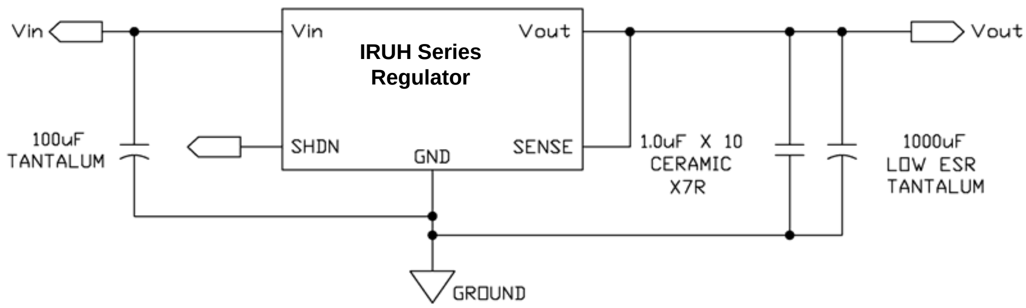


Figure 5 - Fixed 5 Amp Regulator

Stability

Regulator stability depends on many factors. Some of these include the following:

- A clean layout with short, wide traces
- Capacitors located close to the regulator and close to the load
- Low ESR capacitors – See “Output Capacitance” discussion below

Input Capacitance

The recommended input capacitance for a generic application is a 100uF, 16V (or as appropriate for applicable derating criteria) tantalum capacitor. Care should be taken to ensure that the input to the regulator is sufficiently free of noise and disturbances.

Output Capacitance

Like most ultra low dropout high current voltage regulators, these devices require the use of output capacitors as part of their frequency compensation, and to provide sufficiently low output impedance. We highly recommend the use of three 330uF, low equivalent series resistance (ESR) tantalum capacitors on the output. However, some capacitor series contain a mixture of both high and low ESR devices, so the designer must choose carefully.

Many different types of capacitors are available, and they have widely varying characteristics. These capacitors differ in capacitor tolerance, ESR, equivalent series inductance (ESL), and capacitance temperature coefficient. The frequency compensation optimizes frequency response with low ESR capacitors. In general, capacitors should be chosen such that the resulting parallel combination has an ESR of 50 mOhms max.

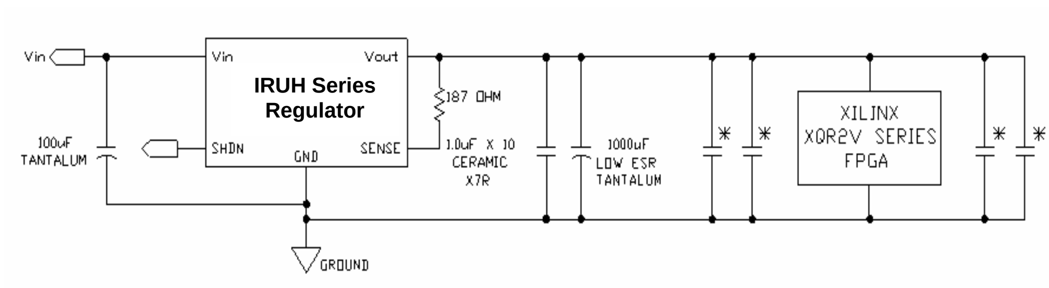
High quality ceramic bypass capacitors must also be used to limit the high frequency noise generated by the load. Multiple small ceramic capacitors are typically required to limit parasitic inductance, ESL and ESR in the capacitors to acceptable levels. We have found those with BX or X7R dielectric to be acceptable.

