Total dose testing of the ISL78845ASRH current mode PWM controller

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1. Introduction

This report summarizes the results of a low and high dose rate total dose test of the ISL78845ASRH current mode PWM controller. The test was conducted in order to determine the sensitivity of the part to the total dose environment and to low dose rate irradiation in particular.

The ISL78845ASRH is available in eight versions differing in undervoltage lockout, maximum duty cycle characteristics, and total ionizing dose acceptance testing. The ISL78840ASRH/ ISL78841ASRH/ ISL78843ASRH/ ISL78845ASRH are acceptance tested on a wafer by wafer basis to 100 krad(Si) at high dose rate (50 – 300 rad(Si)/s) only. The ISL78840ASEH/ ISL78841ASEH/ ISL78843ASEH/ ISL78845ASEH are acceptance tested on a wafer by wafer basis to 100 krad(Si) at high dose rate (50 – 300 rad(Si)/s) and to 50 krad(Si) at low dose rate (0.01 rad(Si)/s). The HDR and LDR performance of the ISL78845ASRH is considered representative of the other devices in the ISL7884x family.

2. Reference Documents

- MIL-STD-883G test method 1019.7
- MIL-PRF-38535 (QML)
- ISL78840ASRH/ISL78841ASRH/ISL78843ASRH/ISL78845ASRH data sheet
- DSCC Standard Microcircuit Drawing (SMD) 5962-07249

3: Part Description

The ISL78845ASRH is a high performance, radiation hardened drop-in replacement for the popular 28C4x and 18C4x PWM controllers suitable for a wide range of power conversion applications including boost, flyback, and isolated output configurations. Its fast signal propagation and output switching characteristics make this an ideal product for existing and new designs.

Features include up to 13.2V operation, low operating current, 90µA typical pre-irradiation start-up current, adjustable operating frequency to 1MHz, and 1 Ampere peak gate drive capability with 50ns rise and fall times.

The ISL78845ASRH is produced in conformance with MIL-PRF-38535 (QML). Specifications for radiation hardness assured (RHA) QML devices are controlled by the Defense Supply Center (DSCC) in Columbus, OH. The SMD numbers listed in the ordering information must be used when ordering. Detailed Electrical Specifications for the ISL788xASRH are contained in SMD 5962-07249.

- Electrically screened to DSCC SMD # 5962-07249
- QML qualified per MIL-PRF-38535 requirements
- 1A MOSFET gate driver
- 90µA (typical) start-up current, 125µA maximum, 500uA maximum post-irradiation
- 35ns propagation delay current sense to output
- Fast transient response with peak current mode control
- 9V to 13.2V operation
- Adjustable switching frequency to 1MHz
- 50ns rise and fall times with 1nF output load
- 50% maximum duty cycle
- 8.4V rising undervoltage lockout (UVLO) voltage
- Trimmed timing capacitor discharge current for accurate dead time/maximum duty cycle control
- 1.5MHz bandwidth error amplifier
- On-chip voltage reference with tight tolerance over line, load and temperature
- ±3% current limit threshold
- Pb-free available (RoHS compliant)

The ISL78845ASRH is part of a family of current-mode PWM controllers differing in undervoltage lockout and maximum duty cycle characteristics. Other parts in the product family include the ISL78840ASRH (7.0V rising UVLO voltage, 100% maximum duty cycle), the ISL78841ASRH (7.0V rising UVLO voltage, 50% maximum duty cycle) and the ISL78843ASRH (8.4V rising UVLO voltage, 100% maximum duty cycle).

