Performance of Rad-Hard Quad Receivers at Extreme Temperatures

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Purpose

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

• Characterize the electrical performance and reliabilities as potential space electronic parts under extreme low and high temperature (-125 ~ +150°C) environments extending nominal device specifications (-55 ~ +125°C).

• Identify needed enabling technologies to improve operation, reliability, and lifetime of future space missions such as Mars.
Presentation outline

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

- Purpose
- Rad-Hard Quad Receivers
- Test Method
- Results
- Conclusions
- Recommendations
Rad-Hard Quad Receiver

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- A quad differential line receiver designed for digital data transmission (logic input buffer) over balanced lines and meets the requirements of RS-422
- Radiation Hardened CMOS processing for low power consumption, high speed, and reliable operation in the most severe radiation environments.
  - Total Dose: 100 KRAD (Si)
  - Single Event Upset (SEU)
  - Single Event Latch-up (SEL)
  - Thresholds: >100 MeV/mg/cm2
- Supply current at low and high state
- Dynamic supply current
- Input current at high and low state
- Output high and low voltages
- Tri-state low and high current
- Propagation delays and transition times.
Rad-Hard Quad Receivers

- Radiation hardened RS-422 line receiver
- Has CMOS enable pin input levels and accepts TTL-level enable signals
- The two circuits are identical except for the configuration of the logic input buffers
- The HS-26C32RH has the same input characteristics (impedance, hysteresis, failsafe) as commercial types.
Functional Diagram

![Diagram]

**Truth Table**

<table>
<thead>
<tr>
<th>Device Power On/Off</th>
<th>Inputs</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>ON</td>
<td>1</td>
<td>X</td>
</tr>
<tr>
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<td>0</td>
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</tbody>
</table>
Die Characteristics

• Die Dimensions: 2140µm x 3290 µm x 533µm ± 25.4µm
• Backside Finish: Silicon
• Passivation:
  – Type: SiO₂
    » Thickness: 800nm ± 100nm
• Metallization:
  – M1: Mo/TiW
    » Thickness: 580nm
  – M2: Al/Si/Cu
    » Thickness: 1000nm ± 100nm
• Substrate Potential: Internally connected to $V_{DD}$
• Worst Case Current Density: < 2.0E5 A/cm²
• Transistor Count: 315
• Process: Radiation Hardened CMOS, AVLSI
Die Layout
Schematic of the HS-26C(T)32RH input structure

Performance of Rad-Hard Quad Receivers at Extreme Temperatures
Parasitic Diodes for Each Output

FIGURE 3A.

FIGURE 3B.

FIGURE 3C.

FIGURE 3D.
Adequate input differential voltage for open line fault conditions

- Produces too small an input differential voltage in the open-line fault condition
- The internal input bias network is shunted by the termination resistor
- The internal input bias network is supplemented externally to compensate for the termination resistor
Input Fail/Safe Differential vs $Z_{in}$ (Open)

$V_{TH(IN)} \leq 400\text{mV MAX}$

$V_{TH(IN)} \leq 200\text{mV TYP}$
Test Setups

Performance of Rad-Hard Quad Receivers at Extreme Temperatures
Characteristics of the quiescent power supply currents

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

Supply Current Low State (ICCL) Versus Temperature & Power Supply Voltage

ICCL (MA)

VCC

25C
-100C
-125C

5.5V 5.0V 4.5V 3.6V 3.3V 3.0V 2.8V
Characteristics of the input current

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

Supply Current High State (ICCH) Versus Temperature & Power Supply Voltage

- 25C
- -100C
- -125C

VCC

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Characteristics of the dynamic supply current

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

Dynamic Supply Current (ICCDY) Versus Temperature & Power Supply Voltage

VCC

ICCDY - (MA)

Temperature

25C

-100C

-125C

Power Supply Voltage

5.5V 5.0V 4.5V 3.6V 3.3V 3.0V 2.8V
Characteristics of the input high current

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

Input High Current (IIH) Versus Temperature & Power Supply Voltage

- 25°C
- -100°C
- -125°C

VCC

IIH - (MA)

5.5V 5.0V 4.5V 3.6V 3.3V 3.0V 2.8V
Characteristics of the input low current

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

![Graph showing Input Low Current (IIL) Versus Temperature & Power Supply Voltage]
Characteristics of the output low voltage

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

Output Low Voltage (VOL) Versus Temperature & Power Supply Voltage

VCC

VOL (MV)

-40.000
-30.000
-20.000
-10.000
0.000

5.5V 5.0V 4.5V 3.6V 3.3V 3.0V 2.8V

25C
-100C
-125C
Characteristics of the output high voltage

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

Output High Voltage (VOH) Versus Temperature & Power Supply

- 25°C
- -100°C
- -125°C

VCC

5.5V 5.0V 4.5V 3.6V 3.3V 3.0V 2.8V

VOH (V)

0.000 1.000 2.000 3.000 4.000 5.000 6.000
Characteristics of the tri-state leakage current for output low

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

Tristate Current with Output Low (IOZL) Versus Temperature & Power Supply Voltage

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Characteristics of the tri-state leakage current for output high

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

Tristate Current with Output High (IOZH) Versus Temperature & Power Supply Voltage

- 25°C
- -100°C
- -125°C

VCC

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Characteristics of the propagation delay times from high to low state

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

Propagation Delay High to Low (TPHL) Versus Temperature & Power Supply Voltage

VCC

TPHL - (NS)
Characteristics of the propagation delay times from low to high state

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

Propagation Delay Low To High (TPLH) Versus Temperature and Power Supply Voltage

TPLH - (ns)

VCC

25C

-100C

-125C

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Characteristics of the transition times from high to low state

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

Transition Time High to Low (TTHL) Versus Temperature & Power Supply Voltage

- 25°C
- -100°C
- -125°C
Conclusions

Performance of Rad-Hard Quad Receivers at Extreme Temperatures

• The test results of the basic parameters of a radiation hardened quad receivers at extreme cold environment indicates that the device can be applied for the potential application in Mars exploration missions even at -125 °C if the operating parameters such as power supply voltages chosen properly.
Recommendations

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- We do not recommend using this part below 3V supply voltage in applications requiring operation down -125°C.
- The output rise and fall times, $t_{\text{TLH}}$ and $t_{\text{THL}}$, were well within the SMD max limits of 12ns at 5V±10% and 15ns at 3.3V ± 10%.
- The parts though exhibited anomalous behavior at the conditions of 2.8V supply voltage and low temperatures.
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