# Rad-Hard DC/DC Converters Deliver Space-Grade Reliability

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**For higher reliability and guaranteed performance under severe environmental conditions in space, military and aerospace satellite applications—for example Low Earth Orbit, Middle Earth Orbit and Geostationary Earth Orbit, as well as scientific missions such as deep-space probes—engineers are seeking power converters that promise to perform under the most hostile conditions.**

Besides functioning under extremes of environmental stresses, DC/DC converters that are designed to power electronics in these systems must operate in the presence of all forms of radiation without any impairment in performance, and with a life span of 10 to 15 years. Additionally, as semiconductor processes are becoming finer, supply voltages for ICs such as FPGAs, ASICs and DSPs are being reduced from 3.3 to 2V and below. In order to meet these requirements, the converters must be capable of generating low voltages from a wide input-voltage range and with high conversion efficiency. Taking such factors into consideration, International Rectifier has developed a family of high-reliability, radiation-hardened DC-DC converters that can handle unprecedented levels of radiation. Labelled the LS series, these devices are rated to deliver an output power of up to 30W from a wide input-voltage range, make use of advances in thick-film multilayer hybrid technology and are produced with space- and DSCC-qualified manufacturing processes and automated test equipment in a facility that is fully qualified to MIL-PRF-38534 standard. Accordingly, they guarantee more than 4.8 million hours of MTBF operation at a +35°C case temperature for stringent space applications. PSpice modeling and simulation was used extensively to predict and optimise circuit performance for both beginning and end of life.

As shown in Figure 1, the DC/DC converters incorporate a nominal 500kHz fixed-frequency single-ended forward topology with magnetic feedback, feed-forward compensation, voltage-mode control and an internal EMI filter. As a result, they are capable of meeting the conducted emissions requirements of MIL-STD-461C without any additional external components. In essence, the EMI filter ensures that the power entering the converter portion of the circuit is clean and devoid of voltage spikes and noise. The magnetic feedback circuit, utilised in this design instead of opto-couplers, minimises sensitivity to temperature, aging and radiation. The converters are designed to provide a variety of output voltages, which comprise both single and dual outputs. While the single-output voltages comprise 1.5, 1.8, 2.5, 3.3, 5 and 12V, the dual versions offer ±5, ±12 and ±15V. In addition, the converters are architected to deliver optimal efficiency throughout a wide operating range of load current and input voltage. Figure 2 shows the typical efficiency curve for a ±15V dual LS2815D converter. The data is provided for three input voltages covering a minimum to maximum input-voltage range at +25°C case temperature. It is observed that from 50% to full load, the conversion efficiency remains above 80% over a wide input range. Similar results were also obtained for low-voltage single-output converters.

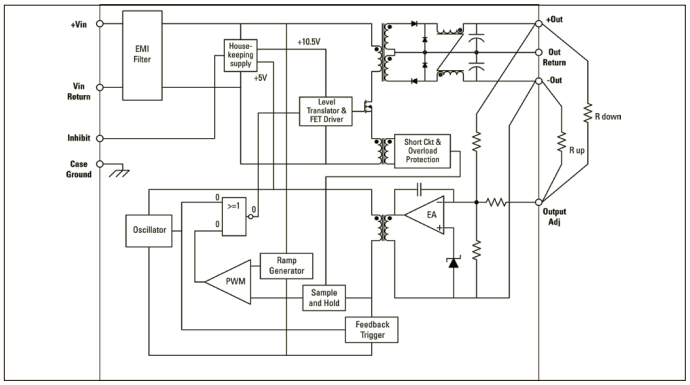


**Figure 1: The high reliability rad-hard LS-series DC/DC converters incorporate a fixed-frequency single-ended forward topology with magnetic feedback, feed-forward compensation and voltage-mode control.**

