V.22(BIS) MODEM PERFORMANCE TESTING

INTRODUCTION

This Application Note offers insight and rationale toward conducting performance tests to thoroughly evaluate ZiLOG's V.22bis modem (Z02201) in the v.22bis (2400 bps data) mode. These tests are intended to evaluate the quality of *connection reliability* and *throughput rate* of data transfer when exposed to *real world* impairments. The sets of accepted evaluation standards ensure the usability and robustness of the modem in the hands of the customer. The results from various test resources are summarized, and the report concludes by briefly discussing the outcomes of the Z02201 modem performance tests.

Public Switched Telephone Network (PSTN) is complicated by its very nature; therefore, no one set of network impairments would be representative enough to provide a meaningful modem performance evaluation. In other words, a single test or even two or three tests would not provide the user with useful information as to how the Z02201, ZiLOG's V.22bis modem, will perform in the real network. Therefore, to evaluate and compare the current modem under consideration, a suite of network impairments using the testing standards (TSB-37A and TSB-38), set by the Telecommunications Industry Association/Electronics Industry Association (TIA/EIA), is used.

Though there are several categories to compare the modem performance, as proposed by TIA/EIA and defined in TSB–38, the three main categories for the Z02201 datapump are:

- Call Connect Reliability testing
- Throughput vs. Network Model Coverage
- Bit Error Rate (BER) and Block Error Rate (BLER) testing

Testing Standards

TIA/EIA TSB-37A and TSB-38 tests are standard procedures that use a telephone network transmission model to determine how well modems perform in the presence of transmission line impairments that duplicate the majority of the line conditions encountered in the real world. The TSB-37A standard was developed by the TR.30 committee of TIA/EIA. It contains a network model that consists of 24 impairment combinations and 7 loop combinations. This document is intended to model the US telephone network conditions. The TSB-38 standard describes a set of tests to evaluate modem performance. TSB-38 tests prescribe test channels found in TSB-37A.

Throughput vs. Network Model testing as defined in TSB-38 6.1.1 involves measuring a modem's ability to transmit data over a variety of telephone network conditions, simulating more than 95% of all telephone line types in the U.S.

BER and BLER Testing

BER and BLER curves represent the expected modem performance over different signal-to-noise ratio (SNR) conditions. These tests are conducted at Softart, Inc. using a Consultronics TCS500 Telephone Line Simulator and an HP 4951B-protocol analyzer/BERT tester. Version 31 of the Datapump code is used under the conditions indicated in Table 1.

Table 1. Setting Used for Obtaining the BER/BLER curves

Line Simulation	Flat
Transmit Level	–10 dBm
Receive Level	–16 dBm
Data Transmitted	511 pseudo-random pattern
Number of Bits sent	1,000,000
Number of Blocks sent	1,000
Bits per Block	1,000
AEQ	Frozen after link establishment
Noise Calibration	C-message

INTRODUCTION (Continued)