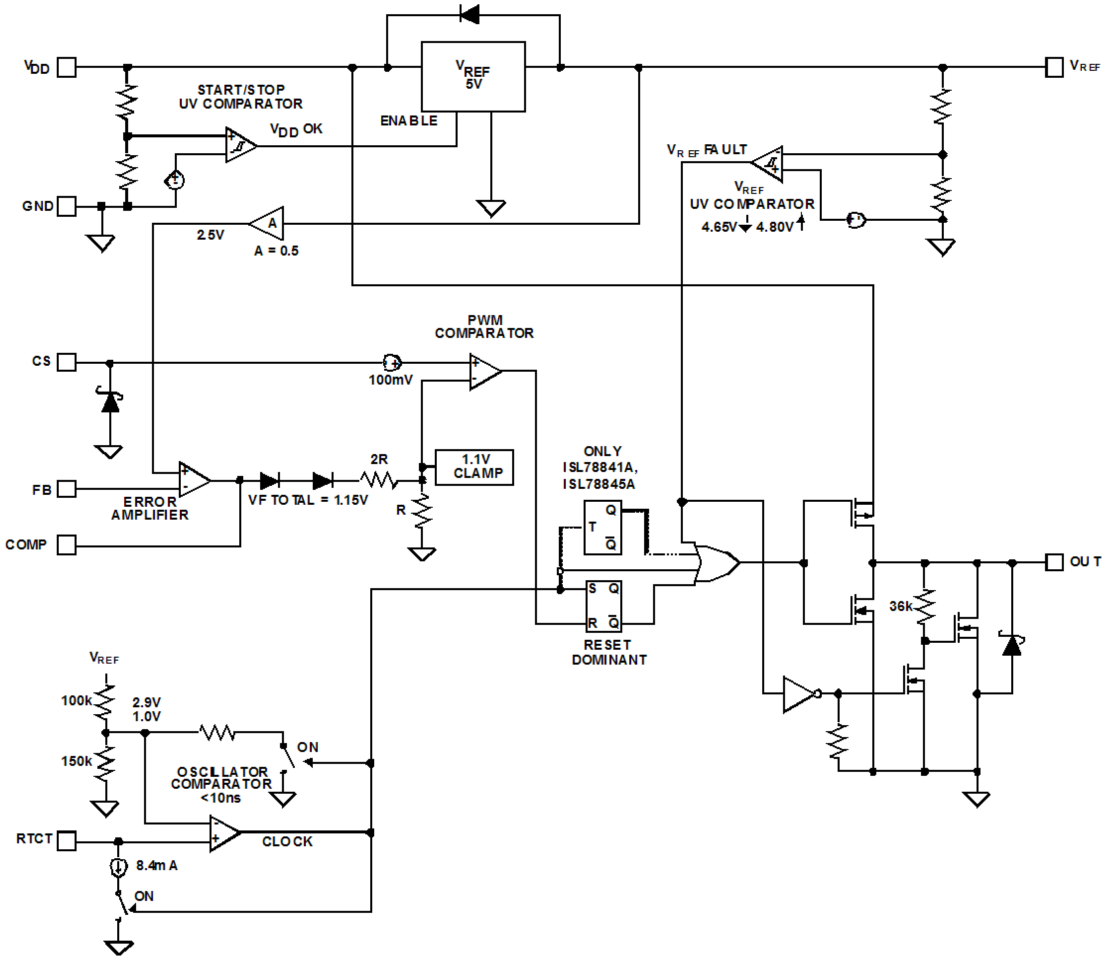

Figure 1: ISL78845ASRH block diagram.

The ISL78845ASRH is implemented in a submicron BiCMOS process optimized for power management applications, with .6um minimum ground rules and three layers of interconnect. The process features salicided source/drain regions for low contact resistance, which is a necessity for integrated power MOSFET applications. Active devices include low voltage CMOS and high voltage DMOS devices as well as complementary bipolars. The process is in volume production under MIL-PRF-38535 certification and is used for a wide range of commercial power management devices. It uses 8” bulk substrates.

4: Test Description

4.1 Irradiation Facilities

High dose rate testing was performed using a Gammacell 220 ^{60}Co irradiator located in the Palm Bay, Florida Intersil facility. Low dose rate testing used a J. L. Shepherd and Associates (JLS) low dose rate ^{60}Co model 484 irradiator located in the same facility. The high dose rate irradiations were done at 55rad(Si)/s and the low dose rate work was performed at .010rad(Si)/s, both per MIL-STD-883 Method 1019.7. Dosimetry for both tests was performed using Far West Technology radiochromic dosimeters and on-site readout equipment. A PbAl box was used to shield the test fixture and devices under test against low energy secondary gamma radiation as required by MIL-STD-883.

4.2 Test Fixturing

Figure 2 shows the configuration used for biased irradiation in conformance with Standard Microcircuit Drawing (SMD) 5962-07249. This configuration was used for both low and high dose rate irradiation. The unbiased low dose rate irradiation was carried out with all pins grounded.

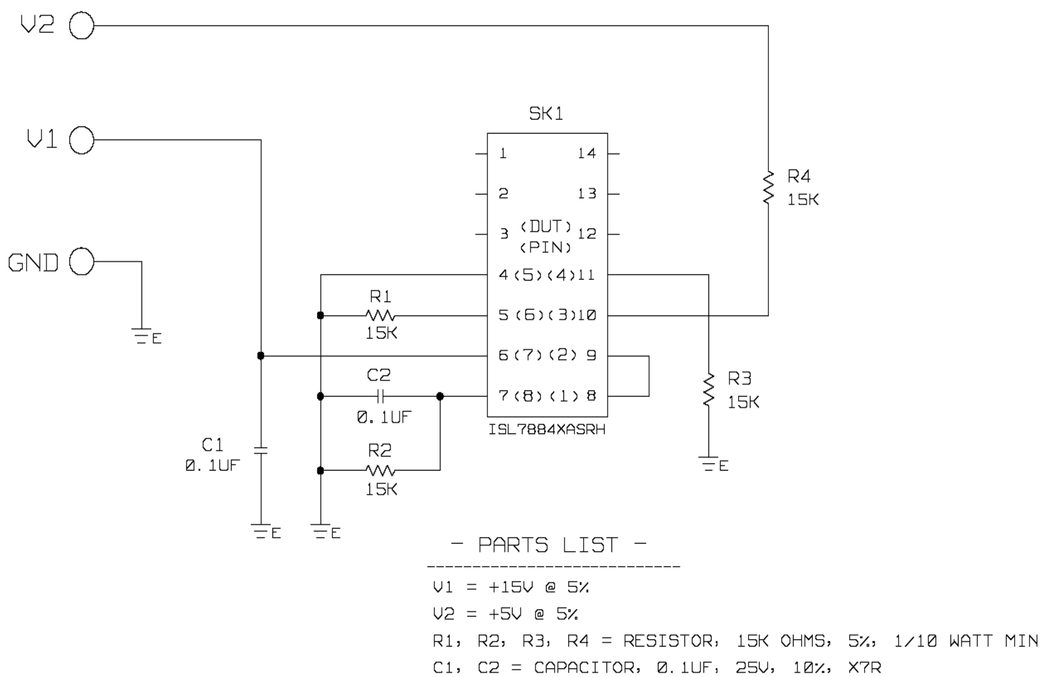

Figure 2: Irradiation bias configuration for the ISL78845ASRH per Standard Microcircuit Drawing (SMD) 5962-07249, as used for both low and high dose rate irradiation.

4.3 Characterization equipment and procedures

All electrical testing was performed outside the irradiator using the production automated test equipment (ATE) with datalogging of all parameters at each downpoint. Downpoint electrical testing was performed at room temperature.

4.5 Experimental matrix

The experimental matrix consisted of three cells: four samples irradiated at high dose rate under bias, four samples irradiated at low dose rate with all pins grounded and four samples irradiated at low dose rate under bias. This experimental approach was consistent with a first engineering test of the part but was not in full compliance with the guidelines of MIL-STD-883 Test Method 1019.7, and a second, fully compliant test sequence is planned at this time.

Samples of the ISL78845ASRH were drawn from preproduction inventory and were packaged in the standard hermetic 8-pin ceramic flatpack (CFP) production package. Samples were processed through the standard burnin cycle before irradiation, as required by MIL-STD-883, and were screened to the SMD 5962-07249 limits at room, low and high temperatures before the test.

