

HS-1825ARH

Neutron Testing

TR032  
Rev 0.00  
June 8, 2016

## Introduction

This report summarizes results of 1MeV equivalent neutron testing of the [HS-1825ARH](#) voltage mode Pulse Width Modulator (PWM). The test was conducted in order to determine the sensitivity of the part to Displacement Damage (DD) caused by neutron or proton environments. Neutron fluences ranged from  $2 \times 10^{12} \text{ n/cm}^2$  to  $1 \times 10^{14} \text{ n/cm}^2$ . This project was carried out in collaboration with Boeing (El Segundo, CA), whose support is gratefully acknowledged.

## Reference Documents

- MIL-STD-883 test method 1017
- [HS-1825ARH](#) Datasheet
- DSCC Standard Microcircuit Drawing (SMD) [5962-99558](#)

## Part Description

The radiation hardened [HS-1825ARH](#) and [HS-1825AEH](#) pulse width modulators are designed to be used in high frequency switched-mode power supplies and can be used in either current-mode or voltage-mode. They are well suited for single-ended boost converter applications. Device features include a precision voltage reference, low power start-up circuit, high frequency oscillator, wide-band error amplifier and a fast current-limit comparator. The HS-1825ARH and HS-1825AEH are fabricated in the Intersil Radiation Hardened Silicon Gate (RSG) dielectrically isolated BiCMOS process. [Table 1](#) shows the pinout of the part.

Detailed electrical specifications for these devices are contained in SMD [5962-99558](#). Specifications for radiation hardened QML devices are controlled by the Defense Logistics Agency Land and Maritime (DLA).

The HS-1825ARH is acceptance tested on a wafer-by-wafer basis to a total dose level of 300krad(Si) at high dose rate (50-300rad(Si)/s). The HS-1825AEH is acceptance tested to 300krad(Si) at high dose rate (50-300rad(Si)/s) and to 50krad(Si) at low dose rate ( $< 0.01 \text{ rad(Si)/s}$ ).

TABLE 1. HS-1825ARH PIN ASSIGNMENTS (16-PIN FLATPACK)

| TERMINAL NUMBER | TERMINAL SYMBOL | TERMINAL NUMBER | TERMINAL SYMBOL |
|-----------------|-----------------|-----------------|-----------------|
| 1               | INV             | 9               | ILIM/SD         |
| 2               | NON-INV         | 10              | GND             |
| 3               | E/A OUT         | 11              | OUTPUT A        |
| 4               | CLOCK           | 12              | POWER GND       |
| 5               | RT              | 13              | VC              |
| 6               | CT              | 14              | OUTPUT B        |
| 7               | RAMP            | 15              | VCC             |
| 8               | SOFT-START      | 16              | VREF 5.1V       |

## Test Description

### Irradiation Facilities

1MeV equivalent neutron irradiation was performed by the Boeing team at the Survivability and Vulnerability Assessment Directorate, US Army, White Sands Missile Range fast burst reactor (White Sands Missile Range, NM 88002). Dosimetry data can be furnished upon request. Parts were tested in an unbiased configuration with all leads shorted together in general accordance with TM 1017 of MIL-STD-883. As neutron irradiation activates many of the heavier elements found in a packaged integrated circuit, the parts exposed at the higher neutron levels required considerable "cooldown" time before being shipped back to Intersil for electrical testing.

### Test Fixturing

No formal irradiation test fixturing was involved. These DD tests are termed "bag tests" in the sense that the parts are irradiated in an inactive state with all leads shorted together.

### Characterization Equipment and Procedures

Electrical testing was performed before and after irradiation using the Intersil Palm Bay, FL Automated Test Equipment (ATE). All electrical testing was performed at room temperature.

### Experimental Matrix

The experimental matrix consisted of 5 samples irradiated at  $2 \times 10^{12} \text{ n/cm}^2$ , 5 irradiated at  $1 \times 10^{13} \text{ n/cm}^2$ , 5 irradiated at  $3 \times 10^{13} \text{ n/cm}^2$  and 5 irradiated at  $1 \times 10^{14} \text{ n/cm}^2$ . Five control units were used. The HS-1825ARH samples were drawn from fabrication lot E0A4PDB and were packaged in the standard 16 Ld ceramic production package. Samples were screened to the SMD limits over temperature before the start of neutron testing.

## Results

Neutron testing of the HS-1825ARH is complete and the results are reported in the balance of this report. It should be carefully realized when interpreting the data that each neutron irradiation was performed on a different five-unit sample; this is not total dose testing, where the damage is cumulative over a number of downpoints.

### Attributes Data

TABLE 2. HS-1825ARH ATTRIBUTES DATA

| PART       | SAMPLE SIZE | FLUENCE, $n/cm^2$  | PASS (Note 1) | FAIL | NOTES                                                 |
|------------|-------------|--------------------|---------------|------|-------------------------------------------------------|
| HS-1825ARH | 5           | $2 \times 10^{12}$ | 5             | 0    | All passed                                            |
| HS-1825ARH | 5           | $1 \times 10^{13}$ | 5             | 0    | All passed                                            |
| HS-1825ARH | 5           | $3 \times 10^{13}$ | 0             | 5    | All failed, start timing, ramp offset, charge current |
| HS-1825ARH | 5           | $1 \times 10^{14}$ | 0             | 5    | All failed, nonfunctional                             |

NOTE:

1. 'Pass' indicates a sample that passes all SMD limits.

### Variables Data

The plots in [Figures 1](#) through [23](#) show data plots for key parameters before and after irradiation to each level. The reported parameters and their data sheet limits are shown in [Table 3](#). As indicated in [Table 2](#) all samples were nonfunctional after exposure to  $1 \times 10^{14} n/cm^2$ ; for several of the figures, we elected to not plot the data at this level as it has little meaning (being nothing more than an ATE overrange) and makes the data at the other three levels more difficult to interpret.

The plots show the population median of each parameter as a function of neutron irradiation as well as population maximum and minimum error bars at each downpoint. We chose to plot the median because of the small sample sizes (five per cell) involved. We also show the applicable post-total dose electrical limits as taken from the SMD; it should be carefully noted that these limits are provided for *guidance only* as the HS-1825ARH is not specified or guaranteed for the neutron environment. Intersil does not design, qualify or guarantee its parts for the DD environment, but has performed limited collaborative neutron testing for customer guidance.

## Variables Data Plots

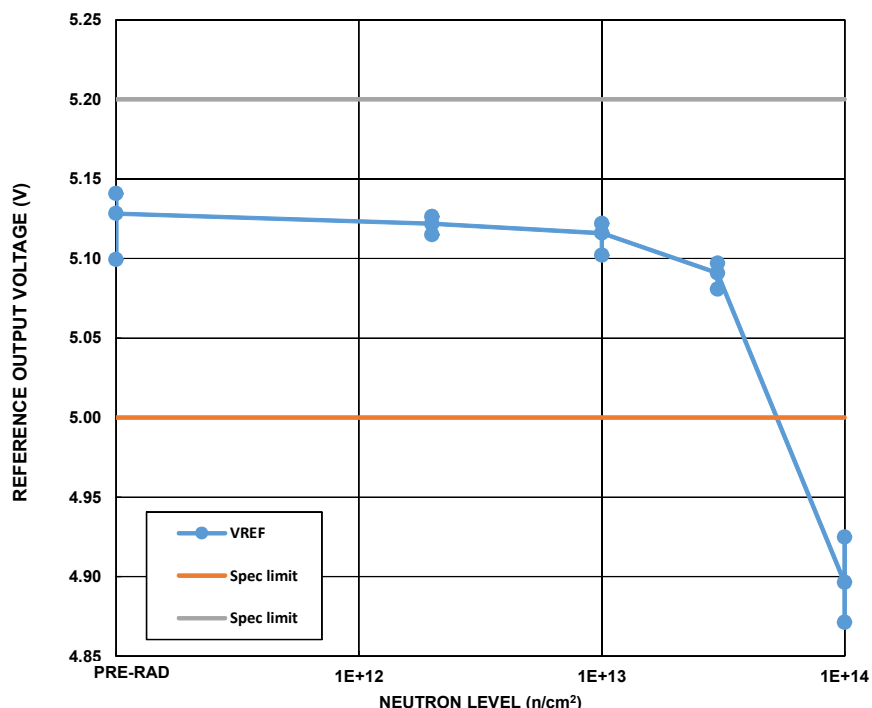


FIGURE 1. HS-1825ARH reference output voltage as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} n/cm^2$ ,  $1 \times 10^{13} n/cm^2$ ,  $3 \times 10^{13} n/cm^2$  and  $1 \times 10^{14} n/cm^2$ . The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 5V to 5.2V.