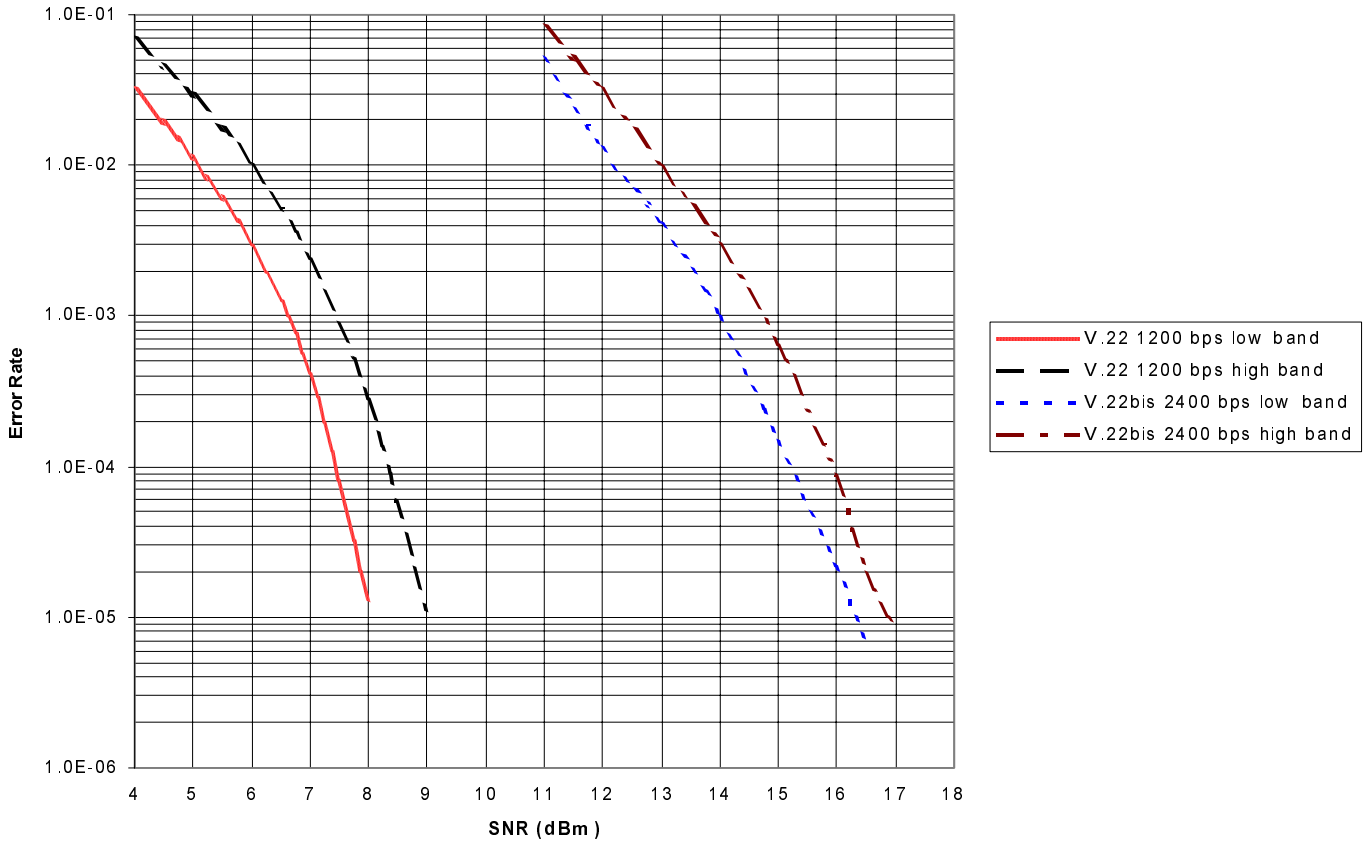

Figure 1. Z02201 BER Curves (Preliminary)

THROUGHPUT VS. NETWORK MODEL COVERAGE

The Network Model is intended to be a realistic representation of the transmission impairment conditions encountered on (intracontinental) network connections within the continental United States of America.

