ISL7202xSEH

CAN Transceiver SEE Packet Error Testing Report

Abstract

SEE test results of a two-node Renesas CAN Bus system. Based on those results, CRÈME96 provided an estimated system error rate in a geosynchronous orbit and a typical low earth orbit.

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Related Literature

For a full list of related documents, visit our website:

- ISL72026SEH, ISL72027SEH, ISL72028SEH device pages

1. SEE 2-Node CAN Bus System Test Platform

1.1 Introduction

Renesas created a 2-node CAN bus system for testing the SET performance of the ISL7202xSEH CAN transceivers when driving and receiving a 1Mbps standard CAN bus data packet message. The system implements all the standard CAN bus packet error checking protocols, (such as Cyclic Redundancy Code (CRC) Error, Formatting Bit Errors, Stuffing Bit Errors, and Acknowledge (ACK) Error).

A block diagram of the test setup is shown in Figure 1. The 2-node CAN bus system consisted of a transmitting node and a receiving node that are connected together over a 10ft 120Ω cable. Each node consists of a Microchip PIC18F4550 microcontroller, a Microchip MCP2515 CAN controller, and an ISL72026SEH CAN transceiver.

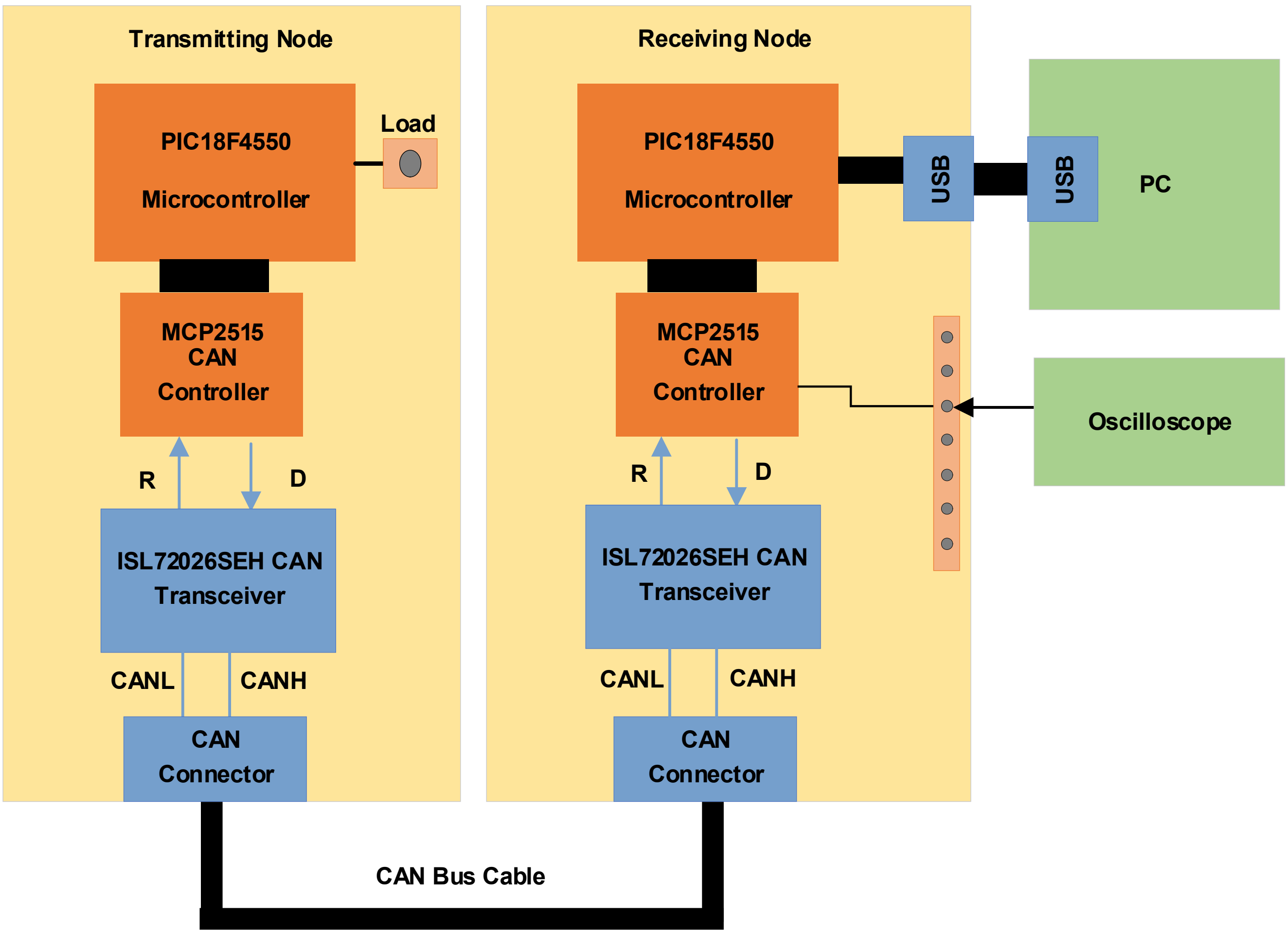


Figure 1. SEE Two Node CAN Bus System Block Diagram

1.2 System Operation

1.2.1 Transmitting Node

The transmitting node CAN controller is programmed with a specific standard CAN data packet message. A timer in the PIC microcontroller is programmed to have the CAN controller output a CAN data packet every 200µs. Every CAN data packet message sent out on the bus is identical and is transmitted at a data rate of 1Mbps.

See “System CAN Data Packet Message” on page 4 for the specific details of the CAN message used for this SEE testing.