## Variables Data Plots (Continued)

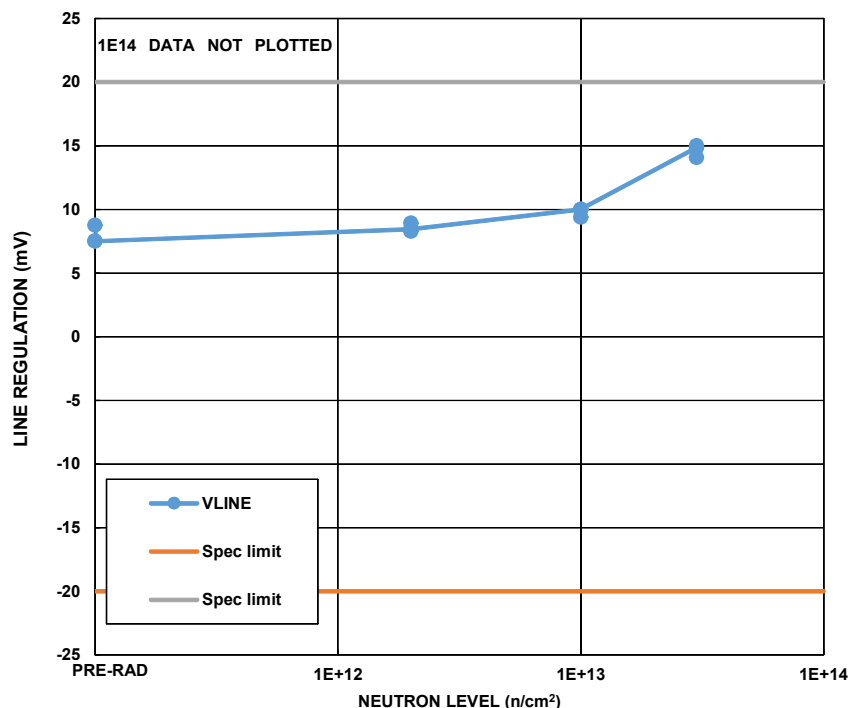


FIGURE 2. HS-1825ARH reference section line regulation as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each downpoint. The  $1 \times 10^{14} \text{ n/cm}^2$  data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are -20mV to 20mV.

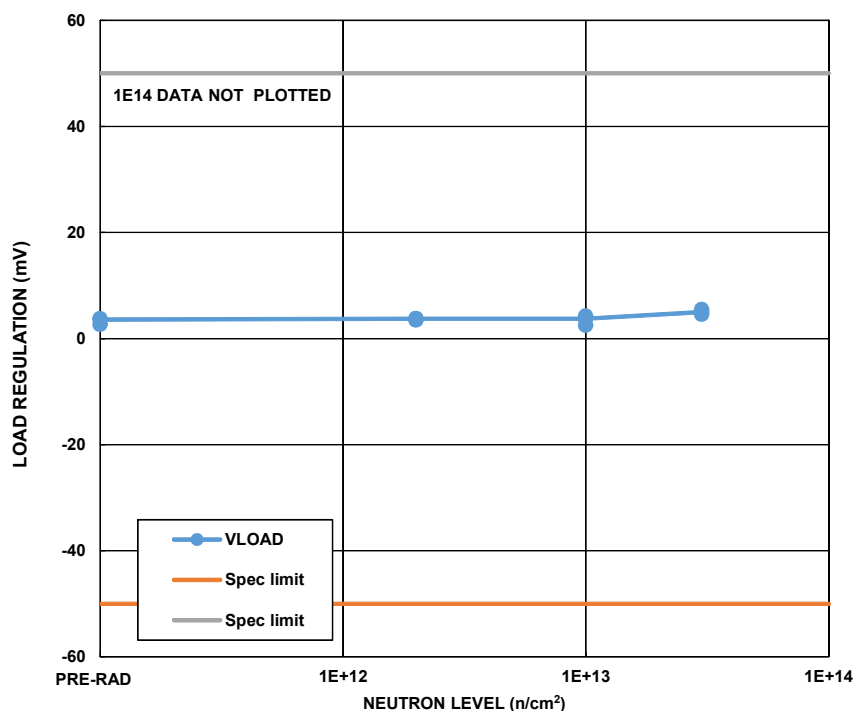


FIGURE 3. HS-1825ARH reference section load regulation as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each downpoint. The  $1 \times 10^{14} \text{ n/cm}^2$  data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are -50mV to 50mV.

## Variables Data Plots (Continued)

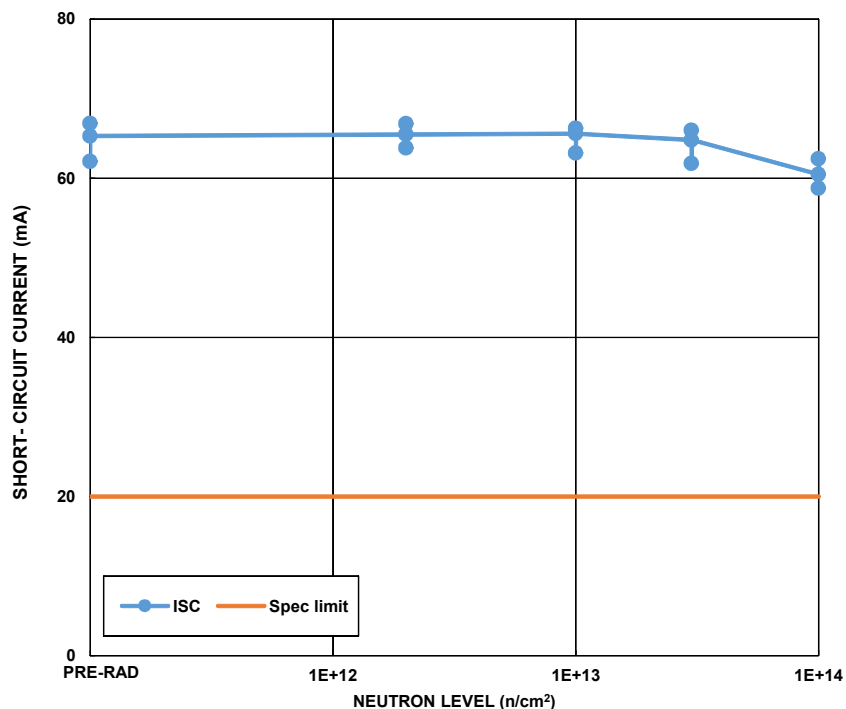


FIGURE 4. HS-1825ARH reference section output short-circuit current as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 20mA minimum