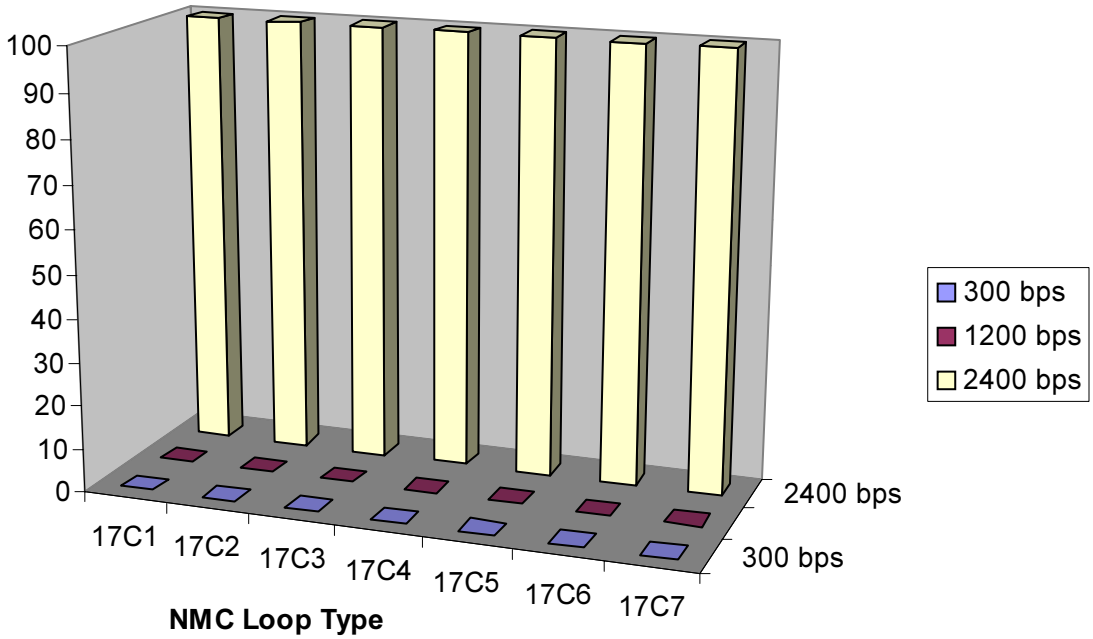

Figure 2. Connection Percentage by Modulation Rate and Loop Type

The idea of this model is to choose each Line and Test Loop Combination (TLC), and yield an associated "score" that reflects the estimated likelihood of occurrence (LOO) of a connection containing such impairments. These scores are then combined to provide an overall Network Model Coverage (NMC) estimate for a particular modem as a percentage of the total network model for the data throughput performance requirement.

This statistical rating of modem throughput performance, based on LOO of a given connection, is a representative sample of local loop topologies and End-Office (EO) facilities.

There are 7 Test Loop Combinations (TLC) and 24 Line Combinations, making 168 (7x24) combinations available for the NMC. Table 2 indicates the Bit Error Rate and Speed Test results sorted by the Likelihood of Occurrence. These tests are conducted at the Henderson Communications Labs, using a Version 27 Datapump code.

Table 2. BER and Speed Tests Sorted by Likelihood of Occurrence

Line/Loop Type	Score (%)	Speed (bps)	Error Rate	Line/Loop Type	Score (%)	Speed (bps)	Error Rate
17c1	22.862	2400	0	17a4	0.28	2400	0
17c2	11.431	2400	0	17a3	0.28	2400	0
18c1	7.544	2400	0	17b3	0.28	2400	0
17c4	4.97	2400	0	18c6	0.2624	2400	0
17c3	4.97	2400	0	19b1	0.23	2400	0

THROUGHPUT VS. NETWORK MODEL COVERAGE (Continued)

Table 2. BER and Speed Tests Sorted by Likelihood of Occurrence (Continued)

