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DEPARTMENT OF DEFENSE
HANDBOOK

GUIDANCE FOR INTERMITTENT FAULT EMULATOR (IFE)

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AMSC N/A

FSC 6625

FOREWORD

1. This handbook is approved for use by all Departments and Agencies of the Department of Defense (DoD).

2. This handbook provides guidance on use and application of the Copernicus Technology Ltd. part number CTL990495 Intermittent Fault Emulator (IFE). This handbook does not assume prior knowledge of the IFE. It is recommended that both beginner and advanced users read the entire user manual for both the intermittent fault diagnostic equipment and IFE before starting any diagnostic equipment evaluation. The IFE is used to verify or qualify the ability of technologies, methods, and devices to detect and isolate intermittent faults. These intermittent faults occur in the conductive path(s) in Line Replaceable Unit/Weapon Replaceable Assembly (LRU/WRA) chassis or backplanes. The chassis or backplanes may contain hundreds to thousands of conductive paths and solder connections.

3. This handbook is intended to aid acquisition organizations in procuring intermittent fault detection and isolation (IFDI) technology. This IFDI technology is designed to be capable of detecting and isolating LRU/WRA chassis and backplane conductive paths, which are exhibiting intermittent behavior when the LRU/WRA is subjected to operational stresses such as temperature and vibration. This intermittent behavior results in the removal and replacement/repair of the LRU/WRA with no fault found resulting in aircraft loss of mission capability and high maintenance costs.

4. Comments, suggestions, questions or additional information on this document should be addressed to: Naval Air Warfare Center Aircraft Division, Code 4.1.2.2, Highway 547, Mail Stop 120-3, Joint Base MDL, NJ 08733-5100 or by email to michael.sikora@navy.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla.mil.

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1. SCOPE

1.1 Scope. This handbook provides guidance and lessons learned for acquisition organizations using the Intermittent Fault Emulator (IFE) to evaluate Intermittent Fault Detection and Isolation (IFDI) technologies, methods, and/or devices prior to acquisition. This information includes: the IFE User Manual, IFE programming considerations, and IFE pinouts for constructing an Interface Adaptor Harness (IAH). IFDI manufacturers and suppliers can demonstrate and verify their test equipment capabilities to detect and isolate intermittent faults by using the IFE. This handbook is for guidance only and cannot be cited as a requirement.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are those needed to understand the information provided by this handbook.

2.2 Government documents.

2.2.1 Specifications and standards. The following specifications and standards form a part of this document to the extent specified herein.

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-PRF-32516	-	Electronic Test Equipment, Intermittent Fault Detection and Isolation for Chassis and Backplane Conductive Paths
MIL-DTL-38999	-	Connectors, Electrical, Circular, Miniature, High Density, Quick Disconnect (Bayonet, Threaded or Breech Coupling), Environment Resistant with Crimp Removable Contacts or Hermetically Sealed with Fixed, Solderable Contacts, General Specification for

DEPARTMENT OF DEFENSE STANDARD

MIL-STD-1560	-	Insert Arrangements for MIL-DTL-38999, MIL-DTL-27599 and SAE-AS29600 Series A Electrical Circular Connectors

(Copies of these documents are available online at http://quicksearch.dla.mil/.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein.

COPERNICUS TECHNOLOGY LTD.

CTL-229-01 - IFE User Manual

(Copies of this document are available from www.copernicustechnology.com.)

NATIONAL CENTER FOR MANUFACTURING SCIENCES

Joint Intermittence Testing (JIT) Capability Final Report 2015
Joint Intermittence Testing (JIT) Capability, Phase II 2016

(Copies of these documents are available from www.ncms.org.)

SAE INTERNATIONAL

SAE AS39029 - Contacts, Electrical Connector, General Specification for (DoD adopted)

(Copies of this document are available online at http://www.sae.org.)

UNIVERSAL SYNAPTICS CORPORATION

Universal Synaptics Technical Evaluation and Simulated Intermittent Event Characterization Report

(Copies of this document are available from www.ussynaptic.com.)

3. ACRONYMS AND DEFINITIONS

3.1 Acronyms. The following acronyms are applicable to this handbook.

ATE	Automatic Test Equipment
BCM	Beyond Capability of Maintenance
CND	Cannot Duplicate
dB	Decibel
DoD	Department of Defense
DCR	Disassemble -Clean-Reassemble
ESD	Electrostatic Discharge
GUI	Graphical User Interface

GCU	Generator Converter Unit
IAH	Interface Adaptor Harness
IDE	Intermittent Diagnostic Equipment
IDFE	Intermittent Fault Diagnostic Equipment
IFDI	Intermittent Fault Detection and Isolation
IFE	Intermittent Fault Emulator
kV	kilovolt
kHz	kilohertz
LRU	Line Replaceable Unit
MHz	megahertz
µs	microseconds
mA	milliamperes
ms	milliseconds
MTBDR	Mean Time Between Depot Repair
nA	nanoamperes
ns	nanoseconds
NFF	No Fault Found
OSD/AT&L	Office of the Secretary of Defense for Acquisition, Technology and Logistics
pF	picofarad
RETOK	Retest OK
SG	Signal Generator
WRA	Weapons Replaceable Assembly

3.2 Definitions. The following definitions are applicable to this handbook.

3.2.1 Cable harness. Cable harness is a generic term for multiple cables gathered together to form a number of circuit paths.

3.2.2 DeltaT. The duration in microseconds of an event. This definition only applies to flexible event profiles. (See figures 2 through 7 and Appendix B, Notes after table B-I.)

3.2.3 Intermittent faults. Intermittent faults are short duration discontinuities (opens/shorts) that occur in conductive paths in LRU/WRA chassis/backplanes and cable harnesses. Intermittent faults occur as a result of various operational environmental stimuli, including, but not limited to, thermal stress, vibrational stress, gravitational G-force loading, moisture and/or contaminant exposure. Intermittent faults can also occur because of changes in the material due to age and use, such as the growth of tin whiskers, metal migration and delamination of materials. These faults can take place individually and/or in rapid succession on any chassis or backplane circuit. Fault durations range in time from nanoseconds to milliseconds and have variable impedances. These circuit path disruptions are frequently caused by: cracked solder joints; intermittent coaxial lines (e.g., shield corrosion, damaged center conductor, etc.); broken, cracked or frayed wires; loose clamps; and unsoldered pins. LRU/WRA chassis and backplanes are commonly reported as NFF or as one of the quasi-NFF repair codes (e.g., CND, RETOK, BCM, DCR, etc.) due to the inability to detect and isolate intermittent failures and provide environmental stimuli during test and repair process.

3.2.4 Intermittent fault emulator (IFE). The IFE is test equipment designed to emulate intermittent faults that occur in the LRU/WRA conductive paths and cable harnesses. The emulator has 256 test channels available that can be programmed with variable resistance faults of 100 nanoseconds to 500 milliseconds duration individual faults, which can also be grouped into burst faults as a 5 MHz pulse from 3 to 5 microseconds. The IFE contains software controlled semiconductor switches, which can simulate combined individual and burst conductive path faults of programmed or pseudorandom duration on programmed or pseudorandom conductive paths. The purpose of the IFE is to emulate an intermittent fault of known duration on a known conductive path to verify the capability of test equipment to detect and isolate this simulated fault. Each IFE channel has four software controlled semiconductor switches to randomly create four variable fault resistances.

3.2.5 LRU. LRU is an essential aircraft support item such as aircraft avionics equipment that is replaced at the field level to restore the aircraft to an operationally ready condition. LRU is a used most commonly by the Air Force to identify aircraft avionics equipment and is often used interchangeably with the term weapons replaceable assembly (WRA).

3.2.6 NFF. NFF is a term used in the field of failure analysis used to describe a situation where an originally reported mode of failure can't be duplicated by the evaluating technician and therefore the potential defect can't be fixed. NFF can be attributed to oxidation, defective connections of electrical components, or temporary shorts or opens in the circuits. These faults can also occur due to software bugs, temporary environmental factors, and operator error. Large numbers of devices that are reported as NFF during the first troubleshooting session often return to the failure analysis lab with the same NFF symptoms or a permanent mode of failure.