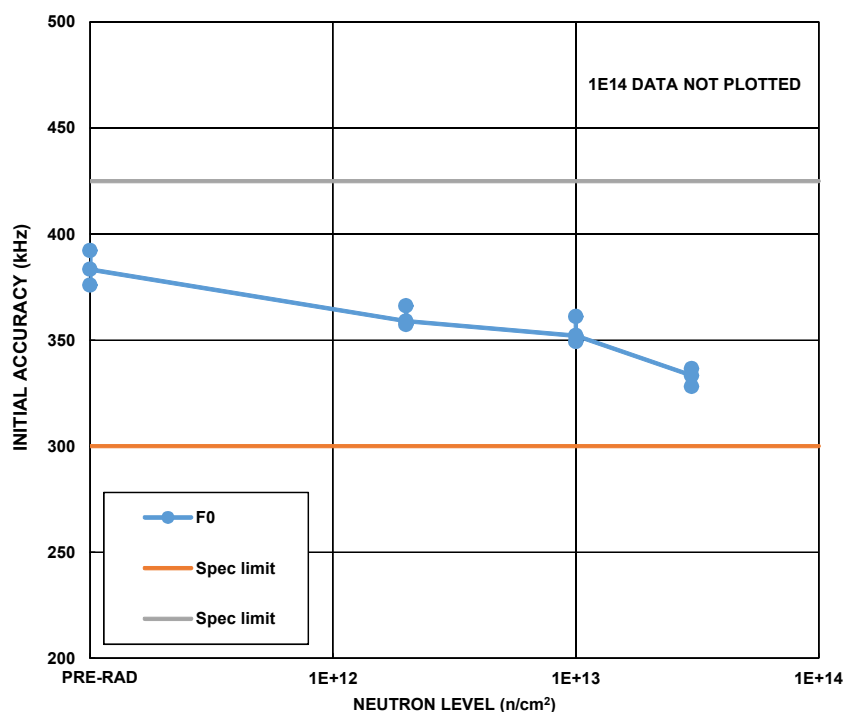


FIGURE 5. HS-1825ARH oscillator section initial accuracy as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each downpoint. The  $1 \times 10^{14} \text{ n/cm}^2$  data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 300kHz to 425kHz.

## Variables Data Plots (Continued)

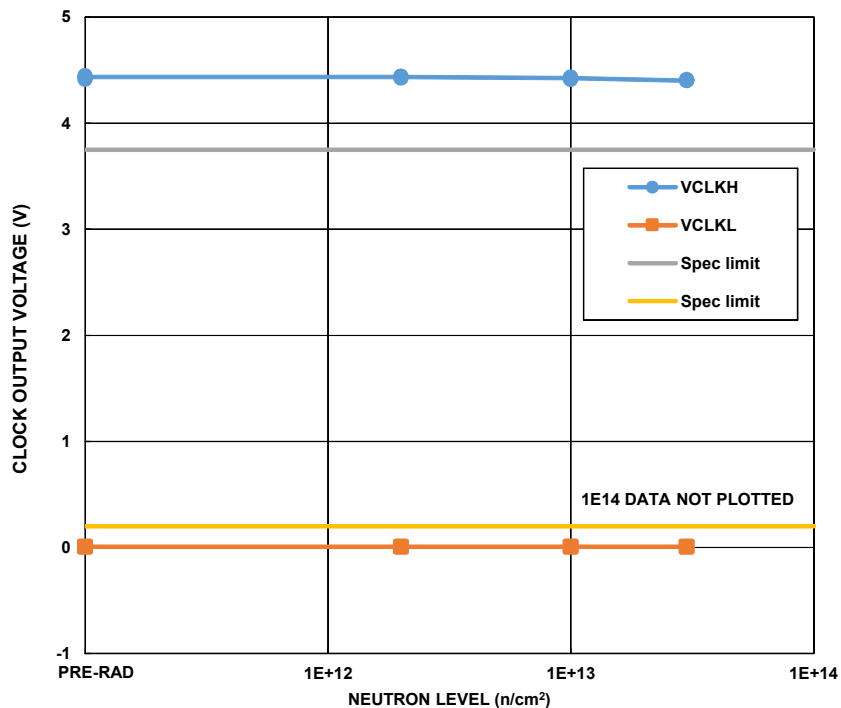


FIGURE 6. HS-1825ARH HIGH and LOW clock output voltage as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The  $1 \times 10^{14} \text{ n/cm}^2$  data were ATE overruns and are not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 3.75V minimum (HIGH) and 0.2V maximum (LOW).

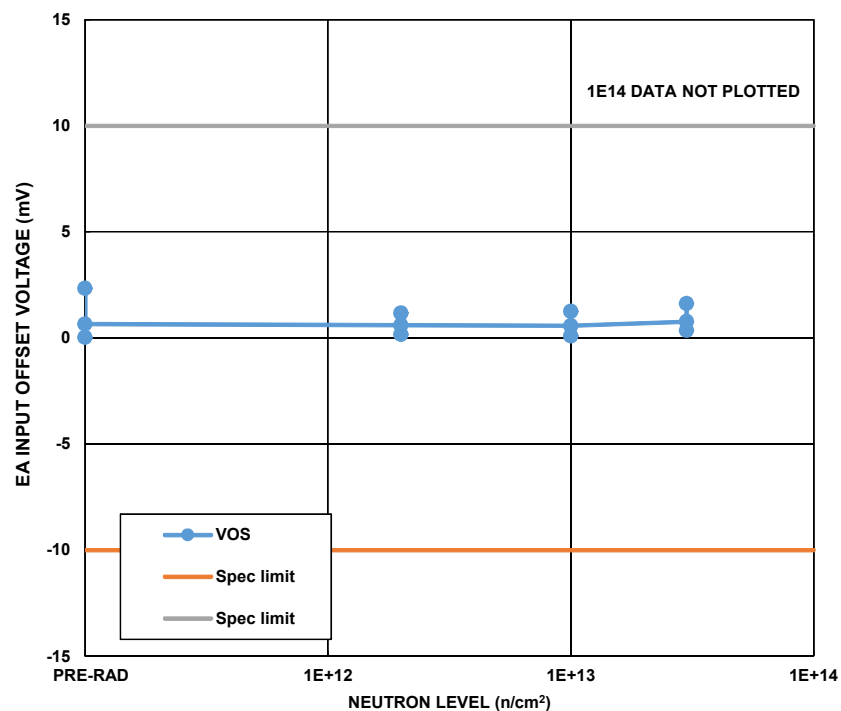


FIGURE 7. HS-1825ARH error amplifier input offset voltage as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The  $1 \times 10^{14} \text{ n/cm}^2$  data was an ATE overrun and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are -10mV to 10mV.

## Variables Data Plots (Continued)

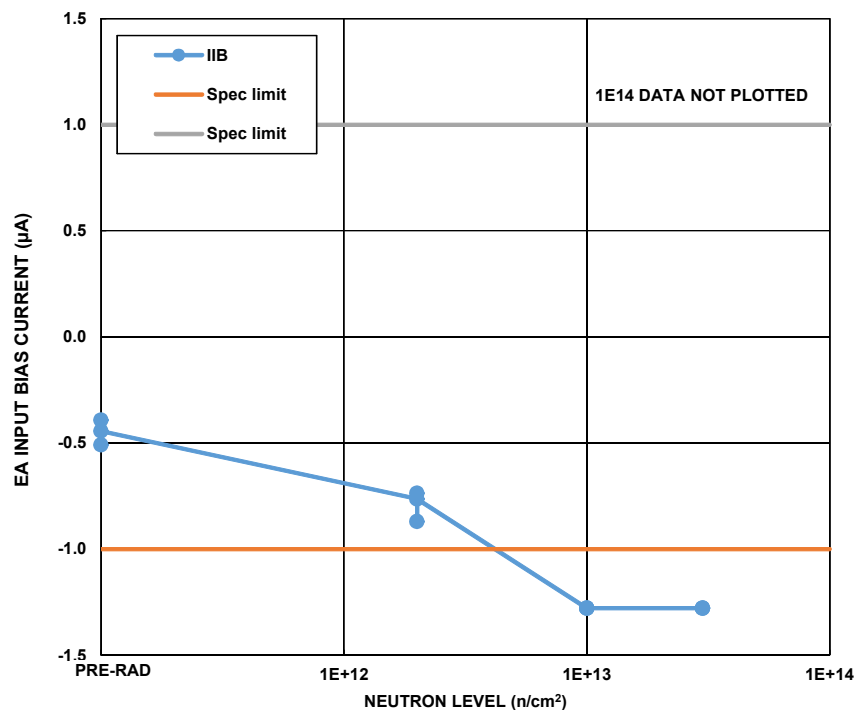


FIGURE 8. HS-1825ARH error amplifier input bias current as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{n}/\text{cm}^2$ ,  $1 \times 10^{13} \text{n}/\text{cm}^2$ ,  $3 \times 10^{13} \text{n}/\text{cm}^2$  and  $1 \times 10^{14} \text{n}/\text{cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The  $1 \times 10^{14} \text{n}/\text{cm}^2$  data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are  $-1 \mu\text{A}$  to  $1 \mu\text{A}$ .