Line/Loop Type	Score (%)	Speed (bps)	Error Rate	Line/Loop Type	Score (%)	Speed (bps)	Error Rate
19c1	4.278	2400	0	19a1	0.23	2400	0
17c5	3.976	2400	0	18c7	0.2296	2400	0
18c2	3.772	2400	0	17b5	0.224	2400	0
20c1	2.162	2400	0	17a5	0.224	2400	0
19c2	2.139	2400	0	22c2	0.207	2400	0
21c1	1.978	2400	0	24c4	0.17	2400	0
18c4	1.64	2400	0	23c4	0.17	2400	0
18c3	1.64	2400	0	24c3	0.17	2400	0
18c5	1.312	2400	0	23c3	0.17	2400	0
17b1	1.288	2400	0	21a1	0.161	2400	0
17a1	1.288	2400	0	21b1	0.161	2400	0
20c2	1.081	2400	0	19c6	0.1488	2400	0
21c2	0.989	2400	0	18b4	0.14	2400	0
19c4	0.93	2400	0	18a4	0.14	2400	0
19c3	0.93	2400	0	18b3	0.14	2400	0
17c6	0.7952	2400	0	18a3	0.14	2400	0
24c1	0.782	2400	0	24c5	0.136	2400	0
23c1	0.782	2400	0	23c5	0.136	2400	0
19c5	0.744	2400	0	19c7	0.1302	2400	0
17c7	0.6958	2400	0	19b2	0.115	2400	0
17b2	0.644	2400	0	19a2	0.115	2400	0
18b1	0.644	2400	0	20b1	0.115	2400	0
18a1	0.644	2400	0	20a1	0.115	2400	0
17a2	0.644	2400	0	18b5	0.112	2400	0
20c4	0.47	2400	0	18a5	0.112	2400	0
20c3	0.47	2400	0	22c4	0.09	2400	0
21c3	0.43	2400	0	22c3	0.09	2400	0
21c4	0.43	2400	0	21b2	0.0805	2400	0
22c1	0.414	2400	0	21a2	0.0805	2400	0
24c2	0.391	2400	0	20c6	0.0752	2400	0
23c2	0.391	2400	0	22c5	0.072	2400	0
20c5	0.376	2400	0	24b1	0.069	2400	0
21c5	0.344	2400	0	23b1	0.069	2400	0
18b2	0.322	2400	0	24a1	0.069	2400	0
18a2	0.322	2400	0	23a1	0.069	2400	0
17b4	0.28	2400	0	21c6	0.0688	2400	0
20c7	0.0658	2400	0	24a4	0.015	2400	0
21c7	0.0602	2400	0	23a4	0.015	2400	0
20b2	0.0575	2400	0	24a3	0.015	2400	0
20a2	0.0575	2400	0	23b3	0.015	2400	0
19b4	0.05	2400	0	23a3	0.015	2400	0
19a4	0.05	2400	0	22c6	0.0144	2400	0
19b3	0.05	2400	0	22c7	0.0126	2400	0

Table 2. BER and Speed Tests Sorted by Likelihood of Occurrence (Continued)

Line/Loop Type	Score (%)	Speed (bps)	Error Rate	Line/Loop Type	Score (%)	Speed (bps)	Error Rate
19a3	0.05	2400	0	24b5	0.012	2400	0
17a6	0.0448	2400	0	24a5	0.012	2400	0
17b6	0.0448	2400	0	23b5	0.012	2400	0
19b5	0.04	2400	0	23a5	0.012	2400	0
19a5	0.04	2400	0	22b2	0.0115	2400	0
17b7	0.0392	2400	0	22a2	0.0115	2400	0
17a7	0.0392	2400	0	19b6	0.008	2400	0
21a4	0.035	2400	0	19a6	0.008	2400	0
21b3	0.035	2400	0	19b7	0.007	2400	0
21b4	0.035	2400	0	19a7	0.007	2400	0
21a3	0.035	2400	0	21b6	0.0056	2400	0
24b2	0.0345	2400	0	21a6	0.0056	2400	0
23b2	0.0345	2400	0	22b4	0.005	2400	0
24a2	0.0345	2400	0	22a4	0.005	2400	0
23a2	0.0345	2400	0	22b3	0.005	2400	0
21b5	0.028	2400	0	22a3	0.005	2400	0
21a5	0.028	2400	0	21a7	0.0049	2400	0
24c6	0.0272	2400	0	21b7	0.0049	2400	0
23c6	0.0272	2400	0	22b5	0.004	2400	0
20a4	0.025	2400	0	22a5	0.004	2400	0
20b4	0.025	2400	0	20b6	0.004	2400	0
20b3	0.025	2400	0	20a6	0.004	2400	0
20a3	0.025	2400	0	20b7	0.0035	2400	0
24c7	0.0238	2400	0	20a7	0.0035	2400	0
23c7	0.0238	2400	0	24b6	0.0024	2400	0
22a1	0.023	2400	0	24a6	0.0024	2400	0
22b1	0.023	2400	0	23b6	0.0024	2400	0
18a6	0.0224	2400	0	23a6	0.0024	2400	0
18b6	0.0224	2400	0	24b7	0.0021	2400	0
20b5	0.02	2400	0	24a7	0.0021	2400	0
20a5	0.02	2400	0	23b7	0.0021	2400	0
18b7	0.0196	2400	0	23a7	0.0021	2400	0
18a7	0.0196	2400	0	22b6	0.0008	2400	0
24b4	0.015	2400	0	22a6	0.0008	2400	0
24b3	0.015	2400	0	22b7	0.0007	2400	0
23b4	0.015	2400	0	22a7	0.0007	2400	0