3.2.7 WRA. WRA is a generic term that includes all replaceable packages of a system installed in the weapons system with the exception of cables, mounting provisions, and fuse boxes or circuit breakers. WRA is generally modular in form and designed to facilitate an organizational level and maintenance concept. The preferred form of WRA is the light replaceable assembly that is easily removed and replaced in the weapons system by one man in not more than 15 minutes. WRA is a used most commonly by the Navy to identify aircraft avionics equipment and is often used interchangeably with the term LRU.

4. GENERAL GUIDANCE

4.1 Background. According to OSD/AT&L, “bad” LRUs/WRAs cost DoD at least two billion dollars annually. Bad LRUs/WRAs are those LRUs/WRAs having a history of failing during in-flight operation, but the failure cannot be duplicated when it is analyzed at the repair depot. The inability to duplicate the failure results in LRUs/WRAs being classified as NFF/BCM by the depot repair facility. Recent engineering efforts have led to the development of a database of serialized repair data used to identify bad LRUs/WRAs by their maintenance histories and significant advances in intermittent fault detection and isolation of LRU/WRA chassis and backplane conductive paths. The combination of these two advances has led to significant increases in MTBDR. The development of this database and improved fault detection and isolation techniques have provided insight into this previously unidentified intermittent failure mode and cyclic stress fatigue induced intermittence in LRU/WRA chassis and backplane wiring and connections. These advances have also led to the discovery that current ATE is unable to detect these failure modes and to the development of intermittent fault diagnostic equipment. To evaluate effectiveness of intermittent fault diagnostic equipment, OSD AT&L developed the IFE. The IFE is a device capable of being programmed to emulate the failure signals of an LRU/WRA experiencing intermittence.

4.2 Known intermittence. As stated in the MIL-PRF-32516, Appendix A: "Each LRU/WRA is different in its function and operational environment. As a result, no single test method or procedure can adequately replicate an intermittent fault occurrence for all LRUs/WRAs. A careful review of the nature of the failure and the operational conditions under which the failure occurred is required."

4.3 IFE background. The part number CTL990495 IFE was designed by Copernicus Technology Ltd. for the DoD to emulate intermittent faults that were commonly classified as NFF when the LRU/WRA was failure analyzed by the repair depot. The IFE is capable of generating individual variable resistance faults and burst of multiple resistance faults. The durations, profiles and pulse durations of the faults are software programmable by the user using IFE profile codes. In addition, the IFE is capable of emulating nodal and data bus circuit types. The IFE allows the evaluator to determine individual intermittent fault diagnostic equipment technology voids or abilities to detect and isolate faults by generating known intermittent faults. The IFE was evaluated against contract design requirements during a joint testing event at Naval Air Warfare Center Aircraft Division Lakehurst, Joint Base MDL NJ using a PicoScope to generate individual and peak signals.

4.4 Two-stage evaluation. A best practice when using the IFE is to have a two-step procedure. The first step is to evaluate the multi-channel capability of the IDFE using the IFE. The second step is to evaluate using a signal generator to determine the equipment's capability to detect events down to 100 nanoseconds. This two-step procedure is particularly important when the IDE stimulus voltages and currents are below 5 volts and 30 milliamps for frequencies from 40 KHz to 10 MHz (see 5.1).

5. DETAILED GUIDANCE

5.1 IFE description. The purpose of the IFE is to evaluate the performance of intermittent fault detection diagnostic equipment by inducing conductive path faults that emulate intermittent faults in LRUs/WRAs. As a result, the IFE enables an evaluation of the diagnostic equipment's ability to detect intermittent faults. Two events were hosted by DoD: Industry Week on 5-6 January 2016 and Industry Day on 22 March 2016. During these events, diagnostic equipment made by Eclypse International Corp.; Ridgetop Group, Inc.; Solavitek, Inc.; and Universal Synaptics Corp., were evaluated with the IFE.

The IFE is similar in appearance to an aircraft LRU/WRA and consists of the IFE unit connected to a host computer running Windows® and the IFE software application. The host computer is the user interface to the IFE. The IFE has 8 connectors, A to H, on the front panel (see figure 1) for connection to the diagnostic equipment. The connectors are MIL-DTL-38999 Series 1 with insert arrangement layout 19-35 (see MIL-STD-1560) having 66 size 22D (see SAE AS39029) male contacts.

The IFE input power is designed to tolerate 90 to 175 volts, or 132 to 264 volts at 47 to 63 Hz, and is protected by in-line fuse in the input connector. The maximum current requirement at 90 volts AC is 1.6 amps with a 55 watt load. The IFE is supplied with a polarized 120 volt 60 Hz plug having one blade wider than the other.

The IFE generates a variance in resistance across 256 channels on connectors A to H, to represent intermittent fault events for the diagnostic equipment to detect. Full details of how the IFE test channels are configured to the connector pin-out are specified in Annex B of the CTL-229-01 User Manual. Sequences of these simulated fault events are run from the IFE software application. Event sequences can be pseudo-random or user-defined event sequences; all sequences are saved and time-stamped and they can be repeated, modified, analyzed and downloaded.

FIGURE 1. Front of intermittent fault emulator.

FIGURE 2. Back of the intermittent fault emulator.

5.1.1 GUI application. During use, the IFE is connected to a host computer running Windows® and GUI application supplied with the IFE on a compact disc. This application is downloadable on to the host computer, is the user interface with the IFE, and is menu-driven. The GUI application is used to set up intermittent event sequences and to manage, save, and download the sequences and corresponding runs or emulations. The primary screens and indications of the application are detailed in the User Manual (see CTL-229-01).

5.1.2 IFE interface requirements. An interface adapter harness is not provided with the IFE and must be constructed. In addition, the GUI application includes profile codes that may be used to define event sequences and single events, but are limited in scope. These profile codes may be used as building blocks to emulate intermittent faults. It is recommended that the following interface elements be considered prior to evaluation of intermittent fault diagnostic equipment.

5.1.2.1 Detailed test design. An analysis should be performed of the LRU/WRA components that are expected to be tested with the intermittent fault diagnostic equipment. This analysis should include: LRU/WRA expected to be analyzed and failure data; types of intermittent faults (short or long duration, bursts); multiple or single faults; periodic or random; nodal or bus channel architecture; etc. In addition, the intermittent fault diagnostic equipment output per channel should not exceed the following:

±15 V tolerant
Continuous current 100 mA
Peak current 200 mA pulsed at 1 ms with a 10 percent duty cycle
Leakage current 0.04 nA typical, 1 nA max
Charge Injection 20 pF typical, 30 pF max
Channel Cross Talk -90 dB at 1 MHz, -30 dB at 100 Mhz

5.1.2.2 Interface adapter harness design. A wire harness will be required to connect the diagnostic equipment to the IFE. The harness design considerations may include: wiring for the total number of channels to be evaluated simultaneously; shielding if required; and the connectors to interface with the diagnostic equipment and IFE. The harness will require MIL-DTL-38999 Series 1 with insert arrangement 19-35 (see MIL-STD-1560) service M 66-way with type #22D female contacts.

Caution

All of the IFE channels have limited ESD protection of 2 kV. Take appropriate precautions to prevent risk of ESD during connecting and disconnecting the intermittent fault diagnostic equipment to the IFE.

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5.1.2.3 Coding and compiling. A GUI software application is provided with the IFE. Information on setting up and controlling the intermittent fault diagnostic equipment will be required and is not included with the IFE. IFE programming will be required to test the required test sequences, depending on the information determined during the detail design test development (see 5.1.2.1) for the diagnostic equipment.

5.1.2.4 Integration. Give consideration to how the diagnostic equipment will be integrated with the IFE. For example, determine if an automated program can be used to test all of the diagnostic functions or determine if an operator will be required to step the diagnostic equipment or IFE through various test steps.

5.1.2.5 Acceptance testing. IDE acceptance testing should include: pre-performance testing (startup, hookup, verification that IFE is properly connected to diagnostic equipment, safe-to-turn-on); performance testing (functional test of the diagnostic equipment, compliance of the diagnostic equipment to operational specification, ability of the diagnostic equipment to locate and isolate simulated intermittent faults; time to complete fault analysis; operator intervention (adjustments or alignments). In addition, criteria should be established for acceptance: time to find faults and percentage of faults located and isolated.