The upper limit of the capacitance is governed by the delayed over-current latch function of the regulator. The regulator has a protection circuit that will latch the device off in the event of a short circuit. However, since it is known that the regulator will draw a large in-rush current upon startup, the latch-off is delayed by 10ms to allow the output capacitors to charge to a steady state without shutting down. During this period, the regulator will reach its output current maximum, typically 5 to 8 Amps for 3 Amp rated devices, and 7 to 10 Amps for 5 Amp rated devices. Therefore, the maximum output capacitance can be as high as 20,000uF

(with little or no DC load) without causing the device to latch-off during start-up. With a substantial DC load, the upper limit on output capacitance will, of course, be lower.
Figures 3 through 5 show typical application circuits. The output load capacitor consists of one or more tantalum capacitors in parallel totaling 1,000 µF with an ESR no higher than 50 mOhms, and ten 1 µF, X7R ceramic capacitors. This yields a stable circuit with 59 degrees of phase margin and 24 dB of gain margin.

Design Example

Figure 6 shows a design example. The load in this case is a Xilinx XQR2V series 1.5 Volt, Radiation Tolerant FPGA.



* - See discussion below concerning capacitors at the point of load.

Figure 6.- Design example for an FPGA

Point of load capacitors should consist of a number of different capacitor styles in parallel in order to achieve as low an impedance as possible. Figure 7 and Table 3 below are reprinted with permission from the Xilinx application note XAPP623 (v2.0). Figure 7 shows the results of a simulation where different values and sizes of capacitors are used in parallel to keep power supply impedance as low as possible to as high a frequency as possible.

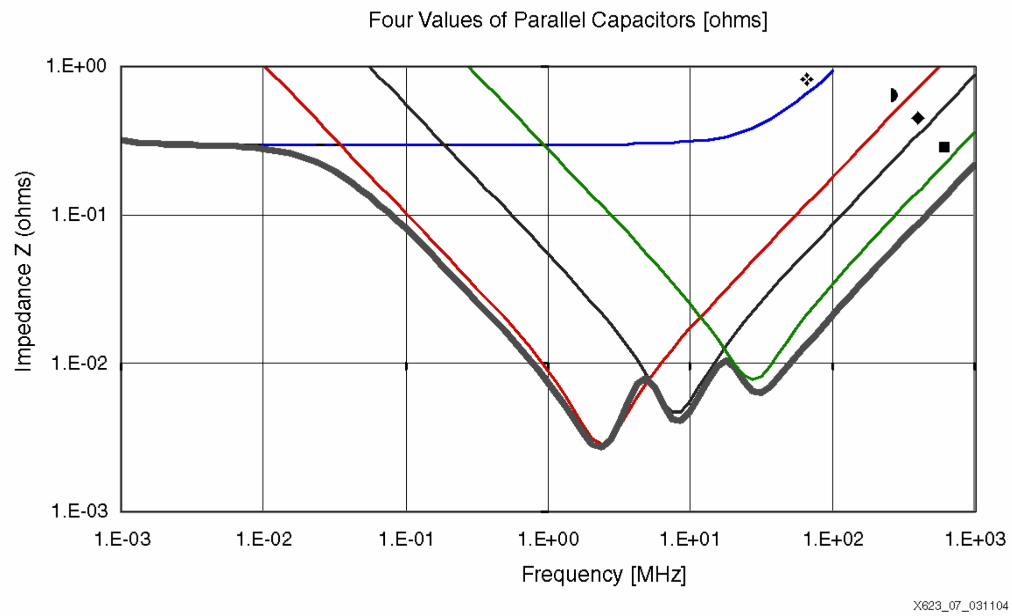


Figure 7 - Simulation of power supply impedance versus frequency for the values in Table 3.

Quantity	Symbol	Package	Capacitive Values (µF)	Parasitic Inductance (nH)	Parasitic Resistance (ohms)
2	❖	E	680	2.8	0.57
7	◗	0805	2.2	2.0	0.02
13	◆	0603	0.22	1.8	0.06
26	■	0402	0.022	1.5	0.20

Table 3 - Value and number of capacitors used in the plot of Figure 7.

This collection of capacitors is a good start. The impedance is below 0.033 Ohm from 500 kHz to 150 MHz, and increases to 0.11 Ohm at 500 MHz. Over this range, there are no significant anti-resonance spikes.