CALL CONNECT RELIABILITY TESTS

These tests measure and determine the ability of the Z02201 to consistently make connections over a range of test loops defined in the TSB-37A. A connection may fail for various reasons such as:

- Failure of calling modem to detect the dial tone
- Failure of the called modem to see the ringing signal
- One of the modems going into "panic" because of an internal logic problem
- Handshaking going into long loop of retrain

In all these tests there is no error correction and data compression. A total of 100 make and break connections are chosen for each set of test vectors. These tests can be diluted to fewer number of make and break connections; however, the statistical validity of the diluted tests may not lie within acceptable confidence intervals, thereby defeating the purpose of testing.

Table 3 provides the test results indicating the bad connection percentage as a function of Line/Loop type. A TCS500 telephone line simulator, with the Version 41 Datapump software is used. These suites of tests are conducted in-house.

CONCLUSIONS

The bit error rate and the throughput are the main results that are used to compare a modem's performance to other modems. The Z02201 is tested over the different line combinations mentioned in the TSB37A document. A zero bit error rate and 100% throughput is measured for all the combinations, which are indeed the qualities of superior modem performance. The Call Connectivity Test results indicate that the Z02201, ZiLOG's V.22bis modem, has a 100% good call connection, strongly indicating its consistency to make connections over the various line/loop conditions outlined in the TIA/TSB-37A document.

Table 3. Call Connect Reliability for Various Line/Loop Types

Line/Loop type	Bad Connections (%)	Line/Loop type	Bad Connections (%)
17A1	0	19A1	0
17A2	0	19A2	0
17A3	0	19A3	0
17A4	0	19A4	0
17A5	0	19A5	0
17A6	0	19A6	0
17A7	0	19A7	0
17B1	0	19B1	0
17B2	0	19B2	0
17B3	0	19B3	0
17B4	0	19B4	0
17B5	0	19B5	0
17B6	0	19B6	0
17B7	0	19B7	0
17C1	0	19C1	0
17C2	0	19C2	0
17C3	0	19C3	0
17C4	0	19C4	0
17C5	0	19C5	0
17C6	0	19C6	0
17C7	0	19C7	0

Table 3. Call Connect Reliability for Various Line/Loop Types (Continued)

Line/Loop type	Bad Connections (%)	Line/Loop type	Bad Connections (%)
18A1	0	20A1	0
18A2	0	20A2	0
18A3	0	20A3	0
18A4	0	20A4	0
18A5	0	20A5	0
18A6	0	20A6	0
18A7	0	20A7	0
18B1	0	20B1	0
18B2	0	20B2	0
18B3	0	20B3	0
18B4	0	20B4	0
18B5	0	20B5	0
18B6	0	20B6	0
18B7	0	20B7	0
18C1	0	20C1	0
18C2	0	20C2	0
18C3	0	20C3	0
18C4	0	20C4	0
18C5	0	20C5	0
18C6	0	20C6	0
18C7	0	20C7	0

APPENDIX A—REAL WORLD IMPAIRMENTS

"Impairments" is the technical term for the transmission defects and deviations that occur on virtually every telephone line. The following is a list of real line imperfections normally encountered in an analog telephone line:

Flat Loss (Attenuation). This condition characterizes the 1004-Hz loss or the Circuit Net loss. The average for all PSTN connections is 16.0 dB. At other frequencies, the attenuation distortion combines with the 1-kHz loss, so that the shape of the response is the same, but it "rises" on the graph.