5.1.3 Concept of operation. The IFE can generate individual, variable resistance faults of 100 nanoseconds to 500 milliseconds nominally, and "burst" conductive faults as a 5 MHz pulse, from 3 to 5 microseconds. All time-based fault durations, profiles and pulse durations (above 100 nanoseconds) are software programmable by the user defining the test by use of the profile codes described in full at Annex A of the User Manual (see CTL-229-01).

There are 3 basic approaches to using the IFE for evaluating the intermittent fault detection performance of the diagnostic equipment being evaluated:

- **Pseudo-Random:** the user generates a pseudo-random event sequence lasting 15 minutes and containing 100 randomly occurring, intermittent single and burst events.
- **User-Defined:** the user creates an Event Sequence with each individual intermittent event defined in terms of channel, timing, profile and burst parameters.
- **Single Event:** the user triggers ad hoc single intermittent events with user-defined parameters.

5.1.4 IFE profiles. Annex A of the User Manual (see CTL-229-01) provides details on the full range of simulated fault profiles that can be selected when populating user-defined event sequences and single events. The 'shape,' ohmic variation, duration and burst settings are defined using preset simulated fault profiles. Figures 3 through 8 (images courtesy of Copernicus Technology Ltd.) are graphic representations of the different profile types:

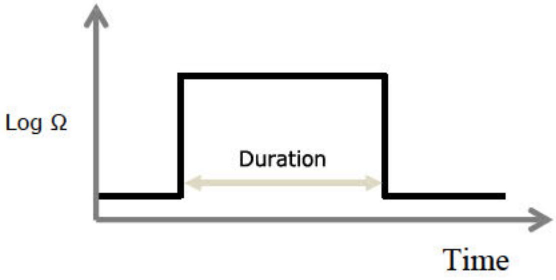


FIGURE 3. Simple pulse.

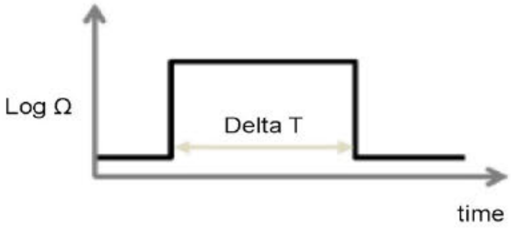


FIGURE 4. Square pulse.

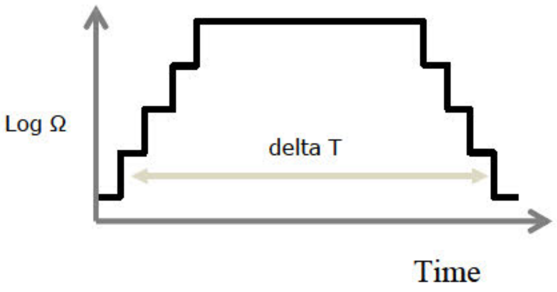


FIGURE 5. Ramped pulse.

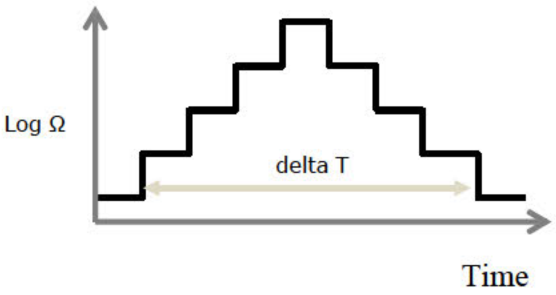


FIGURE 6. Saw-tooth pulse.

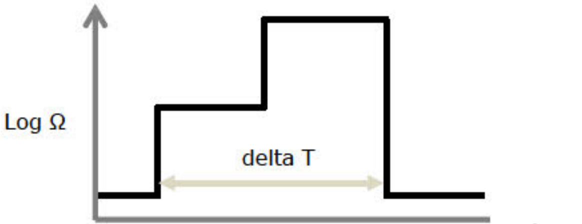


FIGURE 7. Two-step pulse.

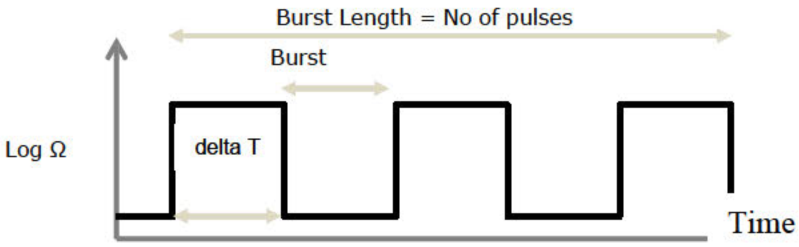


FIGURE 8. Square pulse burst.

5.2 IFE limitations. The IFE was developed for the DoD in order to provide a standardized method of benchmarking diagnostic test equipment with intermittent fault detection capability against MIL-PRF-32516 and may be used to evaluate other diagnostic equipment ability to detect Intermittent Faults. The IFE emulates pseudo-random intermittent faults over 256-channels simulating data bus and nodal architectures, and selectable fault parameters from 4 ohm to 499 ohms, and durations of 100 nanoseconds to 500 milliseconds These faults can be set/saved and replayed as sequences to allow diagnostic equipment to be tested against these sequences and assessed against MIL-PRF-32516. Initial trials of the IFE identified some design constraints that can affect the evaluation of diagnostic equipment that use stimulus voltages and currents in the ranges below 5 V and 30 mA for frequencies from 40 kHz to 10 MHz. The reason for these design constraints is because the IFE was designed to operate across a wide range of stimulus voltages (+15 V to -15 V), have high electrostatic discharge protection and produce simulated faults down to 100 nanoseconds. In order for the IFE to meet its design specification, it was necessary to use an electronic switch as the method of producing a transient break in the circuit for the diagnostic equipment to detect and isolate a fault. Using an electronic switch to simulate this type of failure mode has a degree of limitation because a 'real world' intermittent fault generally results from actual mechanical breaks in a circuit. The IFE's electronic switches exhibit unwanted characteristics that may not exist as part of a mechanical failure, including forward and reverse bias of the internal transistors of the electronic switch, capacitive charge and negative charge induction during switching, and frequency response. Testing of the IFE has found that the IFE functions well at test-stimulus currents of 90 milliamps or greater per test channel and/or above 100 microseconds but may not function outside these parameters.

5.3 User manual. Information necessary to be able to program and interact with the IFE which is controlled by a GUI is located in the user manual (see CTL-229-01). To program the IFE to emulate specific intermittent fault signals, refer to the IFE User Manual as specified in chapter 4.

5.4 Multi-channel detection test procedure.

5.4.1 Tests. This testing requires the IFE, a host Microsoft Windows® computer loaded with the GUI software application loaded on the connected computer. The IFE application is used to set up intermittent event sequences and to manage, save, and download the sequences and corresponding runs or emulations. The primary screens and indications of the application are shown in the User Manual. Using the IFE, perform the sequence of tests listed in table I. Perform Test 1-1 and if the IFE detects the fault on at least 95 percent of the test points, then proceed to Test 1-2 through Test 1-6.

TABLE I. Multi-channel detection tests.

Test No	Number of Test Points Evaluated	MIL-PRF-32516 Category	IFE Fault Duration
1-1	128	Not categorized	500 milliseconds
1-2	128	3	5 milliseconds
1-3	256	3	10 milliseconds
1-4	256	3	501 microseconds
1-5	256	2	250 microseconds
1-6	256	2	25 microseconds

5.4.2 Test results. If the Intermittent Fault Diagnostic Equipment passes all 6 tests, then it can be concluded that the diagnostic equipment is able to test across multiple test points. In addition, these tests also prove that it can detect intermittent faults down to 25 microseconds (40 kHz), which is within the Category 2 range of MIL-PRF-32516. To test the diagnostic equipment's performance below these durations then additional testing is required.