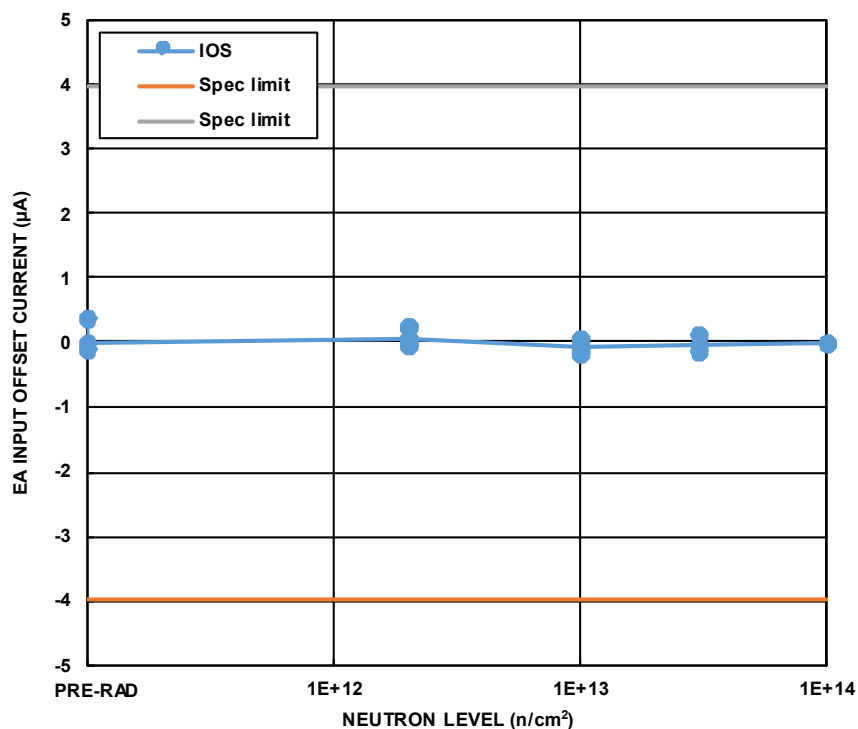


FIGURE 9. HS-1825ARH error amplifier input offset current as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{n}/\text{cm}^2$ ,  $1 \times 10^{13} \text{n}/\text{cm}^2$ ,  $3 \times 10^{13} \text{n}/\text{cm}^2$  and  $1 \times 10^{14} \text{n}/\text{cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The sample size for each cell was 5. The post-total dose irradiation SMD limits are  $-4 \mu\text{A}$  to  $4 \mu\text{A}$ .

## Variables Data Plots (Continued)

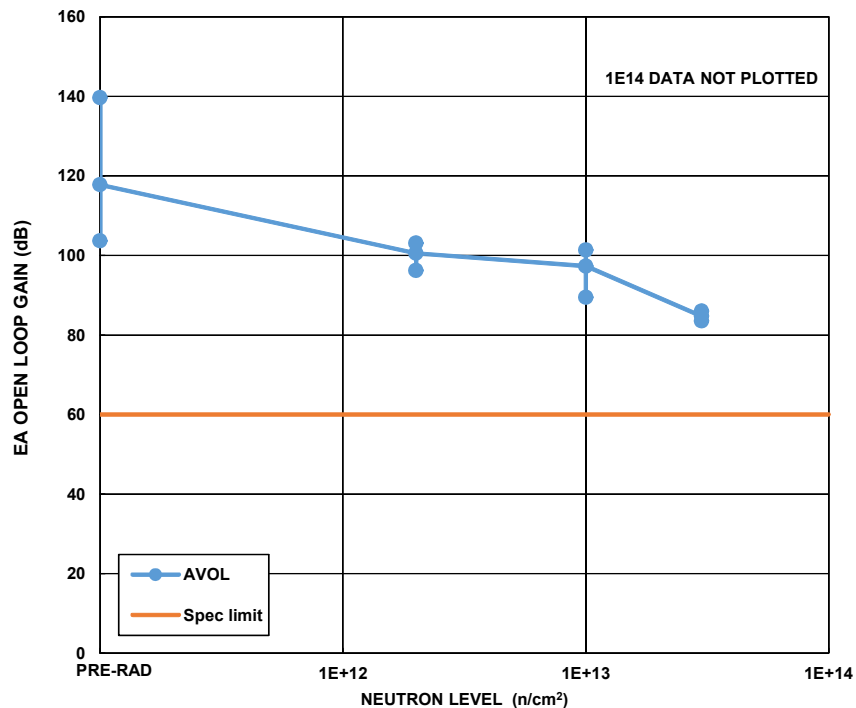


FIGURE 10. HS-1825ARH error amplifier open loop gain as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The  $1 \times 10^{14} \text{ n/cm}^2$  data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 60dB minimum.

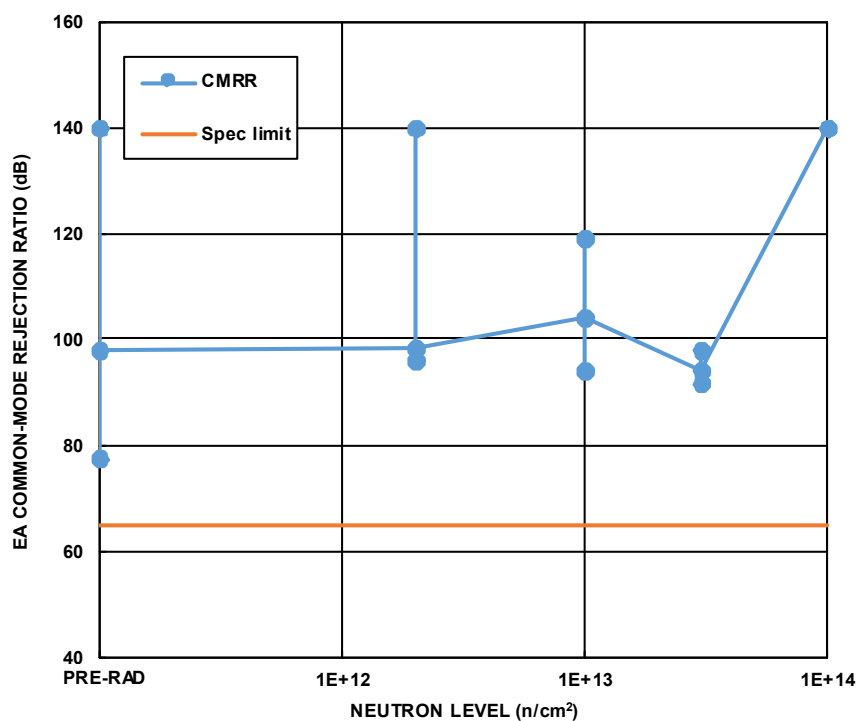


FIGURE 11. HS-1825ARH error amplifier common mode rejection ratio as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 65dB minimum.