Attenuation/Amplitude Distortion (AD). Also referred to as the "frequency response", AD is usually reported as a series of dB offsets from a reference level taken at 1kHz.

Envelope Delay Distortion (EDD). EDD is due to the following:

- The sharp low-end cut-off by the filters used in all toll-connecting multiplexing systems
- The fairly sharp high-end cut-off of the Voice-Frequency Low-Pass (VFLP) filters similarly used
- The low-pass filter effect created by loading coils in the subscriber loops

Listener Echo. This impairment is a result of two reflections somewhere in a connection. All listener echoes cause amplitude and delay distortion.

Input Impedance. This impairment is important for duplex modems because it determines how much of the transmitted signal is reflected back as *talker echo.* This condition must be removed either by filtering or echo canceling. The input impedance depends on the gauge and length of the cable, the loading, and the termination at the exchange.

Noise. This condition occurs in two modes: signal-independent and signal-dependent noise. Signal-independent noise is the standard thermal noise, and signal-dependent noise consists of harmonic distortion and digital quantization noise from A-D and D-A converters.

Harmonic Distortion. Also called Intermodulation (Nonlinear) distortion (IMD); the effect is the folding back (in-band), of the product of two tones.

Phase Jitter. This impairment is simple manifestation caused by the jitter of the zero crossings of a sinusoidal signal or by the noise. The most common source of phase jitter is power supply hum at 60 and 120 Hz, and crosstalk of 20-Hz ringing signal while there is a signal component. The addition of the hum and the signal results in a phase shift being seen on the signal in the telephone pass band.

Frequency Offset (FO). This condition is normally caused by the traditional analog carrier systems. This impairment typically provides a user-to-user frequency shift of 7 Hz. In the recent telephone networks a shift of only 2Hz is seen on only 0.2% of all connections.

Gain Hits. Seen as a rapid change of signal level.

Phase Hits. Seen as a rapid change of the received phase causing bursts of errors.

Propagation Delay. The total time taken for a signal to pass through a wire or other medium to transverse a connection.

Round Trip Delay. Effectively, the double of propagation delay, referring to the time required for the signal to pass through a wire and return.

Robbed Bit Signaling. Some digital systems synthesize a data channel by "robbing" the low-order bit of a PCM (pulse-code modulation) channel, adding what amounts to a low-level random noise to any analog signal.

ADPCM. Adaptive Differential Pulse Code Modulation (ADPCM) describes a digital speech compression scheme (of which there are several) to cram more voice channels into a digital carrier system. Also known as "pair gain" when placed in digital subscriber carrier service.

APPENDIX B

Table 4. Appendix B—TSB 37-A: Impairment Combinations

Impairments	Units	Line 17a	Line 17b	Line 17c	Line 18a	Line 18b	Line 18c
Connection Type—Score	%		55.3			19.2	
IC—Score	%	2.8	2.8	49.7	1.4	1.4	16.4
1. AD		none	none	none	none	none	none
2. EDD		none	none	none	none	none	none
3. 1kHz Loss	dB	6	6	6	8	6	6
4a. Added Noise	dBm	–68	–68	–68	–68	–68	–68
4b. TNR	dB	N/A	N/A	N/A	N/A	N/A	N/A
5. Phase Jitter							
5a. P-P Deviation	Degrees	none	none	none	none	none	none
5b. Frequency	Hz	none	none	none	none	none	none
6. IMD–(4Tone)							
6a. 2nd Order (H2/R2)	dB	40	43	50	43	50	55
6b. 3rd Order (H3/R3)	dB	41	44	51	44	51	56
7. Frequency Offset							
7a. FO (A to B)	Hz	none	none	none	none	none	none
7b. FO (B to A)	Hz	none	none	none	none	none	none
8. PCM (64 Kbits/s)							
8a. Tandem Links	Number	1	1	1	1	1	1
8b. Robbed Bit Signaling		yes	yes	no	yes	yes	no
8c. RBS Location	Link Number	1	1	1	1	1	1
9. ADPCM							
9a. Type		none	none	none	none	none	none
10. Echo							
10a. RTD	ms	80	80	80	80	80	80
10b. THL[1] (A)	dB	12	16	20	12	16	20
10c. THL (B)	dB	12	16	20	12	16	20