4.6 Downpoints

Downpoints were zero, 50krad(Si), 75krad(Si), 100krad(Si) and 150krad(Si) for the low dose rate test. Downpoints were zero, 50krad(Si), 75krad(Si), 100krad(Si) and 125krad(Si) for the high dose rate test.

5: Results

5.1 Test results

The low and high dose rate tests of the ISL78845ASRH are complete and showed no reject devices after irradiation to 150krad(Si) (low dose rate) and 125krad(Si) (high dose rate), screening to the SMD post-irradiation limits.

5.2 Variables data

The plots in Figures 3 through 17 show data at all downpoints. The plots show the median of 15 key parameters as a function of total dose for each of the three irradiation conditions. We chose to plot the median (as opposed to for example mean and standard deviation) because of the small sample sizes involved. All parts showed excellent stability over irradiation, with no observed low dose rate sensitivity. Table 1, below, summarizes key parameters of the device that have been plotted in Figures 3 – 17. Terminology is in accordance with the applicable SMD 5962-07249. Refer to the Discussion section for further analysis.

Table 1: Index to plotted parameters.

Parameter	Symbol	Limits		Units
		minimum	maximum	
START threshold voltage		8.0	9.0	V
STOP threshold voltage		7.3	8.0	V
Startup current	I_{DD}		500	uA
Operating supply current	I_D		5.5	mA
Reference accuracy	V_{REF}	4.925	5.050	V
Reference current limit, sourcing		-20		mA
Reference current limit, sinking		5		mA
Current sense input bias current	I_{IB}	-1.0	1.0	uA
Current sense gain		2.5	3.5	V/V
Error amplifier reference voltage	V_{REF}	2.475	2.530	V
Error amplifier input bias current	FB_{IIB}	-1.0	1.0	uA
Oscillator frequency		48	53	KHz
Oscillator frequency variation with VDD			1.0	%
PWM minimum duty cycle			0	%
PWM maximum duty cycle		47.0		%

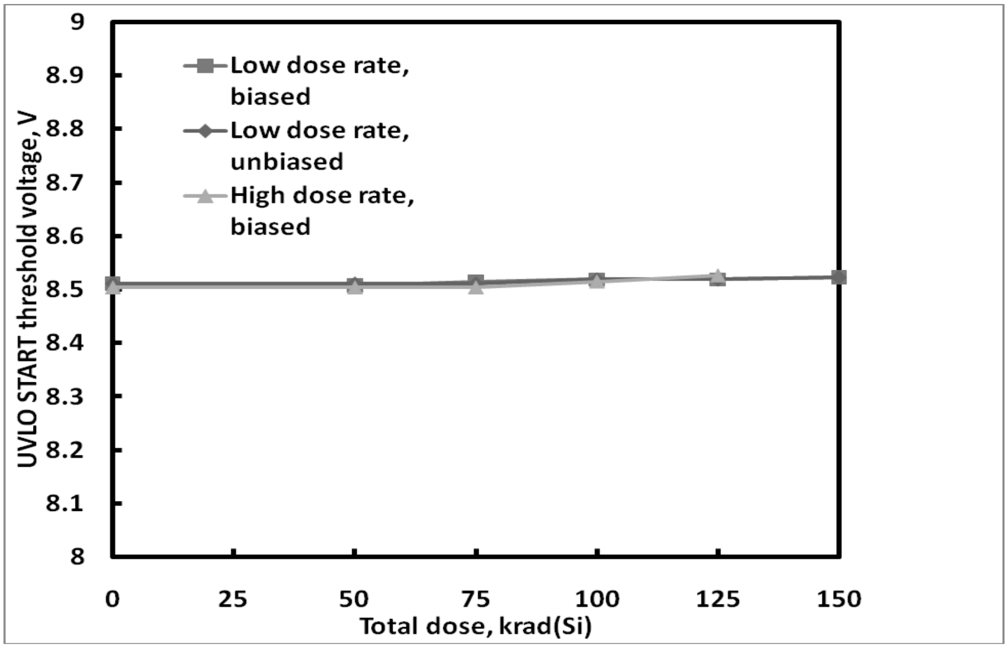

Figure 3: ISL78845ASRH undervoltage lockout START threshold voltage as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limits for this parameter are 8.0 – 9.0V.

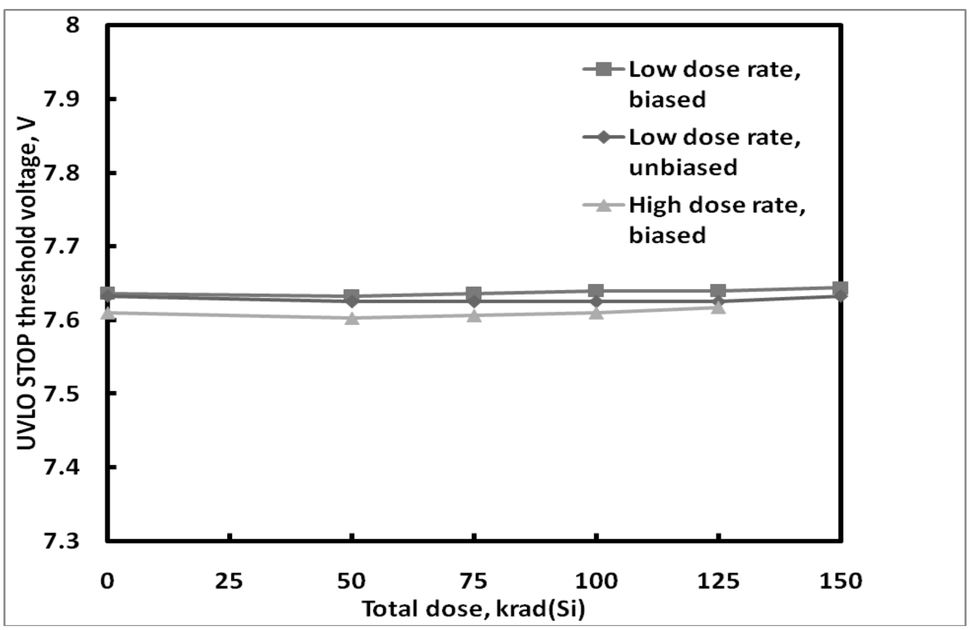

Figure 4: ISL78845ASRH undervoltage lockout STOP threshold voltage as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limits for this parameter are 7.3 – 8.0V.