## Variables Data Plots (Continued)

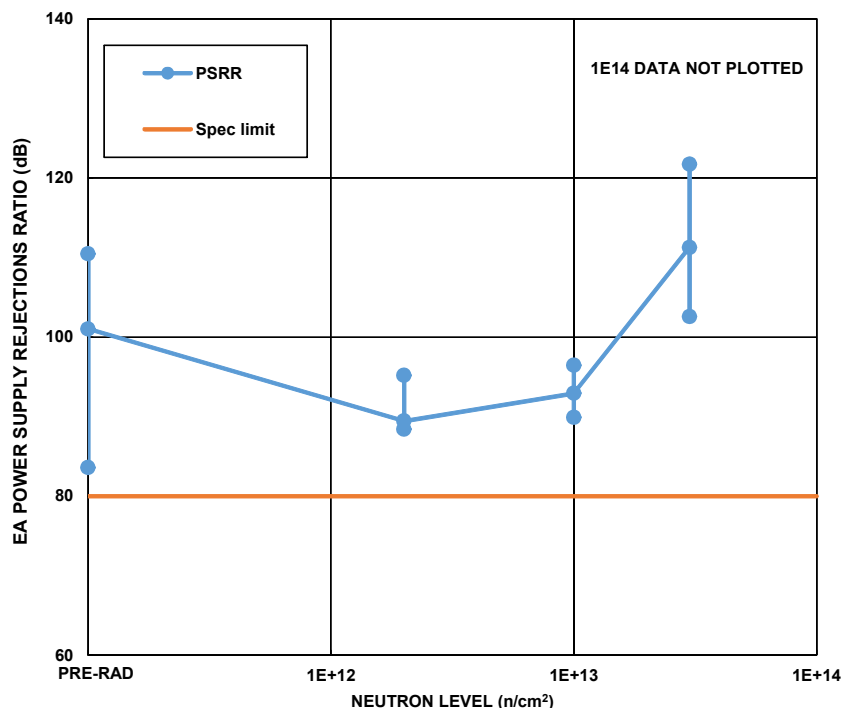


FIGURE 12. HS-1825ARH error amplifier power supply rejection ratio as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The  $1 \times 10^{14} \text{ n/cm}^2$  data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 80dB minimum.

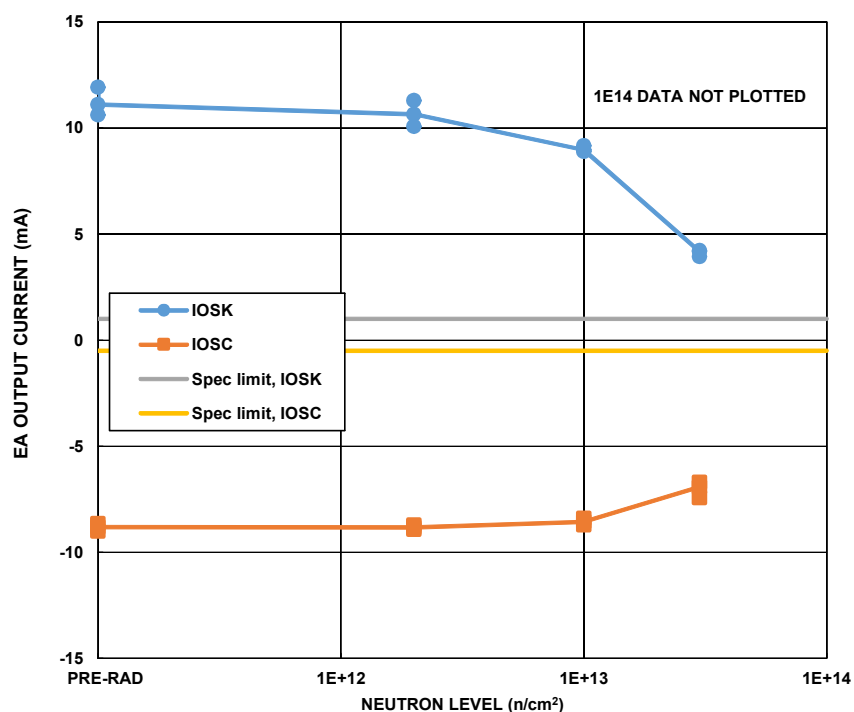


FIGURE 13. HS-1825ARH error amplifier output current, sourcing and sinking, as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The sample size for each cell was 5. The  $1 \times 10^{14} \text{ n/cm}^2$  data points were ATE overranges and are not plotted. The post-total dose irradiation SMD limits are 1mA minimum (sinking) and -0.5mA minimum (sourcing).

## Variables Data Plots (Continued)

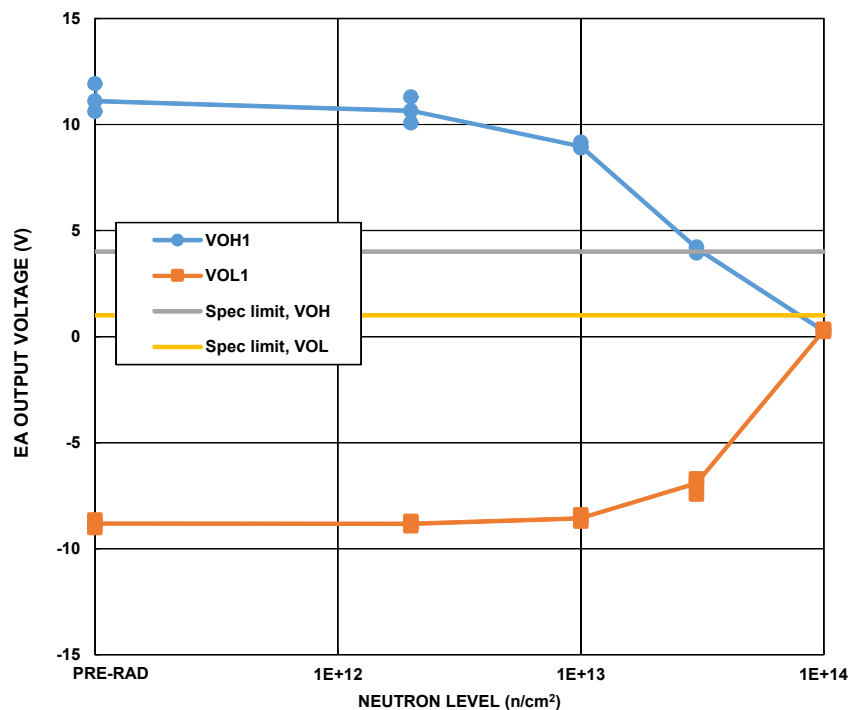


FIGURE 14. HS-1825ARH error amplifier output voltage, HIGH and LOW, as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 4V minimum (HIGH) and 1V maximum (LOW).

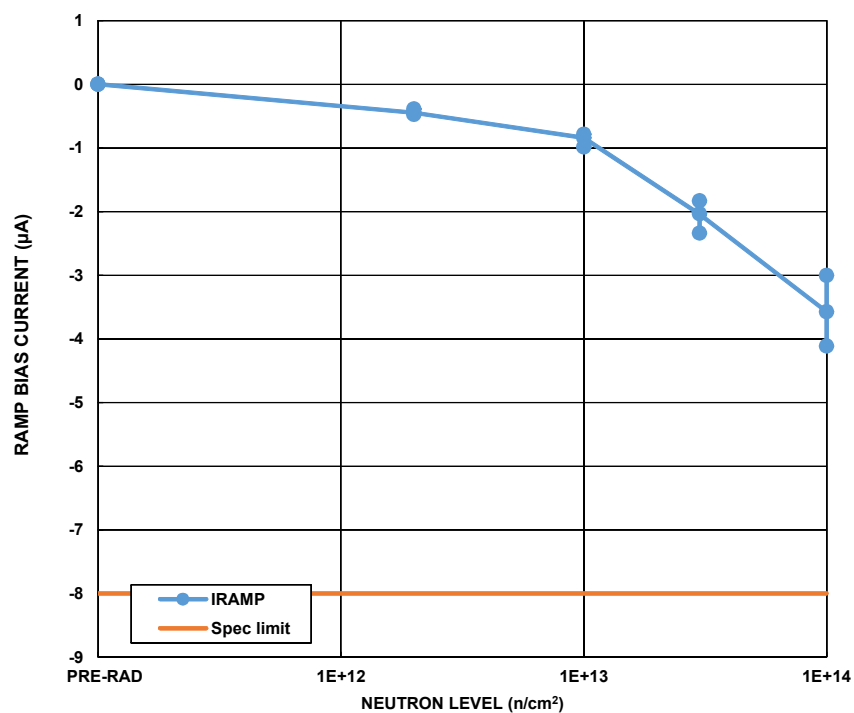


FIGURE 15. HS-1825ARH PWM ramp bias current as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is -8µA minimum.