Note: 1. Total Harmonic Distortion

APPENDIX B (Continued)

Table 5. Appendix B—TSB 37-A: Impairment Combinations

Impairments	Units	Line 19a	Line 19b	Line 19c	Line 20a	Line 20b	Line 20c
Connection Type—Score	%		10.3			5.2	
IC-Score	%	0.5	0.5	9.3	0.25	0.25	4.7
1. AD		none	none	none	none	none	none
2. EDD		none	none	none	none	none	none
3. 1kHz Loss	dB	8	6	6	8	6	6
4a. Added Noise	dBm	–68	–68	–68	–68	–68	–68
4b. TNR	dB	N/A	N/A	N/A	N/A	N/A	N/A
5. Phase Jitter							
5a. P-P Deviation	Degrees	none	none	none	none	none	none
5b. Frequency	Hz	none	none	none	none	none	none
6. IMD–(4Tone)							
6a. 2nd Order (H2/R2)	dB	40	43	50	40	43	50
6b. 3rd Order (H3/R3)	dB	41	44	51	41	44	51
7. Frequency Offset							
7a. FO (A to B)	Hz	none	none	none	none	none	none
7b. FO (B to A)	Hz	none	none	none	none	none	none
8. PCM (64 Kbits/s)							
8a. Tandem Links	Number	2	2	2	3	3	3
8b. Robbed Bit Signaling		yes	yes	no	yes	yes	no
8c. RBS Location	Link Number	1	1				
9. ADPCM							
9a. Type		none	none	none	none	none	none
10. Echo							
10a. RTD	ms	80	80	80	80	80	80
10b. THL (A)	dB	12	16	20	12	16	20
10c. THL (B)	dB	12	16	20	12	16	20

Table 6. Appendix B—TSB 37-A: Impairment Combinations

Impairments	Units	Line 21a	Line 21b	Line 21c	Line 22a	Line 22b	Line 22c
Connection Type—Score	%		5			1	
IC-Score	%	0.35	0.35	4.3	0.05	0.05	0.9
1. AD		AD–7	AD–6	AD–5	AD–7	AD–6	AD–5
2. EDD		none	none	none	none	none	none
3. 1kHz Loss	dB	8	6	6	8	6	6
4a. Added Noise	dBm	–68	–68	–68	–68	–68	–68
4b. TNR	dB	N/A	N/A	N/A	N/A	N/A	N/A
5. Phase Jitter							
5a. P-P Deviation	Degrees	none	none	none	none	none	none
5b. Frequency	Hz	none	none	none	none	none	none
6. IMD–(4Tone)							

Table 6. Appendix B—TSB 37-A: Impairment Combinations (Continued)

Impairments	Units	Line 21a	Line 21b	Line 21c	Line 22a	Line 22b	Line 22c
6a. 2nd Order (H2/R2)	dB	60	60	60	43	50	55
6b. 3rd Order (H3/R3)	dB	58	58	58	44	51	56
7. Frequency Offset							
7a. FO (A to B)	Hz	none	none	none	none	none	none
7b. FO (B to A)	Hz	none	none	none	none	none	none
8. PCM (64 Kbits/s)							
8a. Tandem Links	Number	none	none	none	1	1	1
8b. Robbed Bit Signaling					no	no	no
8c. RBS Location	Link Number						
9. ADPCM							
9a. Type		none	none	none	none	none	none
10. Echo							
10a. RTD	ms	35	35	35	80	80	80
10b. THL (A)	dB	12	16	20	12	16	20
10c. THL (B)	dB	12	16	20	12	16	20