The transmission of the initial data packet is started when the Load pin to the PIC microcontroller is driven high. As long as the Load pin is held high, a data packet is sent out every 200µs. Transmission is halted when the Load pin is driven Low.

Figure 2 on page 3 shows a scope shot of two data packets.

Figure 2. Oscilloscope Plot of Two Data Packets

1.2.2 Receiving Node

The receiving node is programmed to receive and process the CAN data packet message and to send the packet contents over a USB connection to a GUI running on a PC. In addition, the receiving node CAN controller is programed to set an interrupt whenever an erroneous packet is identified by the controller. The CAN controller is programmed to pulse its INT pin low whenever a packet with an error is detected. The INT pin is monitored by an oscilloscope to count the number of packets with errors while the GUI counts the total number of packets sent out on the bus.

1.2.3 SET Testing Procedure

The transmitting node CAN transceiver and the receiving node CAN transceiver of the 2-node CAN bus link are irradiated separately. A transceiver is exposed to the ion beam while the system is running (Load pin = High).

1.2.3.1 CAN Transceiver Testing at the Transmitting Node

Testing is done at various LET levels while irradiating the transmitting node transceiver. For each LET level applied, the total number of packets are counted along with the number of packets that were received with errors. The counts are done over the time that the transceiver is exposed to the ion beam.

1.2.3.2 CAN Transceiver Testing at the Receiving Node

Testing is done at various LET levels while irradiating the receiving node transceiver. For each LET level applied the total number of packets are counted along with the number of packets that were received with errors. The counts are done over the time that the transceiver is exposed to the ion beam.