## Variables Data Plots (Continued)

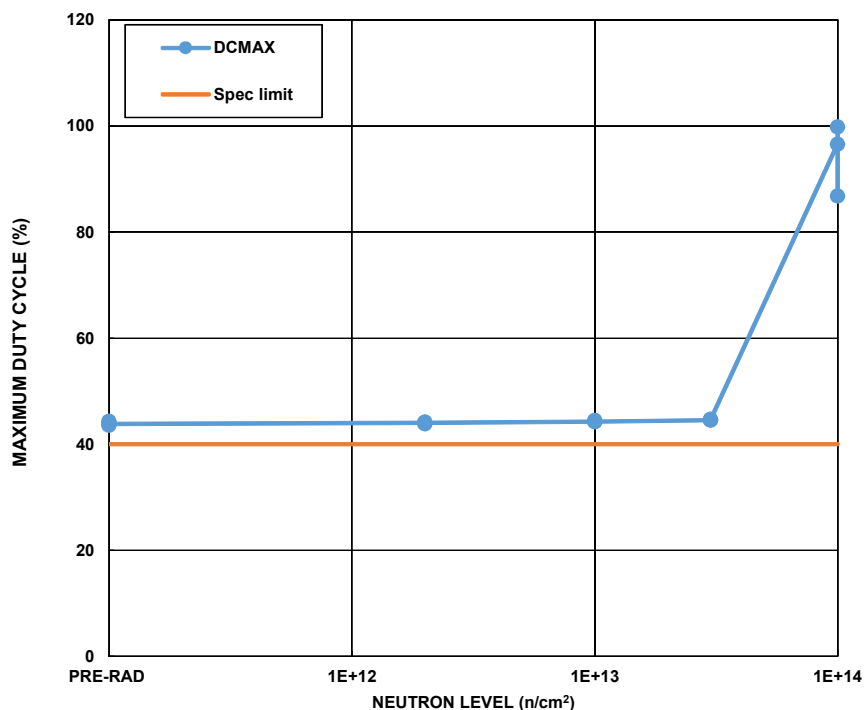


FIGURE 16. HS-1825ARH PWM maximum duty cycle as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 40% minimum.

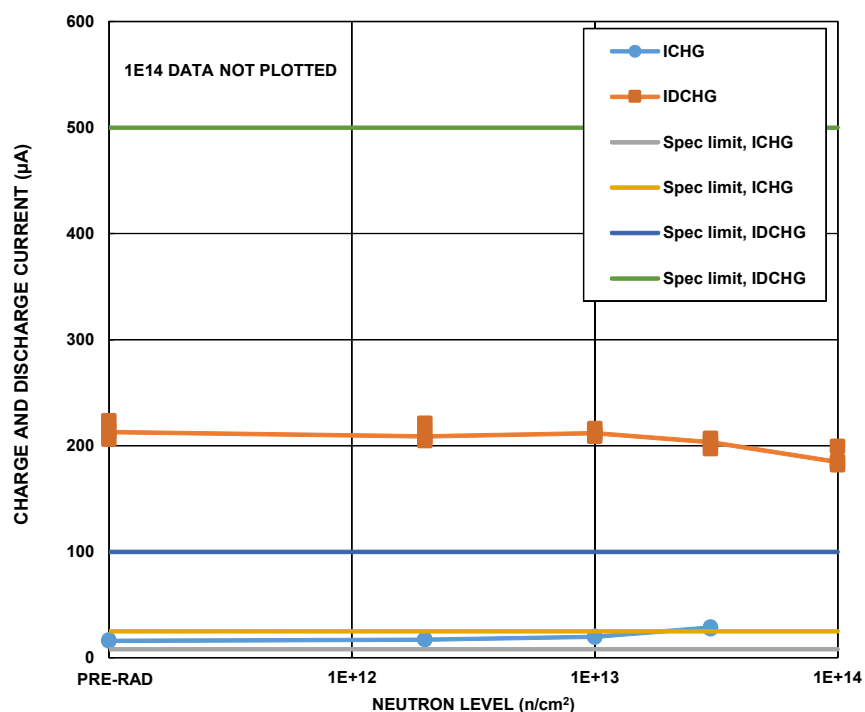


FIGURE 17. HS-1825ARH soft-start charge and discharge current as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The sample size for each cell was 5. The  $1 \times 10^{14} \text{ n/cm}^2$  discharge current data was an ATE overrange and is not plotted. The post-total dose irradiation SMD limits are 8µA to 25µA (charging) and 100µA to 500µA (discharging).

## Variables Data Plots (Continued)

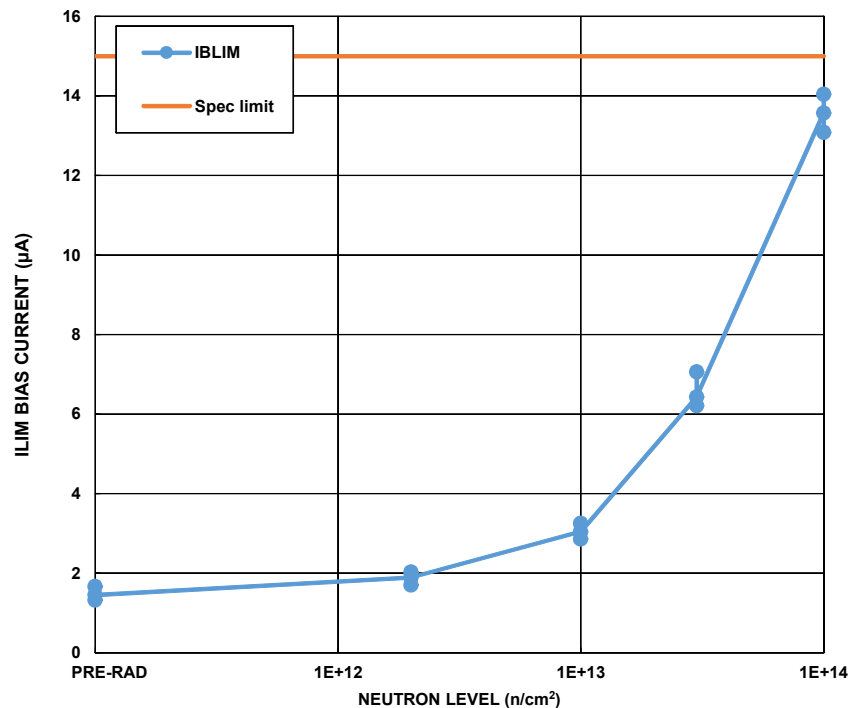


FIGURE 18. HS-1825ARH current limit bias current as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 15µA maximum.

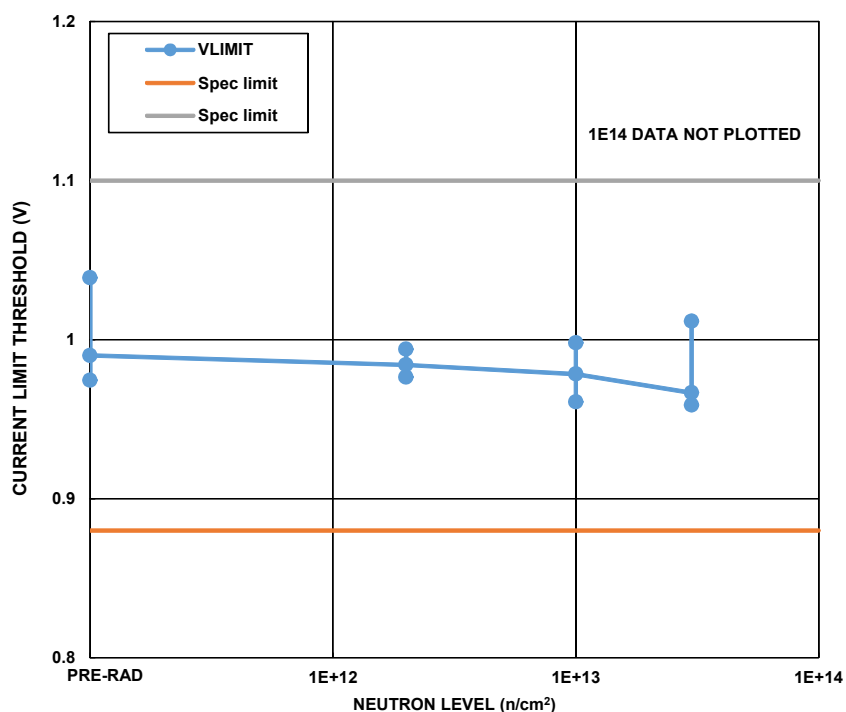


FIGURE 19. HS-1825ARH current limit threshold as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The  $1 \times 10^{14} \text{ n/cm}^2$  data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 0.88V to 1.1V.