Table 7. Appendix B—TSB 37-A: Impairment Combinations

Impairments	Units	Line 23a	Line 23b	Line 23c	Line 24a	Line 24b	Line 24c
Connection Type—Score	%		2			2	
IC—Score	%	0.15	0.15	1.7	0.15	0.15	1.7
1. AD		AD–4	AD–3	AD–1	AD–3	AD–2	AD–1
2. EDD		EDD–1	EDD–1	EDD–1	EDD–1	EDD–1	EDD–1
3. 1kHz Loss	dB	9	8	6	8	6	6
4a. Added Noise	dBm	N/A	N/A	N/A	N/A	N/A	N/A
4b. TNR	dB	30	33	36	33	36	39
5. Phase Jitter							
5a. P-P Deviation	Degrees	3	3	3	3	3	3
5b. Frequency	Hz	60	60	60	60	60	60
6. IMD–(4Tone)							
6a. 2nd Order (H2/R2)	dB	43	46	51	43	46	51
6b. 3rd Order (H3/R3)	dB	44	47	53	44	47	53
7. Frequency Offset							
7a. FO (A to B)	Hz	0.2	0.2	0.2	none	none	none
7b. FO (B to A)	Hz	–0.2	–0.2	–0.2	none	none	none
8. PCM (64 Kbits/s)							
8a. Tandem Links	Number	none	none	none	1	1	1
8b. Robbed Bit Signaling					no	no	no
8c. RBS Location	Link Number						
9. ADPCM							
9a. Type		none	none	none	none	none	none
10. Echo							

APPENDIX B (Continued)

Table 7. Appendix B—TSB 37-A: Impairment Combinations (Continued)

Impairments	Units	Line 23a	Line 23b	Line 23c	Line 24a	Line 24b	Line 24c
10a. RTD	ms	35	35	35	80	80	80
10b. THL (A)	dB	16	20	22	16	20	22
10c. THL (B)	dB	16	20	22	16	20	22

Information Integrity:

The information contained within this document has been verified according to the general principles of electrical and mechanical engineering. Any applicable source code illustrated in the document was either written by an authorized ZiLOG employee or licensed consultant. Permission to use these codes in any form besides the intended application, must be approved through a license agreement between both parties. ZiLOG will not be responsible for any code(s) used beyond the intended application. Contact your local ZiLOG Sales Office to obtain necessary license agreements.

© 1998 by ZiLOG, Inc. All rights reserved. No part of this document may be copied or reproduced in any form or by any means without the prior written consent of ZiLOG, Inc. The information in this document is subject to change without notice. Devices sold by ZiLOG, Inc. are covered by warranty and patent indemnification provisions appearing in ZiLOG, Inc. Terms and Conditions of Sale only.

ZILOG, INC. MAKES NO WARRANTY, EXPRESS, STATUTORY, IMPLIED OR BY DESCRIPTION, REGARDING THE INFORMATION SET FORTH HEREIN OR REGARDING THE FREEDOM OF THE DESCRIBED DEVICES FROM INTELLECTUAL PROPERTY INFRINGEMENT. ZILOG, INC. MAKES NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PURPOSE.

ZiLOG, Inc. shall not be responsible for any errors that may appear in this document. ZiLOG, Inc. makes no commitment to update or keep current the information contained in this document.

ZiLOG's products are not authorized for use as critical components in life support devices or systems unless a specific written agreement pertaining to such intended use is executed between the customer and ZiLOG prior to use. Life support devices or systems are those which are intended for surgical implantation into the body, or which sustains life whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in significant injury to the user.

ZiLOG, Inc.
910 East Hamilton Avenue, Suite 110
Campbell, CA 95008
Telephone (408) 558-8500
FAX 408 558-8300
Internet: http://www.zilog.com