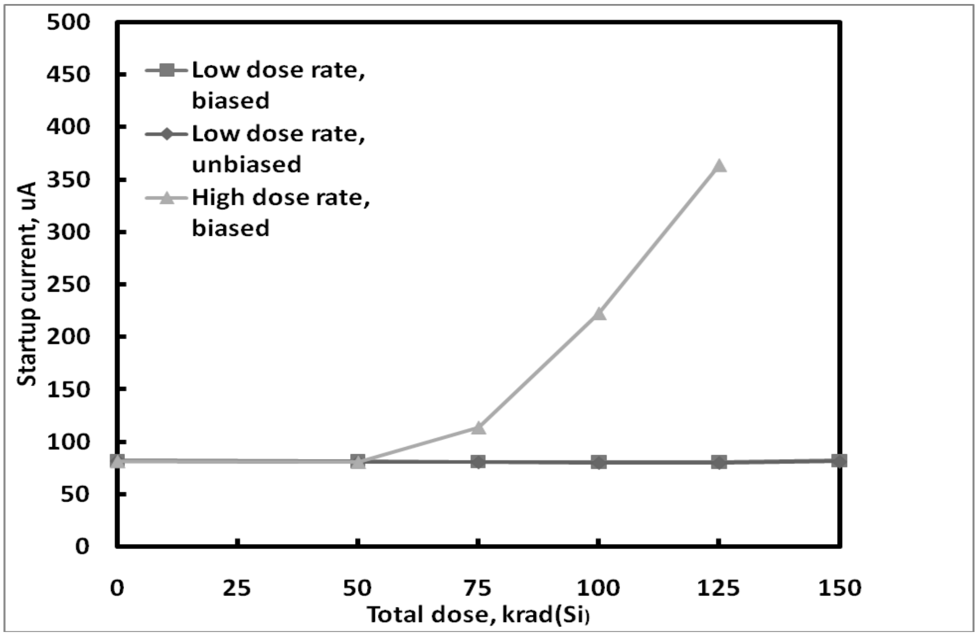

Figure 5: ISL78845ASRH startup current as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The SMD limit for this parameter is 125uA maximum pre-irradiation and 500uA post-irradiation.

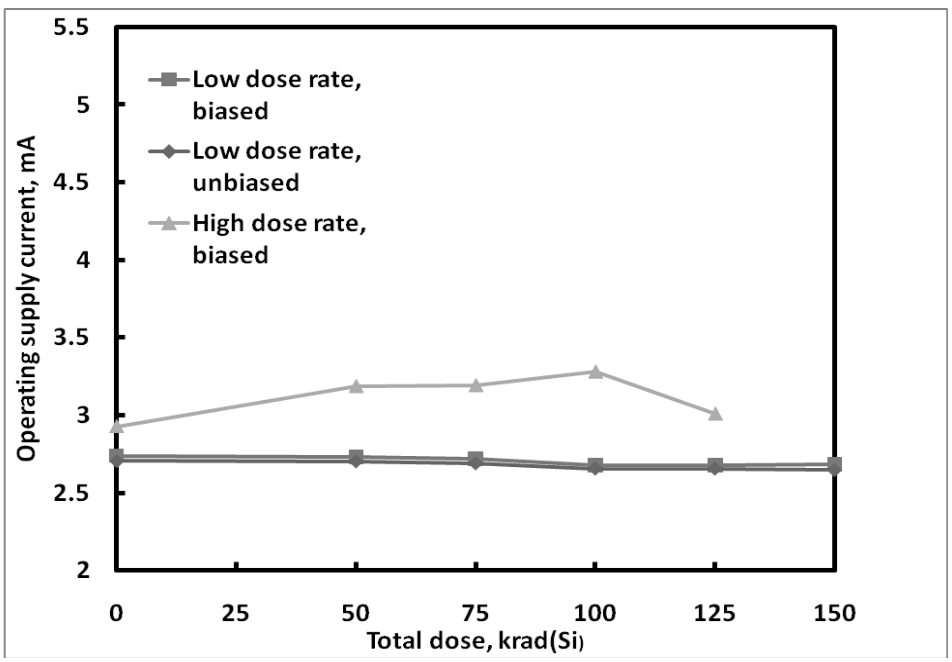

Figure 6: ISL78845ASRH operating supply current as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limit for this parameter is 5.5mA.

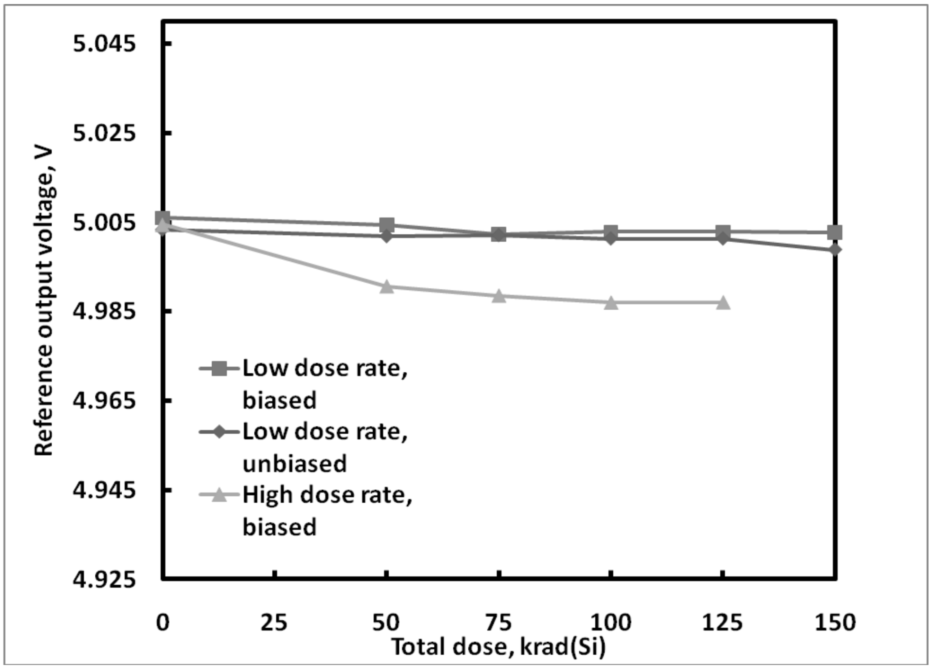

Figure 7: ISL78845ASRH master reference output voltage as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limits for this parameter are 4.925 – 5.050V.