5.4.3 Extended test procedure. After completing the tests of 5.4.1 the following tests determine if the Intermittent Fault Diagnostic Equipment can detect intermittent faults down to 100 nanoseconds (10MHz). This testing assumes that the diagnostic equipment architecture is able to test simultaneously as proven in tests of 5.4.1. The extended test procedure also assumes that IFDE can perform in a simultaneous fault environment at faster frequencies and can pass the extended test procedure tests. Therefore, this Fault Duration Detection Test is designed to ascertain specifically if the diagnostic equipment can detect emulated intermittent faults down to 100 nanoseconds (10MHz).

5.4.3.1 Signal generator (SG). This testing requires the use of an SG with the ability to generate an arbitrary waveform generator output. Set the SG with a square wave with peak to peak voltage set to 1.5V and the frequency set as outlined in the table II, and place the selected test points across the output of the SG's output. The circuit will produce a raw simulated intermittent event each time the SG is triggered and the operator can assess if the diagnostic equipment has detected the simulated fault.

5.4.3.2 Tests. This testing should include the tests listed below as a minimum. Note: for ease of setup and operation it may be more appropriate to use 1 test point on the Intermittent Fault Diagnostic Equipment and carry out each of the frequencies 3 times for each test point.

5.5 Pinouts. Information necessary to develop the interface adapter harness for individual technologies should comply with the pinouts as shown in Appendix A.

TABLE II. Emulator tests.

Test No	Method	MIL-PRF-32516 Category	SG Fault Duration
2-1	Use 5 different test points on the diagnostic equipment and trigger the SG 3 times with a gap of 1 second between triggers. Record how many of the 15 faults are detected by the diagnostic equipment.	2	25 microseconds (40kHz)
2-2		2	5 microseconds (200kHz)
2-3		2	1 microseconds (1MHz)
2-4		2	500 nanoseconds (2MHz)
2-5		2	125 nanoseconds (8MHz)
2-6		1	95 nanoseconds (10.5MHz)

6. NOTES

6.1 Intended use. This handbook provides guidance for using the IFE to demonstrate the capabilities of IFDI technologies, methods, and devices capability to detect and isolate intermittent faults.

6.2 Subject term (key word) listing.

Electronic Test Equipment

INTERMITTENT FAULT EMULATOR TEST CHANNELS

A.1 SCOPE

A.1.1 Scope. This appendix provides information on the configuration of the IFE's test channels to assist in determining how to connect the diagnostic equipment to the IFE.

Note: Figures A-1 to A-4 and tables A-II to A-V courtesy of Copernicus Technology Ltd.

A.2 Test channels. The IFE has 256 test channels each with the following switchable resistances (see figure A-1): Figure A-2 shows examples of the 66 way electrical connector, the pin and channel layout for IFE input connectors.

4 ohms Represents a Closed Circuit condition (default on all channels)

56 ohms

1.1k ohms

10.1k ohms

499k ohms (Represents an open circuit condition)

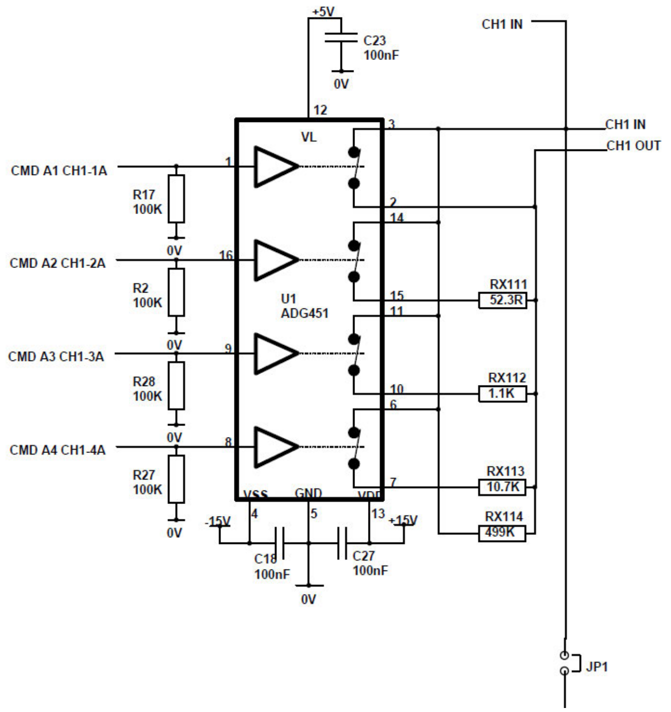


FIGURE A-1. <u>Channel schematic</u>.

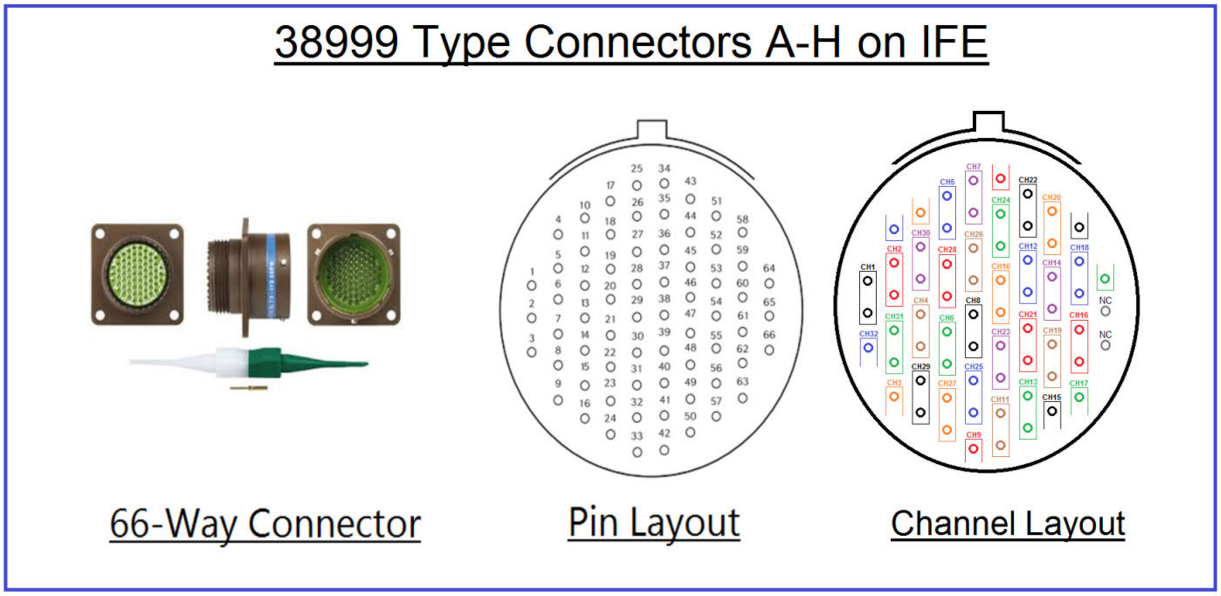


FIGURE A-2. <u>IFE Input connectors</u>.

A.2.1 Test connectivity architecture. To represent the connectivity architectures found in LRU/WRA components, the IFE's 256 channels are configured in either a databus (see figure A-3 (i.e., point-to-point)), or nodal (see figure A-4 (i.e., more than one channel interconnected)) arrangement. These configuration concepts are illustrated below:

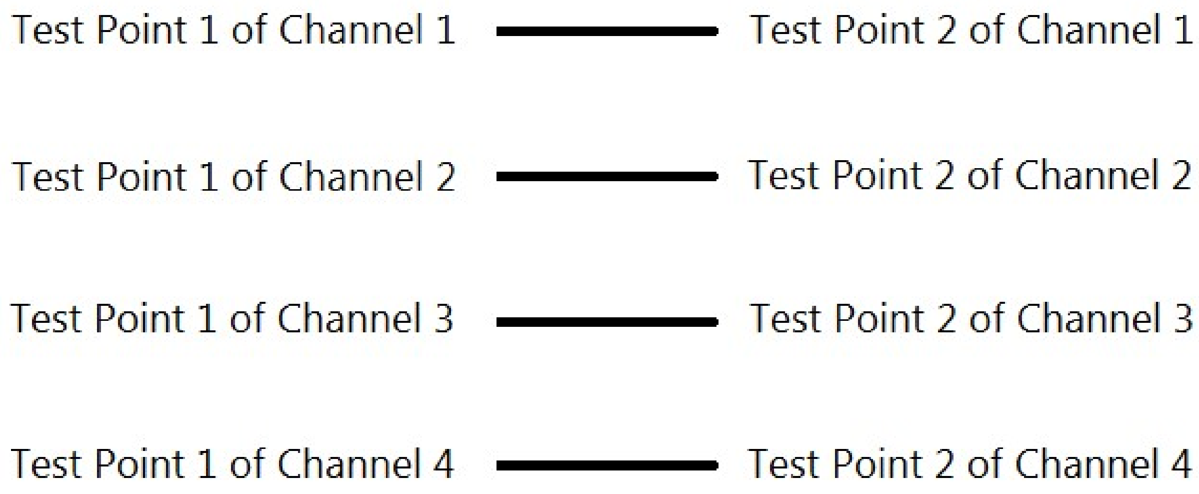


FIGURE A-3. Databus configuration.