| Test Parameter | 0Rad | 0Rad | 25kRad | 50kRad | 75kRad | 100kRad | 125kRad | 150kRad | 150kRad | Annealed |
|---|---|---|---|---|---|---|---|---|---|---|
| $V_{out}$, $V_{in}$ = 18V, no load | | 5.022 | 5.017 | 5.011 | 4.998 | 4.986 | 4.975 | 4.964 | | |
| $V_{out}$, $V_{in}$ = 18V, half load | | 501 | 5.004 | 4.999 | 4.986 | 4.975 | 4.965 | 4.952 | | |
| $V_{out}$, $V_{in}$ = 18V, full load | | 4.996 | 4.991 | 4.986 | 4.974 | 4.963 | 4.954 | 4.94 | | |
| | | | | | | | | | | |
| $V_{out}$, $V_{in}$ = 28V, no load | | 5.022 | 5.017 | 5.011 | 4.998 | 4,965 | 4.975 | 4.964 | | |
| $V_{out}$, $V_{in}$ = 28V, half load | | 5.010 | 5.004 | 4.999 | 4.986 | 4.975 | 4.965 | 4.952 | | |
| $V_{out}$, $V_{in}$ = 28V, full load | 5.009 | 4.996 | 4.991 | 4.986 | 4.974 | 4.963 | 4.954 | 4.940 | 4.946 | 5.002 |
| | | | | | | | | | | |
| $V_{out}$, $V_{in}$ = 40V, no load | | 5.023 | 5.017 | 5.011 | 4.998 | 4.987 | 4.975 | 4.964 | | |
| $V_{out}$, $V_{in}$ = 40V, half load | | 5.010 | 5.004 | 4.999 | 4.986 | 4.975 | 4.965 | 4.953 | | |
| $V_{out}$, $V_{in}$ = 40V, full load | | 4.996 | 4.991 | 4.986 | 4.974 | 4.963 | 4.954 | 4.940 | | |
| | | | | | | | | | | |
| $I_{in}$ inhibited (mA), $V_{in}$ = 18 | | 1.71 | 1.67 | 1.69 | 1.69 | 1.68 | 1.69 | 1.69 | | |
| $I_{in}$ inhibited (mA), $V_{in}$ = 28 | 1.93 | 1.89 | 1.88 | 1.88 | 1.88 | 1.88 | 1.83 | 1.89 | 1.95 | 2.03 |
| $I_{in}$ inhibited (mA), $V_{in}$ = 40 | | 2.14 | 2.12 | 2,10 | 2.12 | 2.11 | 2.11 | 2.11 | | |
| | | | | | | | | | | |
| $I_{in}$ no load (mA), $V_{in}$ = 18 | | 30.4 | 30.6 | 30.5 | 30.7 | 31.0 | 31.1 | 31.3 | | |
| $I_{in}$ no load (mA), $V_{in}$ = 38 | 25.41 | 27.5 | 27.7 | 27.7 | 27.8 | 27.8 | 27.8 | 27.8 | 25.92 | 26.32 |
| $I_{in}$ no load (mA), $V_{in}$ = 50 | | 25.1 | 25.2 | 25.2 | 25.2 | 25.3 | 25.7 | 26.6 | | |
| | | | | | | | | | | |
| Eff. $V_{in}$ = 18V, half load | | 85.7% | 85.7% | 86.1% | 86.0% | 86.0% | 85.9% | 85.9% | | |
| Eff. $V_{in}$ = 18V, full load | | 82.2% | 82.2% | 82.2% | 82.2% | 82.2% | 82.1% | 82.1% | | |
| Eff. $V_{in}$ = 38V, half load | | 84.6% | 84.7% | 84.6% | 84.6% | 84.4% | 84.4% | 84.0% | | |
| Eff. $V_{in}$ = 38V, full load | 81.8% | 82.7% | 82.7% | 83.8% | 82.7% | 82.6% | 82.5% | 82.4% | 81.3% | 81.2% |
| Eff. $V_{in}$ = 40V, half load | | 81.5% | 81.9% | 81.8% | 81.6% | 81.4% | 81.3% | 81.1% | | |
| Eff, $V_{in}$ = 40V, full load | | 81.6% | 81.8% | 81.7% | 81.6% | 81.4% | 81.4% | 81.2% | | |

**Table 1: Test data for a single-output LS2805S.**

All models in the series include an external inhibit pin and have an adjustable output voltage. They are enclosed in a hermetic 1.5x2.3x0.425inch steel package and weigh less than 80g. The package utilises rugged ceramic feed-through copper core pins and is sealed using parallel seam welding. As per the requirements of MIL-STD-975, all the components are fully de-rated. In addition, extensive documentation is available, which includes thermal analysis, stress analysis, worst-case analysis, failure modes, effects analysis and reliability predictions.