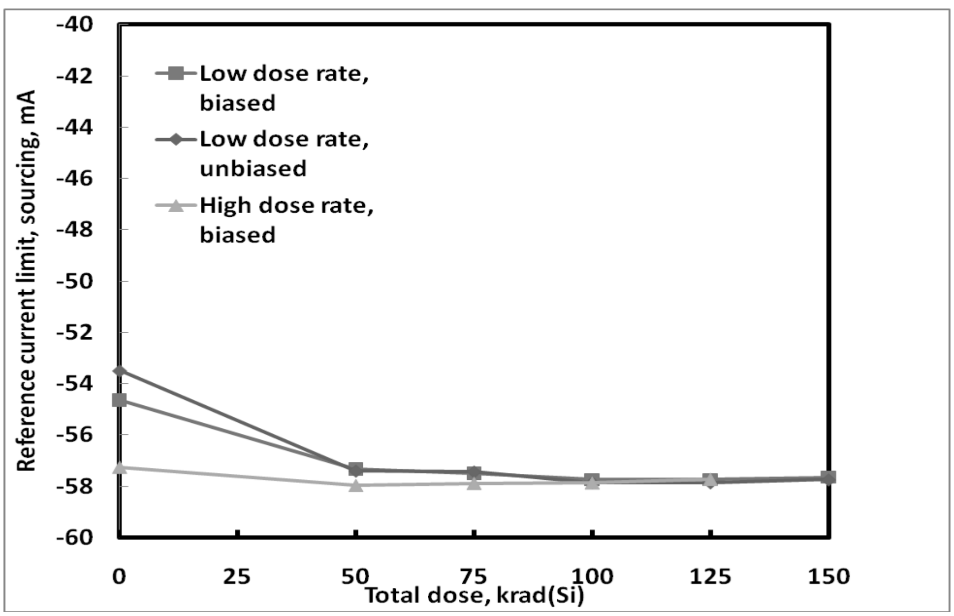

Figure 8: ISL78845ASRH reference current limit, sourcing, as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limit for this parameter is 20mA.

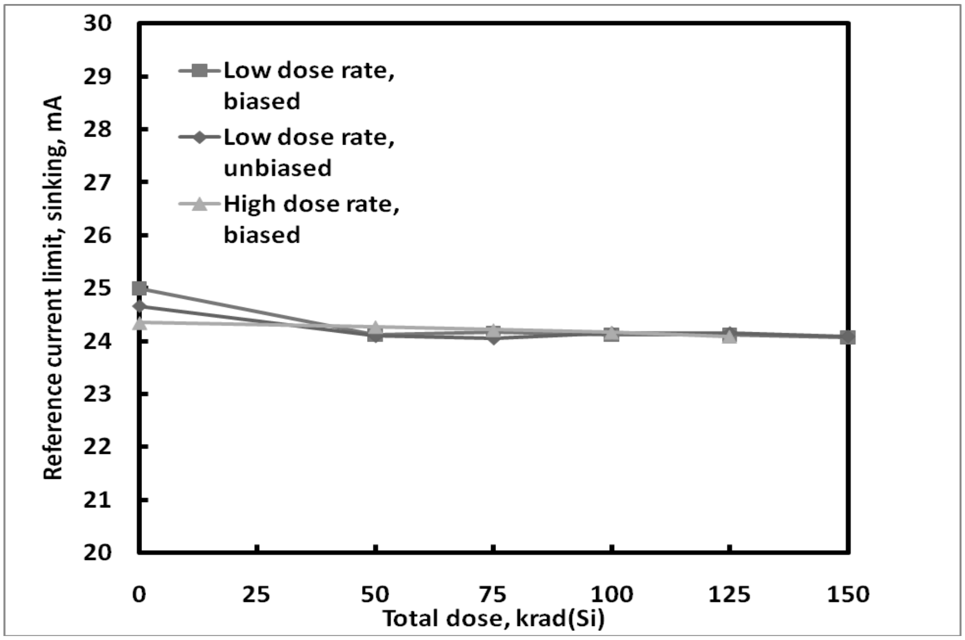

Figure 9: ISL78845ASRH reference current limit, sinking, as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limit for this parameter is 5mA minimum.