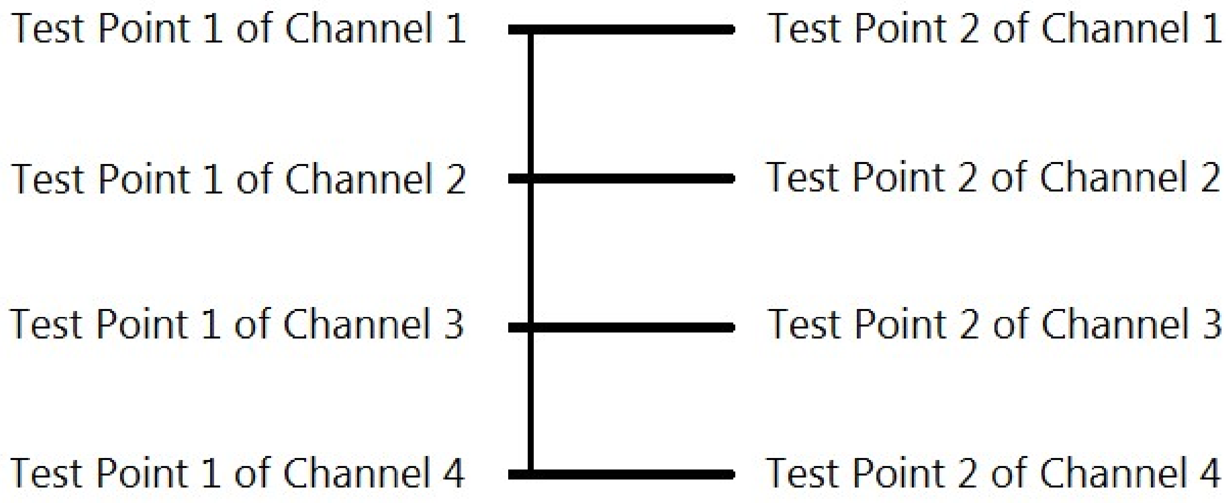


FIGURE A-4. Nodal configuration.

A.2.1.1 Test channel architecture. The 256 IFE test channels' architecture is specifically configured as per the following list, with channel-specific details shown in tables A-II through A-V:

128 channels consist of 1 channel each in databus configuration - all annotated with a 'D'

8 nodes consist of 4 channels each - Nodes: N1, N2, N3, N4, N5, N6, N7, N8

4 nodes consist of 8 channels each – Nodes: N9, N10, N11, N12

2 nodes consist of 16 channels each - Nodes N13, N14

1 node consists of 32 channels - Node: N15

A.2.1.2 Test channel configuration. The specific test channel configuration details are illustrated for each connector in tables A-II to A-V.

TABLE A-I. Connector plug key for tables.

D	Denotes that a channel is in a databus configuration and that the channels In/Out are not interconnected with any other channel.
N	Denotes a nodal configuration, with each separate node annotated with the requisite number, e.g., N5 means that all channels annotated against N5 will be on that same node.

TABLE A-II. Channel and databus/nodal configuration vs connector pins: plugs A through D.

Plug A

Channel	Pin Out	D/N
CH1	1,2	D
CH32	3,4	D
CH2	5,6	D
CH31	7,8	D
CH3	9,10	D
CH30	11,12	D
CH4	13,14	D
CH29	15,16	D
CH5	17,18	D
CH28	19,20	D
CH6	21,22	D
CH27	23,24	D
CH7	25,26	D
CH26	27,28	D
CH8	29,30	D
CH25	31,32	D
CH9	33,34	D
CH24	35,36	D
CH10	37,38	D
CH23	39,40	D
CH11	41,42	D
CH22	43,44	D
CH12	45,46	D
CH21	47,48	D
CH13	49,50	D
CH20	51,52	D
CH14	53,54	D
CH19	55,56	D
CH15	57,58	D
CH18	59,60	D
CH16	61,62	D
CH17	63,64	D

Plug B

Channel	Pin Out	D/N
CH1	1,2	D
CH32	3,4	D
CH2	5,6	D
CH31	7,8	D
CH3	9,10	D
CH30	11,12	D
CH4	13,14	D
CH29	15,16	D
CH5	17,18	D
CH28	19,20	D
CH6	21,22	D
CH27	23,24	D
CH7	25,26	D
CH26	27,28	D
CH8	29,30	D
CH25	31,32	D
CH9	33,34	D
CH24	35,36	D
CH10	37,38	D
CH23	39,40	D
CH11	41,42	D
CH22	43,44	D
CH12	45,46	D
CH21	47,48	D
CH13	49,50	D
CH20	51,52	D
CH14	53,54	D
CH19	55,56	D
CH15	57,58	D
CH18	59,60	D
CH16	61,62	D
CH17	63,64	D

Plug C

Channel	Pin Out	D/N
CH1	1,2	D
CH32	3,4	**N4**
CH2	5,6	D
CH31	7,8	**N4**
CH3	9,10	D
CH30	11,12	**N4**
CH4	13,14	D
CH29	15,16	**N4**
CH5	17,18	**N1**
CH28	19,20	D
CH6	21,22	**N1**
CH27	23,24	D
CH7	25,26	**N1**
CH26	27,28	D
CH8	29,30	**N1**
CH25	31,32	D
CH9	33,34	D
CH24	35,36	**N3**
CH10	37,38	D
CH23	39,40	**N3**
CH11	41,42	D
CH22	43,44	**N3**
CH12	45,46	D
CH21	47,48	**N3**
CH13	49,50	**N2**
CH20	51,52	D
CH14	53,54	**N2**
CH19	55,56	D
CH15	57,58	**N2**
CH18	59,60	D
CH16	61,62	**N2**
CH17	63,64	D

Plug D

Channel	Pin Out	D/N
CH1	1,2	D
CH32	3,4	**N8**
CH2	5,6	D
CH31	7,8	**N8**
CH3	9,10	D
CH30	11,12	**N8**
CH4	13,14	D
CH29	15,16	**N8**
CH5	17,18	**N5**
CH28	19,20	D
CH6	21,22	**N5**
CH27	23,24	D
CH7	25,26	**N5**
CH26	27,28	D
CH8	29,30	**N5**
CH25	31,32	D
CH9	33,34	D
CH24	35,36	**N7**
CH10	37,38	D
CH23	39,40	**N7**
CH11	41,42	D
CH22	43,44	**N7**
CH12	45,46	D
CH21	47,48	**N7**
CH13	49,50	**N6**
CH20	51,52	D
CH14	53,54	**N6**
CH19	55,56	D
CH15	57,58	**N6**
CH18	59,60	D
CH16	61,62	**N6**
CH17	63,64	D

TABLE A-III. Channel and databus/nodal configuration vs connector pins: plugs E through H.