## Variables Data Plots (Continued)

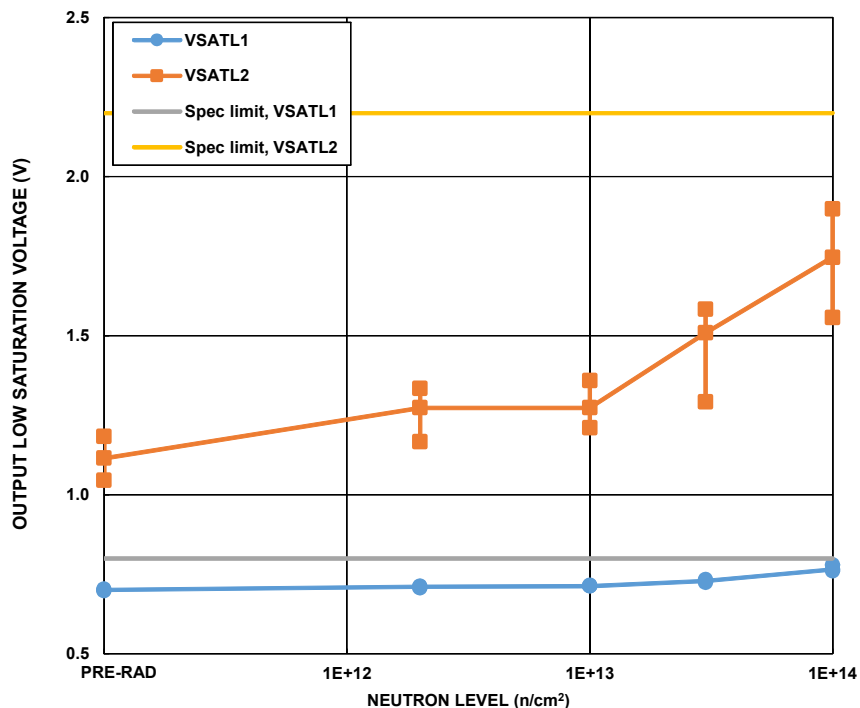


FIGURE 20. HS-1825ARH output LOW saturation voltage, 20mA ( $V_{SATL1}$ ) and 200mA ( $V_{SATL2}$ ), as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 0.8V maximum (20mA) and 2.2V maximum (200mA).

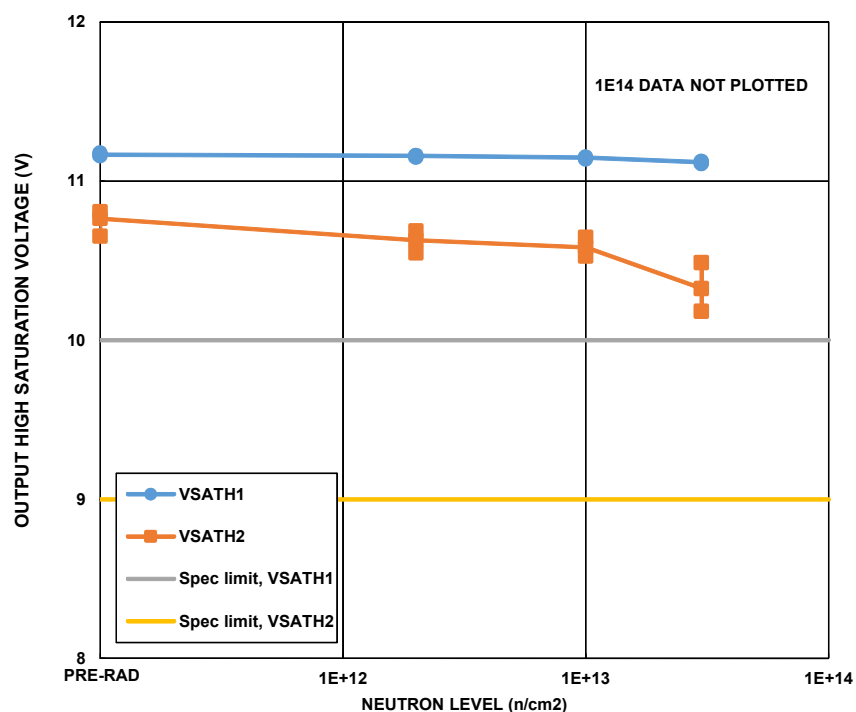


FIGURE 21. HS-1825ARH output HIGH saturation voltage, 20mA ( $V_{SATH1}$ ) and 200mA ( $V_{SATH2}$ ), as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each downpoint. The  $1 \times 10^{14} \text{ n/cm}^2$  data points were ATE overranges and are not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 10V minimum (20mA) and 9V minimum (200mA).

## Variables Data Plots (Continued)

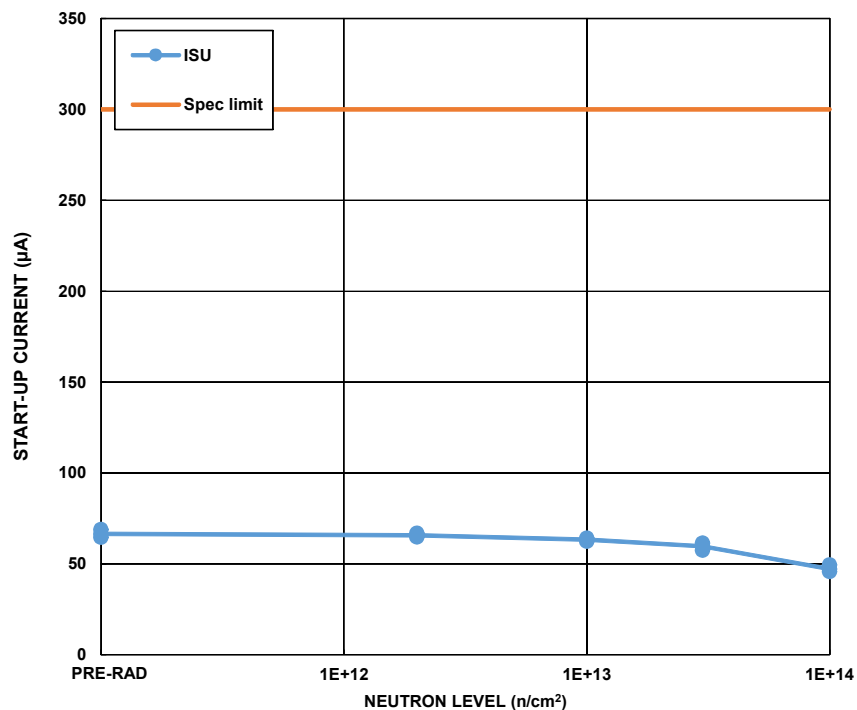


FIGURE 22. HS-1825ARH start-up current as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 300µA maximum.