1.3 System CAN Data Packet Message

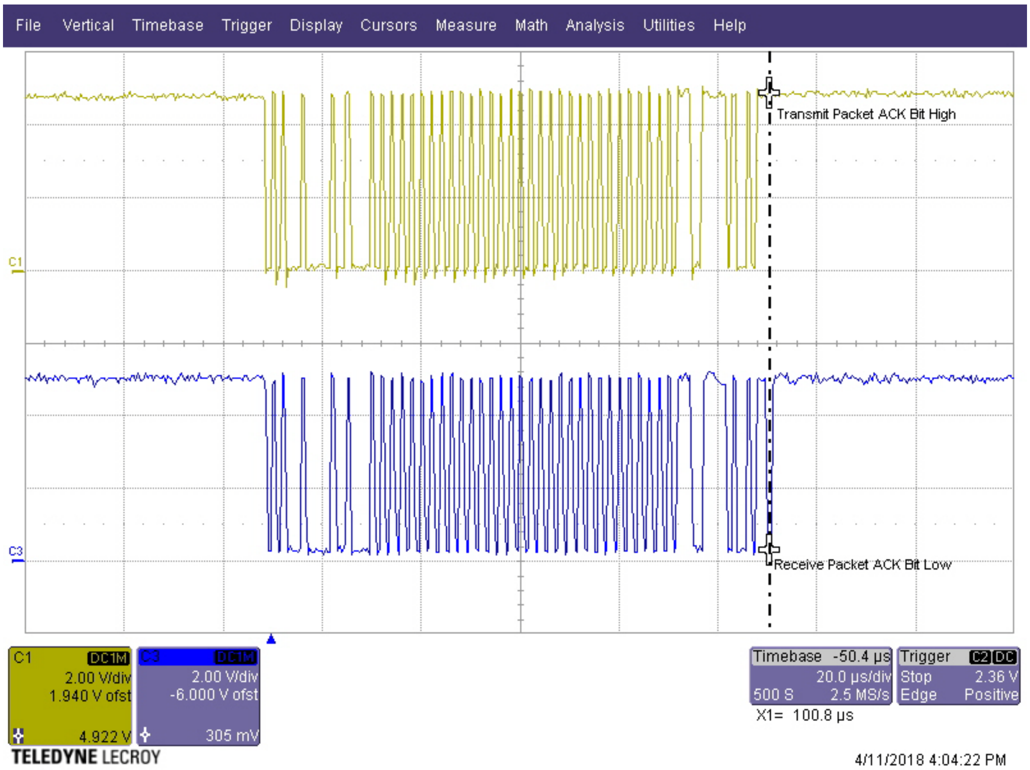
The system was programmed to transmit a standard CAN data packet message at a data rate of 1Mbps. Each data packet message transmitted onto the bus are identical. Table 1 gives the details of the CAN data packet used for the testing. The data packet consists of 117 bits (standard CAN frame format of 115 bits plus two stuffing bits). At a data rate of 1Mbps, it takes 117µs to transmit a single packet. Figure 3 on page 5 shows the scope plots of the system CAN data packet at the transmitting node and at the receiving node.

Table 1. CAN Data Packet Bit Values and Packet Frame Definitions

Packet Bits 0 -19																			
SOF	**11 bit Identifier**											**RTR**	**Stuff Bit**	**IDE**	**RO**	**DLC**			
0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0
Packet Bits 20 - 39																			
Data Byte 1								**Data Byte 2**								**Data Byte 3**			
0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Packet Bits 40 - 59																			
Data Byte 3				**Data Byte 4**								**Data Byte 5**							
0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Packet Bits 60 - 79																			
Data Byte 6								**Data Byte 7**								**Data Byte 8**			
0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Packet Bits 80 - 99																			
Data Byte 8				**CRC**									**Stuff Bit**	**CRC**					
0	1	0	1	1	1	0	0	1	1	1	1	1	0	1	0	0	1	0	1
Packet Bits 100 - 117																			
CRC DEL	**ACK**	**ACK DEL**	**EOF**							**IFS**									
1	Note 1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			

Note:

1. The receiving node overwrites the transmitting node recessive bit (1) with a dominant bit (0) to indicate to the transmitting node that an error-free message has been received.



Note: Yellow Trace: Packet from Transmitting Node, Blue Trace: Packet at the Receiving Node

Figure 3. Scope Plot of the System CAN Data Packet

2. CAN Transceiver SEE Packet Error Testing

The transmitter and receiver of the 2-node CAN bus link were irradiated separately while the packet errors were counted by oscilloscope captures set to trigger on packet error events as reported by the receiving CAN controller. The CAN transceivers used were the ISL72026SEH with the RS pin grounded for high speed slewing (typical 55ns rise time and 25ns fall time). A cable of length 10ft was used to connect the two nodes, and the transceivers were at approximately 25°C. The count of total packets transmitted during an irradiation was also captured. Over all the irradiations, the calculated average packet rate was 5016 packets per second (between 4765 and 5212), which resulted in approximately one million packets per irradiation. Each irradiation was done with normal incidence to a fluence of $1x10^7$ion/cm^2 at a flux of approximately $5x10^4$ion/(s•cm^2). The summary of the tests from the irradiating the transmitter of the CAN transceiver pair while sending a continuous stream of packets appears in Table 2. The summary for irradiating the receiver of the CAN transceiver pair while sending a continuous stream of packets is presented in Table 3 on page 6.