Plug E

Channel	Pin Out	D/N
CH1	1,2	D
CH32	3,4	D
CH2	5,6	D
CH31	7,8	D
CH3	9,10	D
CH30	11,12	N11
CH4	13,14	D
CH29	15,16	N11
CH5	17,18	N9
CH28	19,20	N11
CH6	21,22	N9
CH27	23,24	N11
CH7	25,26	N9
CH26	27,28	N11
CH8	29,30	N9
CH25	31,32	N11
CH9	33,34	N9
CH24	35,36	N11
CH10	37,38	N9
CH23	39,40	N11
CH11	41,42	N9
CH22	43,44	N11
CH12	45,46	N9
CH21	47,48	N11
CH13	49,50	N10
CH20	51,52	N10
CH14	53,54	N10
CH19	55,56	N10
CH15	57,58	N10
CH18	59,60	N10
CH16	61,62	N10
CH17	63,64	N10

Plug F

Channel	Pin Out	D/N
CH1	1,2	N12
CH32	3,4	D
CH2	5,6	N12
CH31	7,8	D
CH3	9,10	N12
CH30	11,12	D
CH4	13,14	N12
CH29	15,16	D
CH5	17,18	N12
CH28	19,20	D
CH6	21,22	N12
CH27	23,24	D
CH7	25,26	N12
CH26	27,28	D
CH8	29,30	N12
CH25	31,32	D
CH9	33,34	N13
CH24	35,36	N13
CH10	37,38	N13
CH23	39,40	N13
CH11	41,42	N13
CH22	43,44	N13
CH12	45,46	N13
CH21	47,48	N13
CH13	49,50	N13
CH20	51,52	N13
CH14	53,54	N13
CH19	55,56	N13
CH15	57,58	N13
CH18	59,60	N13
CH16	61,62	N13
CH17	63,64	N13

Plug G

Channel	Pin Out	D/N
CH1	1,2	N14
CH32	3,4	D
CH2	5,6	N14
CH31	7,8	D
CH3	9,10	N14
CH30	11,12	D
CH4	13,14	N14
CH29	15,16	D
CH5	17,18	N14
CH28	19,20	D
CH6	21,22	N14
CH27	23,24	D
CH7	25,26	N14
CH26	27,28	D
CH8	29,30	N14
CH25	31,32	D
CH9	33,34	N14
CH24	35,36	D
CH10	37,38	N14
CH23	39,40	D
CH11	41,42	N14
CH22	43,44	D
CH12	45,46	N14
CH21	47,48	D
CH13	49,50	N14
CH20	51,52	D
CH14	53,54	N14
CH19	55,56	D
CH15	57,58	N14
CH18	59,60	D
CH16	61,62	N14
CH17	63,64	D

Plug H

Channel	Pin Out	D/N
CH1	1,2	N15
CH32	3,4	N15
CH2	5,6	N15
CH31	7,8	N15
CH3	9,10	N15
CH30	11,12	N15
CH4	13,14	N15
CH29	15,16	N15
CH5	17,18	N15
CH28	19,20	N15
CH6	21,22	N15
CH27	23,24	N15
CH7	25,26	N15
CH26	27,28	N15
CH8	29,30	N15
CH25	31,32	N15
CH9	33,34	N15
CH24	35,36	N15
CH10	37,38	N15
CH23	39,40	N15
CH11	41,42	N15
CH22	43,44	N15
CH12	45,46	N15
CH21	47,48	N15
CH13	49,50	N15
CH20	51,52	N15
CH14	53,54	N15
CH19	55,56	N15
CH15	57,58	N15
CH18	59,60	N15
CH16	61,62	N15
CH17	63,64	N15

TABLE A-IV. Channel configuration vs IFE channels 1 through 256: plugs A through D.

Plug A		
Channel	Ref Ch	D/N
CH1	1	D
CH2	2	D
CH3	3	D
CH4	4	D
CH5	5	D
CH6	6	D
CH7	7	D
CH8	8	D
CH9	9	D
CH10	10	D
CH11	11	D
CH12	12	D
CH13	13	D
CH14	14	D
CH15	15	D
CH16	16	D
CH17	17	D
CH18	18	D
CH19	19	D
CH20	20	D
CH21	21	D
CH22	22	D
CH23	23	D
CH24	24	D
CH25	25	D
CH26	26	D
CH27	27	D
CH28	28	D
CH29	29	D
CH30	30	D
CH31	31	D
CH32	32	D

Plug B		
Channel	Ref Ch	D/N
CH1	33	D
CH2	34	D
CH3	35	D
CH4	36	D
CH5	37	D
CH6	38	D
CH7	39	D
CH8	40	D
CH9	41	D
CH10	42	D
CH11	43	D
CH12	44	D
CH13	45	D
CH14	46	D
CH15	47	D
CH16	48	D
CH17	49	D
CH18	50	D
CH19	51	D
CH20	52	D
CH21	53	D
CH22	54	D
CH23	55	D
CH24	56	D
CH25	57	D
CH26	58	D
CH27	59	D
CH28	60	D
CH29	61	D
CH30	62	D
CH31	63	D
CH32	64	D

Plug C		
Channel	Ref Ch	D/N
CH1	65	D
CH2	66	D
CH3	67	D
CH4	68	D
CH5	69	N1
CH6	70	N1
CH7	71	N1
CH8	72	N1
CH9	73	D
CH10	74	D
CH11	75	D
CH12	76	D
CH13	77	N2
CH14	78	N2
CH15	79	N2
CH16	80	N2
CH17	81	D
CH18	82	D
CH19	83	D
CH20	84	D
CH21	85	N3
CH22	86	N3
CH23	87	N3
CH24	88	N3
CH25	89	D
CH26	90	D
CH27	91	D
CH28	92	D
CH29	93	N4
CH30	94	N4
CH31	95	N4
CH32	96	N4

Plug D		
Channel	Ref Ch	D/N
CH1	97	D
CH2	98	D
CH3	99	D
CH4	100	D
CH5	101	N5
CH6	102	N5
CH7	103	N5
CH8	104	N5
CH9	105	D
CH10	106	D
CH11	107	D
CH12	108	D
CH13	109	N6
CH14	110	N6
CH15	111	N6
CH16	112	N6
CH17	113	D
CH18	114	D
CH19	115	D
CH20	116	D
CH21	117	N7
CH22	118	N7
CH23	119	N7
CH24	120	N7
CH25	121	D
CH26	122	D
CH27	123	D
CH28	124	D
CH29	125	N8
CH30	126	N8
CH31	127	N8
CH32	128	N8

TABLE A-V. Channel configuration vs IFE channels 1 through 256: plugs E through H.

Plug E		
Channel	Ref Ch	D/N
CH1	129	N9
CH2	130	N9
CH3	131	N9
CH4	132	N9
CH5	133	N9
CH6	134	N9
CH7	135	N9
CH8	136	N9
CH9	137	D
CH10	138	D
CH11	139	N10
CH12	140	N10
CH13	141	N10
CH14	142	N10
CH15	143	N10
CH16	144	N10
CH17	145	N10
CH18	146	N10
CH19	147	D
CH20	148	D
CH21	149	N11
CH22	150	N11
CH23	151	N11
CH24	152	N11
CH25	153	N11
CH26	154	N11
CH27	155	N11
CH28	156	N11
CH29	157	D
CH30	158	D
CH31	159	D
CH32	160	D

Plug F		
Channel	Ref Ch	D/N
CH1	161	N12
CH2	162	N12
CH3	163	N12
CH4	164	N12
CH5	165	N12
CH6	166	N12
CH7	167	N12
CH8	168	N12
CH9	169	D
CH10	170	D
CH11	171	D
CH12	172	D
CH13	173	D
CH14	174	D
CH15	175	D
CH16	176	D
CH17	177	N13
CH18	178	N13
CH19	179	N13
CH20	180	N13
CH21	181	N13
CH22	182	N13
CH23	183	N13
CH24	184	N13
CH25	185	N13
CH26	186	N13
CH27	187	N13
CH28	188	N13
CH29	189	N13
CH30	190	N13
CH31	191	N13
CH32	192	N13

Plug G		
Channel	Ref Ch	D/N
CH1	193	N14
CH2	194	N14
CH3	195	N14
CH4	196	N14
CH5	197	N14
CH6	198	N14
CH7	199	N14
CH8	200	N14
CH9	201	N14
CH10	202	N14
CH11	203	N14
CH12	204	N14
CH13	205	N14
CH14	206	N14
CH15	207	N14
CH16	208	N14
CH17	209	D
CH18	210	D
CH19	211	D
CH20	212	D
CH21	213	D
CH22	214	D
CH23	215	D
CH24	216	D
CH25	217	D
CH26	218	D
CH27	219	D
CH28	220	D
CH29	221	D
CH30	222	D
CH31	223	D
CH32	224	D

Plug H		
Channel	Ref Ch	D/N
CH1	225	N15
CH2	226	N15
CH3	227	N15
CH4	228	N15
CH5	229	N15
CH6	230	N15
CH7	231	N15
CH8	232	N15
CH9	233	N15
CH10	234	N15
CH11	235	N15
CH12	236	N15
CH13	237	N15
CH14	238	N15
CH15	239	N15
CH16	240	N15
CH17	241	N15
CH18	242	N15
CH19	243	N15
CH20	244	N15
CH21	245	N15
CH22	246	N15
CH23	247	N15
CH24	248	N15
CH25	249	N15
CH26	250	N15
CH27	251	N15
CH28	252	N15
CH29	253	N15
CH30	254	N15
CH31	255	N15
CH32	256	N15

INTERMITTENT FAULT EMULATOR WAVEFORMS

B.1 SCOPE

B.1.1 Scope. The appendix provides examples of intermittent fault waveforms that can be generated using flexible profile codes that are built into the IFE.