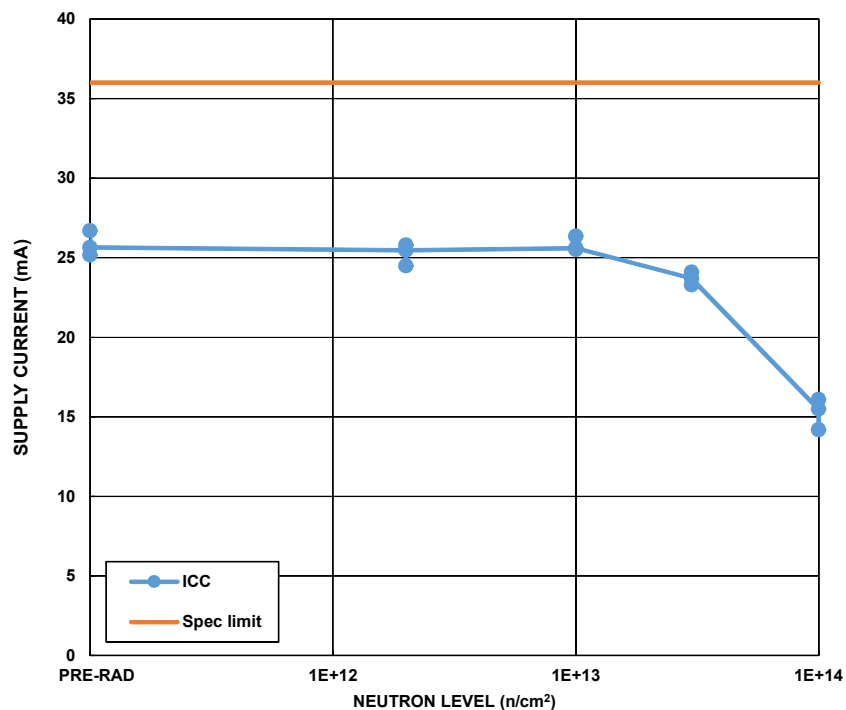


FIGURE 23. HS-1825ARH supply current as a function of 1MeV equivalent neutron irradiation at  $2 \times 10^{12} \text{ n/cm}^2$ ,  $1 \times 10^{13} \text{ n/cm}^2$ ,  $3 \times 10^{13} \text{ n/cm}^2$  and  $1 \times 10^{14} \text{ n/cm}^2$ . The plot shows the population median and minimum and maximum error bars at each datapoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 36mA maximum.

## Conclusion

This report summarizes results of the 1MeV equivalent neutron testing of the HS-1825ARH Pulse Width Modulator (PWM). The test was conducted in order to determine the sensitivity of the part to Displacement Damage (DD) caused by neutron or proton environments in space. Neutron fluences ranged from  $2 \times 10^{12} \text{ n/cm}^2$  to  $1 \times 10^{14} \text{ n/cm}^2$ . This test was carried out as part of a collaborative project with Boeing (El Segundo, CA), whose support is gratefully acknowledged.

The samples met all specifications (Bin 1) after  $2 \times 10^{11} \text{ n/cm}^2$  and  $1 \times 10^{13} \text{ n/cm}^2$ . The samples showed parametric degradation after  $3 \times 10^{13} \text{ n/cm}^2$  and were nonfunctional after the  $1 \times 10^{14} \text{ n/cm}^2$  irradiation.

## Appendices

### Reported Parameters

Reported parameters are shown in [Table 3](#). The limits are taken from the applicable SMD and are provided for guidance only as the part is not designed or guaranteed for the neutron environment. The plots show the population median and minimum and maximum error bars at each downpoint.

TABLE 3. REPORTED PARAMETERS

| FIGURE             | PARAMETER                       | LIMIT, LOW | LIMIT, HIGH | UNITS         | NOTES       |
|--------------------|---------------------------------|------------|-------------|---------------|-------------|
| <a href="#">1</a>  | Reference Output Voltage        | 5          | 5.2         | V             |             |
| <a href="#">2</a>  | Reference Line Regulation       | -20        | 20          | mV            |             |
| <a href="#">3</a>  | Reference Load Regulation       | -50        | 50          | mV            |             |
| <a href="#">4</a>  | Reference Output SC Current     | 20         | -           | mA            |             |
| <a href="#">5</a>  | Oscillator Initial Accuracy     | 300        | 425         | kHz           |             |
| <a href="#">6</a>  | Clock Output Voltage            | 3.75       | -           | V             | HIGH        |
|                    | Clock Output Voltage            | -          | 0.2         | V             | LOW         |
| <a href="#">7</a>  | EA Input Offset Voltage         | -10        | 10          | mV            |             |
| <a href="#">8</a>  | EA Input Bias Current           | -1         | 1           | $\mu\text{A}$ |             |
| <a href="#">9</a>  | EA Input Offset Current         | -4         | 4           | $\mu\text{A}$ |             |
| <a href="#">10</a> | EA Open Loop Gain               | 60         | -           | dB            |             |
| <a href="#">11</a> | EA Common-Mode Rejection Ratio  | 65         | -           | dB            |             |
| <a href="#">12</a> | EA Power Supply Rejection Ratio | 80         | -           | dB            |             |
| <a href="#">13</a> | EA Output Current               | -0.5       | -           | mA            | Sourcing    |
|                    | EA output current               | 1          | -           | mA            | Sinking     |
| <a href="#">14</a> | EA Output Voltage               | 4          | -           | V             | HIGH        |
|                    | EA Output Voltage               | -          | 1           | V             | LOW         |
| <a href="#">15</a> | PWM Ramp Bias Current           | -8         | -           | $\mu\text{A}$ |             |
| <a href="#">16</a> | PWM Maximum Duty Cycle          | 40         | -           | %             |             |
| <a href="#">17</a> | Soft-Start Current              | 8          | 25          | $\mu\text{A}$ | Charging    |
|                    | Soft-Start Current              | 100        | 500         | $\mu\text{A}$ | Discharging |
| <a href="#">18</a> | Current Limit Bias Current      | -          | 15          | $\mu\text{A}$ |             |
| <a href="#">19</a> | Current Limit Threshold         | 0.88       | 1.1         | V             |             |
| <a href="#">20</a> | Output Saturation Voltage       | -          | 0.8         | V             | LOW, 20mA   |
|                    | Output Saturation Voltage       | -          | 2.2         | V             | LOW, 200mA  |

TABLE 3. REPORTED PARAMETERS (Continued)

| FIGURE             | PARAMETER                 | LIMIT, LOW | LIMIT, HIGH | UNITS | NOTES       |
|--------------------|---------------------------|------------|-------------|-------|-------------|
| <a href="#">21</a> | Output Saturation Voltage | 10         | -           | V     | HIGH, 20mA  |
|                    | Output Saturation Voltage | 9          | -           | V     | HIGH, 200mA |
| <a href="#">22</a> | Start-Up Current          | -          | 300         | μA    |             |
| <a href="#">23</a> | Supply Current            | -          | 36          | mA    |             |

## Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
  2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
  3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
  4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
  5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.

"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.

"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.

Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
  6. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
  7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
  8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
  9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
  10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
  11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
  12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.
- (Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.
- (Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)



### SALES OFFICES

### Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com/>" for the latest and detailed information.

**Renesas Electronics America Inc.**  
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.  
Tel: +1-408-432-8888, Fax: +1-408-434-5351

**Renesas Electronics Canada Limited**  
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3  
Tel: +1-905-237-2004

**Renesas Electronics Europe Limited**  
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K  
Tel: +44-1628-651-700, Fax: +44-1628-651-804

**Renesas Electronics Europe GmbH**  
Arcadiastrasse 10, 40472 Düsseldorf, Germany  
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

**Renesas Electronics (China) Co., Ltd.**  
Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China  
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

**Renesas Electronics (Shanghai) Co., Ltd.**  
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China  
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

**Renesas Electronics Hong Kong Limited**  
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong  
Tel: +852-2265-6688, Fax: +852-2886-9022

**Renesas Electronics Taiwan Co., Ltd.**  
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan  
Tel: +886-2-8175-9600, Fax: +886-2-8175-9670

**Renesas Electronics Singapore Pte. Ltd.**  
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949  
Tel: +65-6213-0200, Fax: +65-6213-0300

**Renesas Electronics Malaysia Sdn.Bhd.**  
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia  
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

**Renesas Electronics India Pvt. Ltd.**  
No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India  
Tel: +91-80-67208700, Fax: +91-80-67208777

**Renesas Electronics Korea Co., Ltd.**  
17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea  
Tel: +82-2-558-3737, Fax: +82-2-558-5338