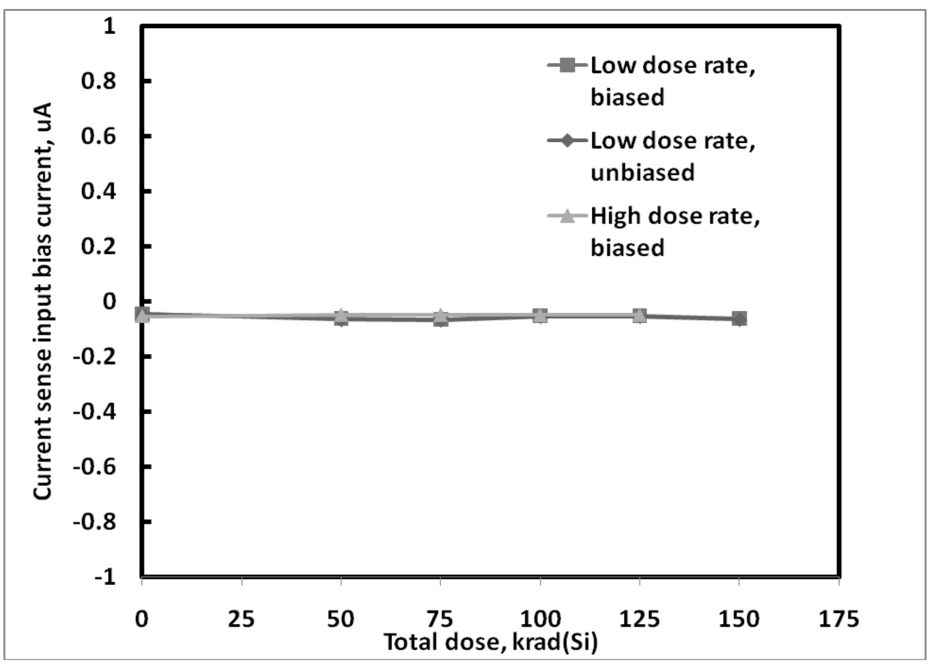

Figure 10: ISL78845ASRH current sense amplifier input bias current as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limits for this parameter are -1.0 – 1.0uA.

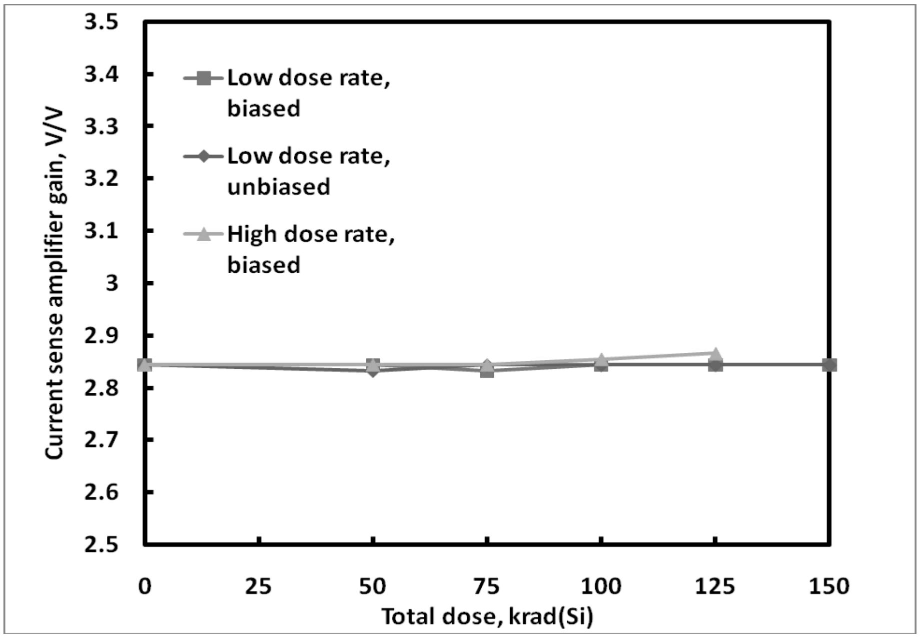

Figure 11: ISL78845ASRH current sense amplifier gain as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limits for this parameter are 2.5 – 3.5V/V.

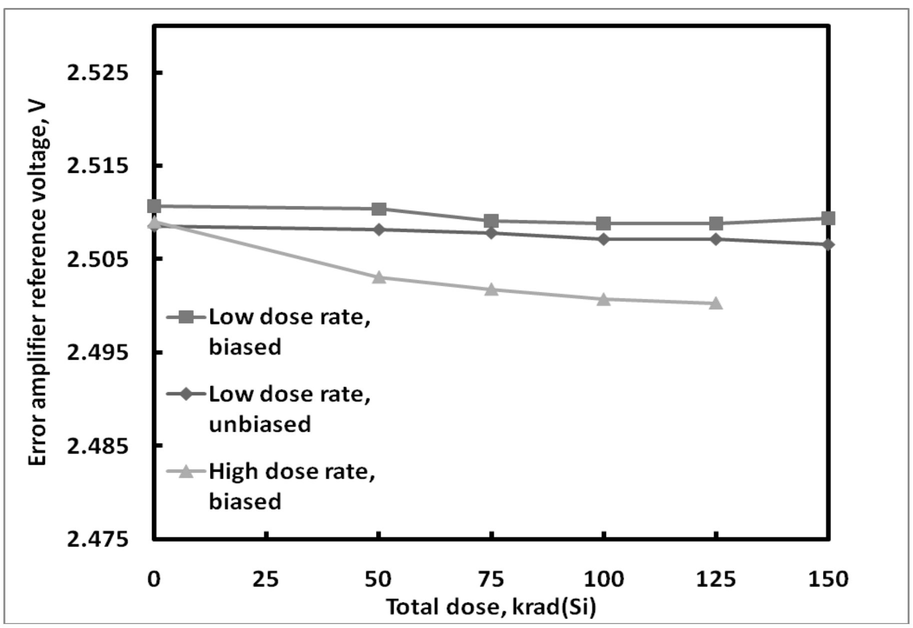

Figure 12: ISL78845ASRH error amplifier reference voltage as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limits for this parameter are 2.475 – 2.530V.