B.2 Background. The IFE is a useful tool in evaluating intermittent diagnostic equipment that is very easy to set up and operate. The IFE has the ability to quickly validate diagnostic equipment capabilities. The IFE does an excellent job categorizing test equipment and gauging intermittence detection performance when testing a single wire (databus) or interconnected (nodal) circuitry.

An independent evaluation of the IFE found that the IFE works extremely well on the slow-duration end of the testing spectrum (ranging from one hundred microseconds to seconds) regardless of the test stimulus (current) applied. Unfortunately, this evaluation also found that the IFE struggles to perform as necessary on the fast-duration (nanoseconds [ns]) end when low-power test stimulus is applied.

Intermittence is a complex failure mode that typically begins in the nanosecond to microsecond realm. The physical root causes of intermittence are often only evident under a microscope.

Simulating this low-level, complex environment is difficult, especially when a broad range of testing stimulus is considered.

Solid state switches used in the IFE were the only option for providing the speed of switching required for short duration intermittent fault emulation, but there are a number of performance trade-offs. The higher the voltage requirement, the slower the speed of switching and as speed increases in the same voltage range, the amount of charge injected into the channel from these switches also increases. This unwanted injected charge changes the voltage in the switched circuit for a period that depends on the amount of current flowing in the circuit. The lower the current, the longer the voltage is not at the expected level. Therefore, a switch capable of generating a 100ns pulse-width with a voltage of up to plus or minus 15 volts will have enough charge injection as to require a current of several tens of milliamps to overcome the effects of the charge injection.

Due to inherent limitations in the electronic switches used in the IFE, it will not properly gauge the ability to detect intermittence below 15 microseconds on a databus if the diagnostic equipment test stimulus is below 40 milliamps. At low-power stimulus, pulse-widths greater than 15 microseconds are more accurate, and the accuracy increases as the test current increases from 40 to 90 milliamps.

The IFE performs well for simulated intermittent events employing 90 milliamps of stimulus and above, but may not provide validation of diagnostic equipment, which have test stimulus currents less than 90 milliamps, especially in nodal circuit configurations.

The example waveforms shown in this appendix illustrate the limitations of the solid state switches and are provided to give the user a reference point in regard to waveforms that can be generated with various levels of test voltage, current, and time durations.

B.3 Flexible profile codes (see B.1.1) Table B-I gives the flexible profile codes for the intermittent fault waveforms that can be generated by the IFE.

TABLE B-I. Flexible profile codes.

Code Letter	Event Characteristic
Q	**Square -** A simple pulse changing to its maximum ohmic variance.
R	**Ramped** – the event starts and ends with ohmic variance stepping through the values available to the defined maximum. One eighth of the event duration is ramping up, one eighth ramping down with six eights at the required resistance.
S	**Saw-tooth** – The event steps through each resistance for an equal time up and down.
T	**Two-step** – The event spends half its time at half the required resistance and the other half at the full value.

Notes:

1. Each event will have the duration in microseconds set by its deltaT parameter. There is a small overhead in the generation of these events so that each event is always 300 nanoseconds longer than the deltaT value set.

2. Events that step through resistance values are limited by the four steps available. Therefore, if a T profile (see code letter T in table B-I) is set with a code number of 3, the first part will be at level 1 (as 1.5 is not feasible).

3. All durations and sub-parts thereof are carried out for whole microsecond durations. Therefore if a T profile is set with a delta T of 3 microseconds, the first part will be 1 microsecond not 1.5 microseconds.

4. Due to the calculations involved, profiles R and S do not create accurate ‘shapes’ if shorter than 10 microseconds.

B.3.1 Profile code numbers. The emulator has built-in waveform profiles that are identified by a single code letter and number. The number identifies the resistance variance (see table B-II).

TABLE B-II. Profile code numbers.

Code Number	Variance (Ω)
1	53
2	1,000
3	10,000
4	500,000

B.4 Example waveforms. The following waveforms on figures B-2 through B-15 were generated using the flexible profile codes built into the IFE.

B.4.1 Test setup. Figure B-1 is a picture of the test setup used to generate the waveforms shown on figures B-2 through B-15. A decade resistance box and power supply were used to generate the 3 and 30 milliamperes input across one of the IFE channels. Once the IFE input was established, the profile code was programmed into the IFE and the intermittent event was triggered. The resultant waveform was captured on a PicoScope® and laptop computer shown on figure B-1.

FIGURE B-1. IFE waveform test setup.

B.4.2 Waveform figures. Figures B-2 to B-15 illustrate waveforms that can be generated by using the IFE flexible profile codes and show the limitations of the IFE's ability to generate various waveforms. The input and output of a channel are normally a closed circuit, which resistive values (see table B-II) can be individually turned on or any combination can be turned on. The resistance in any given channel can vary from the inherent resistance of the closed circuit to approximately 511K ohms. The following is an explanation of the waveforms:

Figure B-2	Single pulse square wave formed by switching from a closed circuit to 500K ohms for 100 ns duration using a 30 mA source.
Figure B-3	Single pulse square wave formed by switching from a closed circuit to 500K ohms for 1 ms duration using a 3 mA source.
Figure B-4	Single pulse square wave formed by switching from a closed circuit to 500K ohms for 1 ms duration using a 30 mA source.
Figure B-5	Single pulse square wave formed by switching from a closed circuit to 500K ohms for 1 µs duration using a 30 mA source.
Figure B-6	Burst of five square waves formed by switching from a closed circuit to 500K Ohms for 10 µs duration using a 30 mA source.
Figure B-7	Single pulse square wave formed by switching from a closed circuit to 500K ohms for 10 µs duration using a 30 mA source.
Figure B-8	Single pulse square wave formed by switching from a closed circuit to 500K ohms for 100 µs duration using a 30 mA source.
Figure B-9	Ramped square waves formed by switching from a closed circuit to 53, 1K, 10K and 500K ohms and back to the closed circuit for 1 ms duration using a 3 mA source.
Figure B-10	Ramped square waves formed by switching from a closed circuit to 53, 1K, 10K and 500K ohms and back to the closed circuit for 100 µs duration using a 30 mA source. Ramping up is 12.5 µs, ramping down is 12.5 µs and 75 µs at 500K ohms.
Figure B-11	Saw-tooth square waves formed by switching from a closed circuit to 53, 1K, 10K and 500K ohms and back to the closed circuit for 1ms duration using a 3 mA source. Each resistance duration is equal time up and down.

Figure B-12 Saw-tooth square waves formed by switching from a closed circuit to 53, 1K, 10K and 500K ohms and back to the closed circuit for a total 100 µs duration using a 30 mA source. Each resistance duration is equal in time during both the up and down cycles.

Figure B-13 Two-step square wave formed by switching from a closed circuit in two steps at half 500K and 500K ohms for 1 ms duration using a 3 mA source. Half of the duration is spent at each resistance.

Figure B-14 Burst of five two step square wave formed by switching from a closed circuit in two steps at half 500K and 500K ohms for 10 µs duration using a 30 mA source. In the two step square wave, half of the duration is spent at each resistance.

Figure B-15 Two-step square wave formed by switching from a closed circuit in two steps at half 500K and 500K ohms for 100 µs duration using a 30 mA source. Half of the duration is spent at each resistance.