Table 2. Packet Error Results from Irradiating the Transmitter

Irradiated DUT	Species and LET (MeV•cm^2/mg)	VCC (V)	Packet Errors	Ion Beam Time (s)	Mega Packets	Errors per Mega Packet	Cross Section (cm^{-2})
DUT1	Au 86	3	6	241	1.23	4.87	6E-07
		4.5	1	277	1.40	0.71	1E-07
DUT3		3	4	204	1.03	3.90	4E-07
		4.5	0	231	1.15	0.00	0
DUT5		3	5	213	1.07	4.68	5E-07
		4.5	0	202	1.01	0.00	0
DUT7		3	6	220	1.10	5.45	6E-07
		4.5	0	226	1.12	0.00	0

Table 2. Packet Error Results from Irradiating the Transmitter (Continued)

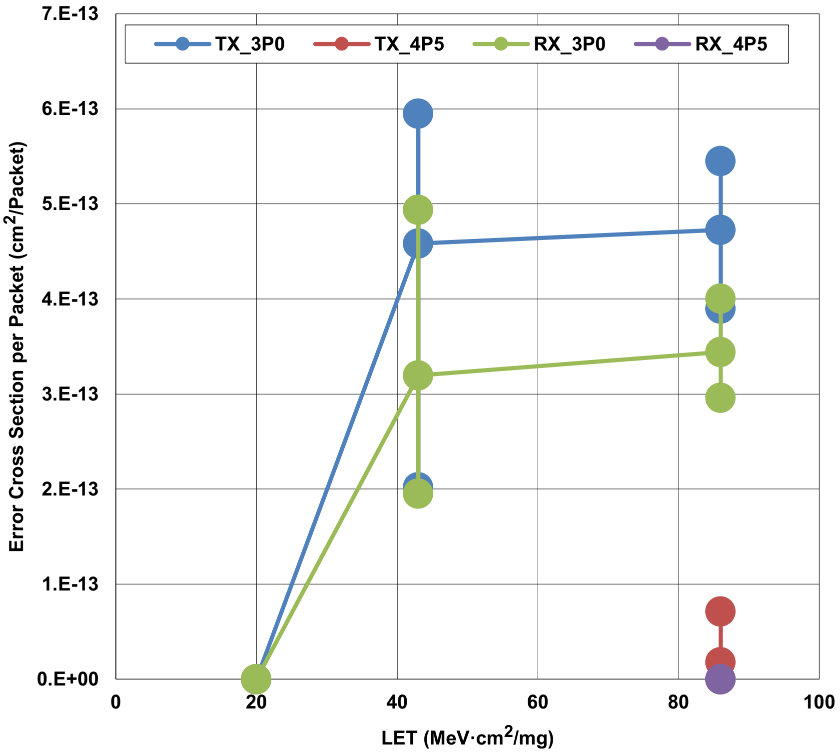
Irradiated DUT	Species and LET (MeV•cm^2/mg)	VCC (V)	Packet Errors	Ion Beam Time (s)	Mega Packets	Errors per Mega Packet	Cross Section (cm^{-2})
DUT9	Ag 43	3	6	200	1.01	5.95	6E-07
DUT11			2	198	0.99	2.02	2E-07
DUT13			6	211	1.07	5.61	6E-07
DUT15			5	210	1.05	4.77	5E-07
DUT17	Cu 20		0	185	0.96	0.00	0
DUT19			0	206	1.02	0.00	0
DUT21			0	197	1.00	0.00	0

Note: Each line represents a fluence of 1x10^{7}ion/cm^2 of the indicated ion species.

Table 3. Packet Error Results from Irradiating the Receiver

Irradiated DUT	Species & LET (MeV·cm^2/mg)	VCC (V)	Packet Errors	Ion Beam Time (s)	Mega Packets	Errors per Mega Packet	Error Cross Section (cm^{-2})
DUT2	Au 86	3	4	239	1.20	3.34	4E-07
		4.5	0	240	1.20	0.00	0
DUT4		3	4	232	1.16	3.45	4E-07
		4.5	0	189	0.94	0.00	0
DUT6		3	4	199	1.00	4.00	4E-07
		4.5	0	201	1.01	0.00	0
DUT8		3	3	202	1.01	2.96	3E-07
		4.5	0	193	0.97	0.00	0
DUT10	Ag 43	3	5	200	1.01	4.94	5E-07
DUT12			2	203	1.03	1.95	2E-07
DUT14			4	205	1.02	3.92	4E-07
DUT16			2	202	1.01	1.98	2E-07
DUT18	Cu 20		0	199	1.02	0.00	0
DUT20			0	213	1.02	0.00	0
DUT22			0	203	1.00	0.00	0

Note: Each line represents a fluence of 1x10^{7}ion/cm^2 of the indicated ion species.