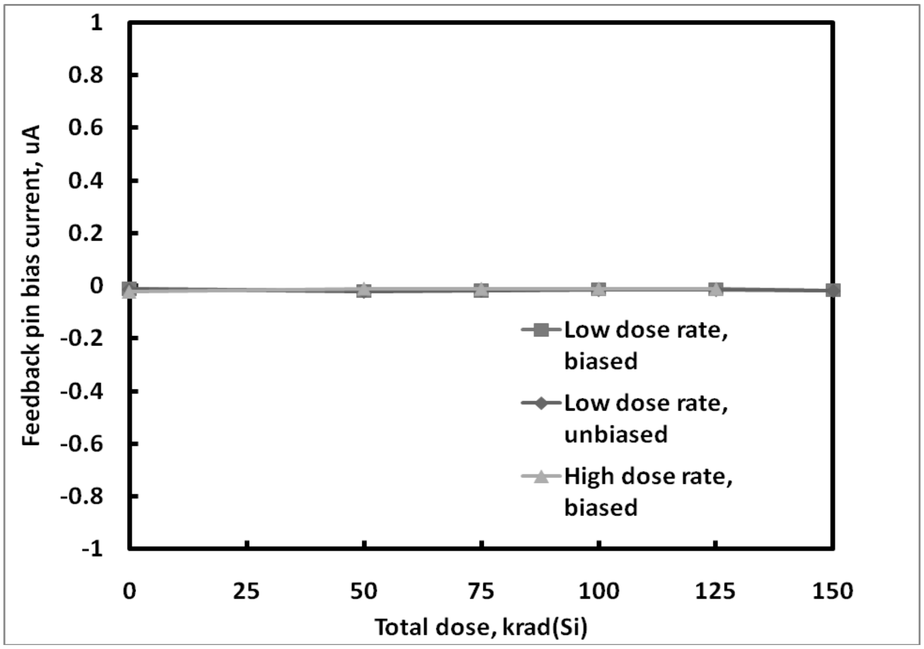

Figure 13: ISL78845ASRH error amplifier feedback pin bias current as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limits for this parameter are -1.0 – 1.0uA.

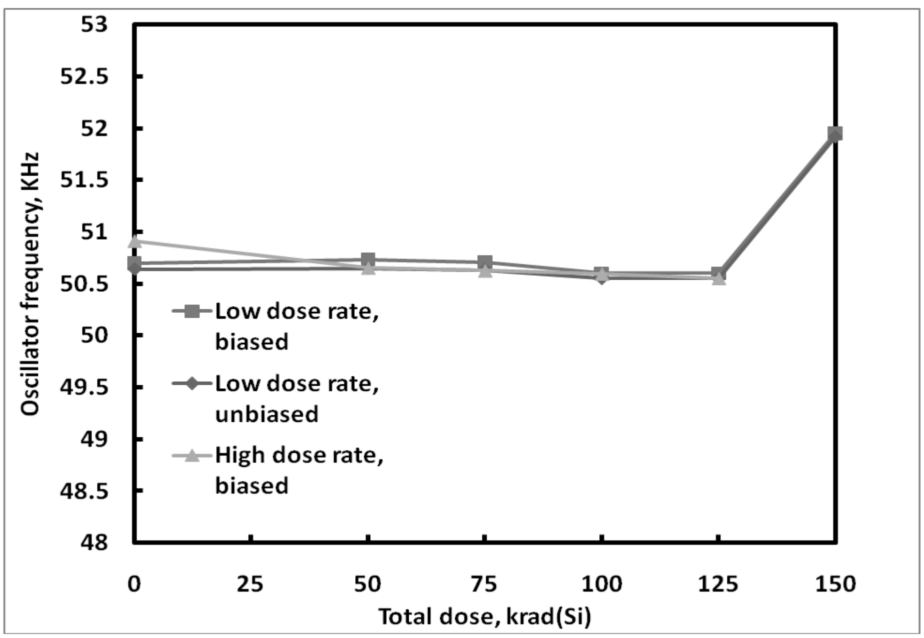

Figure 14: ISL78845ASRH oscillator frequency as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limits for this parameter are 48 – 53KHz.

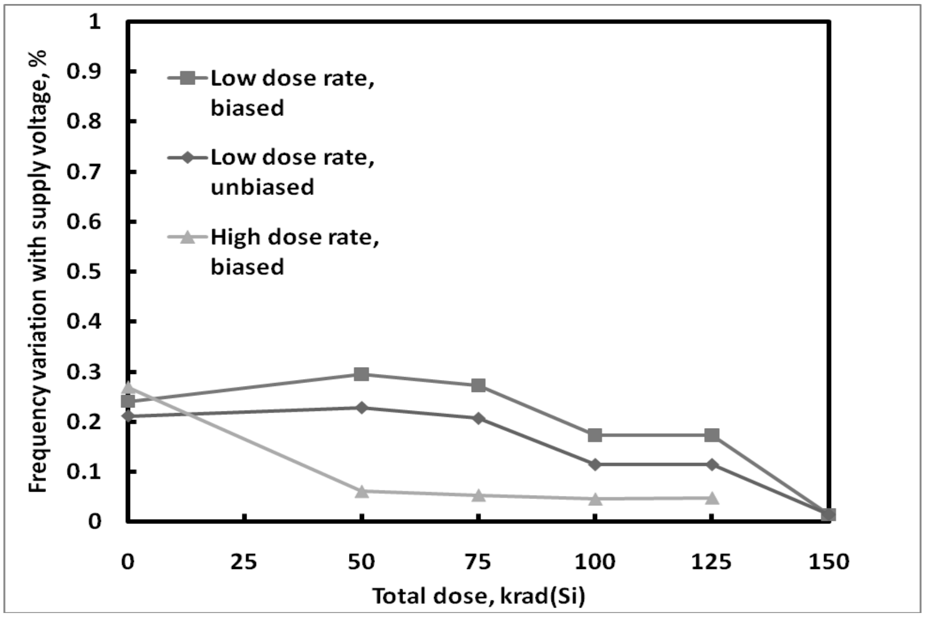

Figure 15: ISL78845ASRH oscillator frequency variation with V_{DD} as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limit for this parameter is 1% maximum.