## Radiation-hardened

Designed for defence and aerospace applications, the converters are also radiation-hardened with the ability to handle a cumulative TID (total ionizing dose) of over 100krad (Si). They resist SEEs (single-event effects) such as single-event upsets,

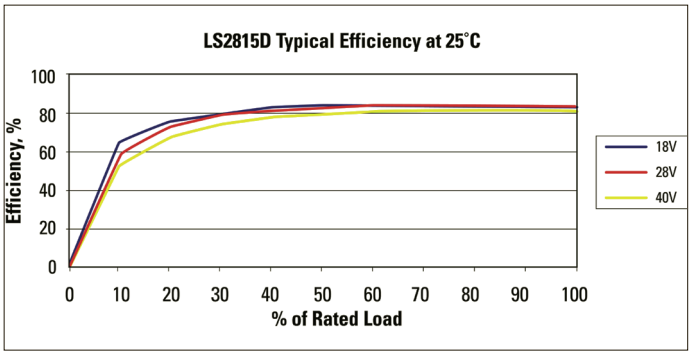


**Figure 2: The typical efficiency curve for a ±15V dual-converter.**

single-event latch-ups and single-event burnouts. SEE LET (linear energy transfer) of heavy ions is rated at 82MeV.cm$^2$/mg, in accordance with MIL-STD-883 standard.

To assure that there is no significant impairment after exposure to a steady state of TID dosage of 150krad (Si), these converters were tested for TID as well as SEE effects. A total of four models were used: two of the units tested were single-output devices, while the other two units were dual types. In the single-output category, the 5V output model was selected for testing; in the dual version, a 15V unit was chosen. Since all models in the series are of similar circuit configuration, the differences are in magnetic turns ratios, output-filtering-component values, and compensation-circuit values to accommodate the specific outputs. The outputs of the units were loaded with a resistive load equal to half of the rated maximum.

## Single-event testing

The units were irradiated in a dose-rate chamber containing 19,200 curies of Co60. The chamber was set up to provide a dose rate of approximately 1krad (SiO2)/minute. A screw-driven automatic cart was used to position the units relative to the source to obtain the desired dose rate. Tests were conducted in accordance with MIL-STD-883, Method 1019.5, condition B. After radiation exposure, the parts were annealed at +100°C for 160 hours.

Likewise, single-event testing was performed on two samples. These were a 2.5V single-output unit and a 15V dual-output model. Both units were biased at full load during irradiation. The parts were irradiated with xenon and gold ions, producing LET levels of 47, 60 and 83MeV.cm$^2$/mg.

Test results show that the LS series parts passed the irradiation tests consisting of TID up to 150krad (Si) and SEE up to LET levels of 83MeV.cm$^2$/mg. Test data for a single-output model LS2805S is illustrated in Table 1. It is observed that parametric changes after TID exposure were negligible. While there is a slight downward trend with increasing exposure for the output-voltage set points, it is noted that this downward trend was reduced after the units were annealed. Also, there is a slight drop in efficiency—less than 1%—after a 150krad TID exposure.

Although not all the series' output voltages were tested, the results should be considered applicable to the complete series by the virtue of its members' similarity. Parametric changes after TID testing were minor. Some disturbances were observed during SEE testing. However, no upsets or latch-ups were observed.

Besides high tolerance to radiation and environmental stresses—such as temperature and humidity extremes, mechanical shock and vibration—the converters have optimal regulation, stability, low-output ripple, and protection from overload and short-circuit conditions. Among additional features are input-line-dependent duty-factor limiting, undervoltage protection, soft-start inrush-current limiting and an efficiency of over 82% over a -40 to +85°C operating-temperature range.

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