Note: The means at each LET are connected while the minimum and maximum at each LET are also plotted vertically.

Figure 4. Error Cross Section Per packet

The error data can be converted to a chart. Figure 4 represents the error cross section per packet, which is found by dividing the counted errors by the fluence ($1x10^7$ion/cm^2) and dividing by the number of packets transmitted during the fluence. Clearly the error cross section here depends upon the number of packets transmitted. The transmitter appears more prone to inducing a packet error than the receiver. Worst case numbers are $6x10^{-13}cm^2$/packet for the transmitter and $5x10^{-13}cm^2$/packet for the receiver with means at $4.7x10^{-13}cm^2$/packet and $3.4x10^{-13}cm^2$/packet. Of course in a complete bus system, all nodes are subject to irradiation at the same time so that the cross sections per packet would have to be summed to give a complete bus error cross section per packet. For example, a worst case for a ten node bus would be approximately $5.1x10^{-12}cm^2$/packet, the summation of nine receivers and one transmitter.

2.1 CRÈME96 Results

Using the SEE test results and orbital parameters in the SEE Simulation program CRÈME96, it was possible to estimate the errors/device/day and errors/device/year for a 2-node system in a geosynchronous orbit as well as a typical low earth orbit. **Note:** Testing with Au at 86MeV•cm^2/mg and V_{CC} = 4.5V did not yield any packet errors on three of the four parts tested and only one error on the fourth part, so testing with Ag (43MeV•cm^2/mg) and Cu (20MeV•cm^2/mg) was only done at V_{CC} = 3V. Accordingly, the 3V data was chosen to analyze.

CRÈME96 LET spectrum files were generated for a satellite in a geosynchronous orbit and a low earth orbit of 1100km at a 45° inclination, using all species of heavy ion particles (atomic numbers 2 through 92) with a minimum energy value of 0.1MeV/nuc and solar minimum conditions (worst case for longterm cosmic rays). 100 mils of Aluminum shielding was assumed for both cases.

Based on the 3V SET test results, Weibull parameters were estimated. These parameters, along with the appropriate LET Spectrum file, were used to obtain the heavy ion error rates per mega-packet for the transmitter and receiver operating at 1Mbps, as shown in Table 4 on page 8, for the 2-node CAN system. Of course in a complete multi-node bus system (such as nine receivers and one transmitter), all nodes are subject to irradiation at the same time, so the error rates per packet would have to be summed accordingly to give a complete bus error cross section per packet.

Table 4. 2-Node CAN System Error Rates per Mega-packet for LEO and GEO Missions

	Low Earth Orbit		Geosynchronous Orbit	
	Transmitter	**Receiver**	**Transmitter**	**Receiver**
Errors/device/day	1.30E-09	1.06E-09	1.64E-07	1.36E-07
Errors/device/year	4.73E-07	3.86E-07	5.98E-05	4.96E-05

Using the error rates from Table 4, we can estimate that a GEO mission with a system consisting of 25 nodes would experience a mega-packet transmit error to heavy ion exposure, on the average, no more than once every 769 years. Also, on average, a LEO mission a system with 25 nodes would experience a mega-packet transmit error to heavy ion exposure no more than once every 98,907 years.

2.2 Conclusion

A CAN transmitter and receiver comprising a 2-node CAN bus link were irradiated with heavy ions, and saturated cross-sections were determined. These cross-sections were much lower than those previously seen from SEE testing of individual parts, demonstrating the robustness of the system to single event transients. Based on those values, the error rates/mega-packet for a transmitter and a receiver in a LEO orbit and a GEO orbit were calculated using CRÈME96. While the actual system error rate depends on the number of nodes, it can be seen that the ISL7202xSEH CAN transceivers, built on SOI, provide excellent system SEE immunity.

3. Revision History

Rev.	Date	Description
1.00	Aug.7.19	Initial release

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