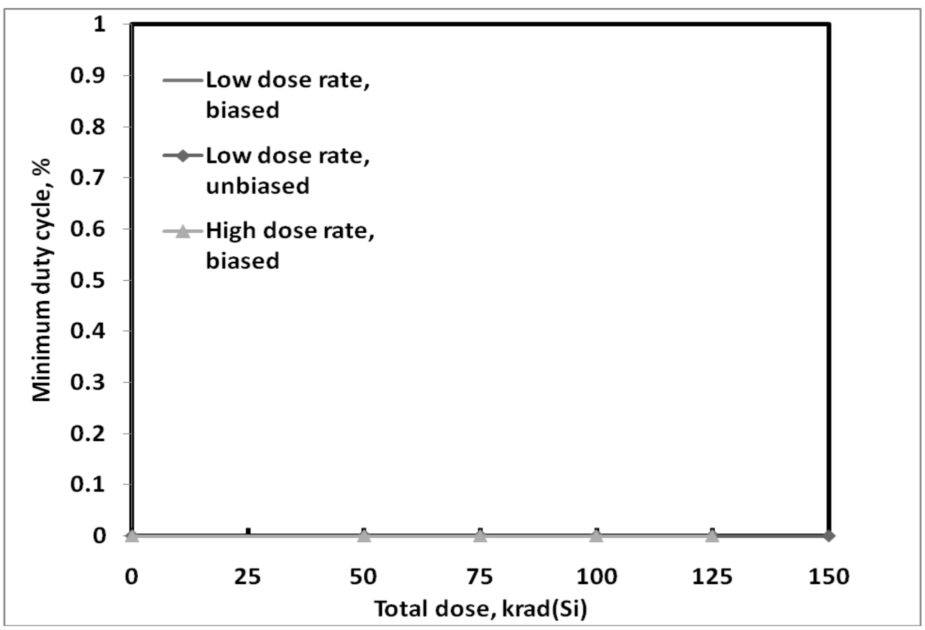

Figure 16: ISL78845ASRH minimum duty cycle as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limit for this parameter is 0% maximum. Note all plotted values were 0%.

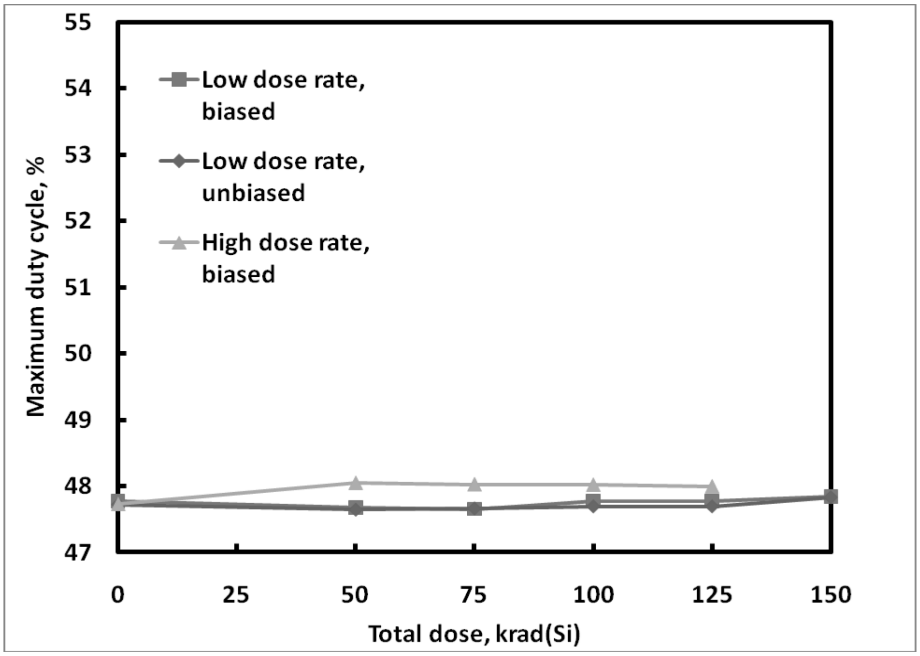

Figure 17: ISL78845ASRH maximum duty cycle as a function of total dose irradiation at low and high dose rate. The low dose rate was 0.01rad(Si)/s and the high dose rate was 55rad(Si)/s. Sample size for each cell was 4. The post-irradiation SMD limit for this parameter is 47% minimum.

6: Discussion

ATE characterization of the samples at all downpoints showed no rejects tot the SMD post-irradiation limits. The data is plotted in the figures and generally showed good stability over total dose irradiation. Three figures are interesting.

Figure 5 shows startup current as a function of total dose. The two low dose rate responses are essentially flat over the entire range of the plot, but the high dose rate curve shows a monotonic increase beginning at the 50krad(Si) point; the curve is well within the 500uA SMD post-irradiation limit at 125krad(Si), which is 25krad(Si) above the 100krad(Si) maximum total dose specification of the part. This response is the opposite of classical low dose rate sensitivity and is believed to represent the largely CMOS design of the part. In this sense the startup current is equivalent to the quiescent supply current parameter (Iddq) which is commonly used to quantify the radiation hardness of digital logic arrays.

Figures 7 and 12 show the master voltage reference output voltage and the error amplifier reference voltage, respectively, as a function of total dose. This behavior is similar to that of the startup current in that the part is more sensitive to high dose rate than to low dose rate, but the exact mechanism for these two parameters is not as clear. Both references contain bipolar junction transistors which would be expected to be low dose rate sensitive.

All other plotted parameters show little and sometimes no difference between the high and low dose rate response. The conclusion is that the part is not low dose rate sensitive and displays no bias sensitivity.

7: Conclusion

This document reports interim results of a total dose test of the ISL78845ASRH current-mode PWM controller. Parts were tested at low dose rate under biased and unbiased conditions to a maximum total dose of 150krad(Si) and were tested at high dose rate under biased conditions to a maximum total dose of 125krad(Si).

No low dose rate sensitivity was noted; rather, several parameters appeared to be more sensitive to high dose rate, an eventuality not foreseen or defined by MIL-STD-883 for parts containing bipolar junction transistors (BJT). Accordingly, the part is considered ELDRS-free up to the 100krad(Si) data sheet total dose rating. It should be noted that this test sequence represented a first look at the part's response and was not in strict accordance with MIL-STD-883, as a high dose rate test under unbiased (grounded) conditions was not performed. A complete test in full compliance is currently being planned.

Similarly, no differences between biased and unbiased irradiation were noted, and the part is not considered bias sensitive.

7: Appendices

None.

8: Document revision history

Revision	Date	Pages	Comments
0	28 May 2010	All	Original issue
1	14 August 2012	2	Add ISL7884xASEH language
2	12 April 2013	1	Added logo