B.4.3 Waveform summary. There are several conclusions that can be made based on the waveforms shown on figures B-2 through B-15.

a. As illustrated on figure B-2 the IFE is not able to fully create the required waveform in very short durations such as 100 ns on figure B-2.

b. The IFE generates a significant positive and negative spike during both the opening and closing of the resistance in the channel path. This spike is due to charge injection characteristics inherent in the IFE electronic switches. The waveforms generated and spike reduction by the IFE improve as the stimulus current of the diagnostic equipment increases above 40 mA.

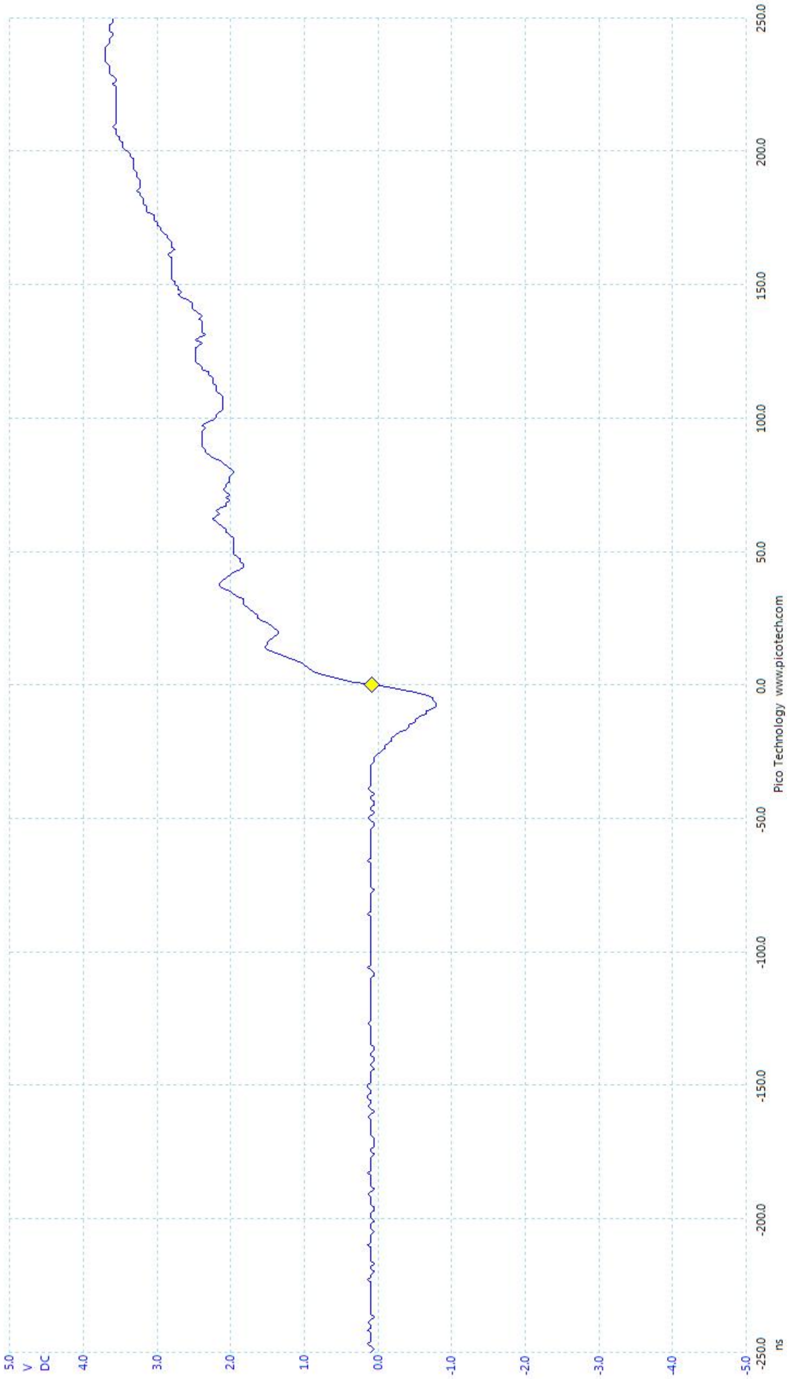


FIGURE B-2. Waveform A4 30 mA 100 ns.

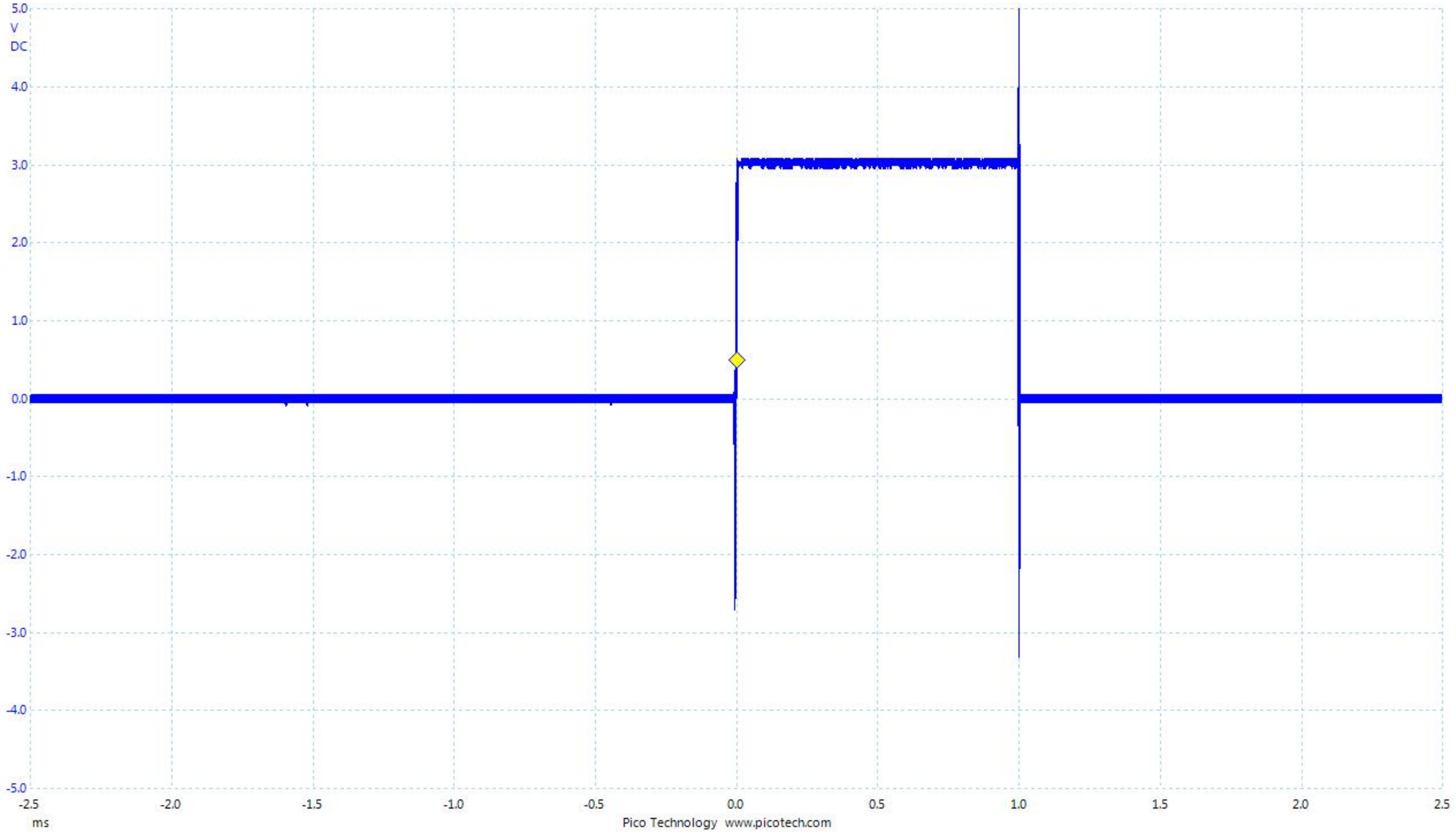


FIGURE B-3. Waveform Q4 3 mA 1 ms.

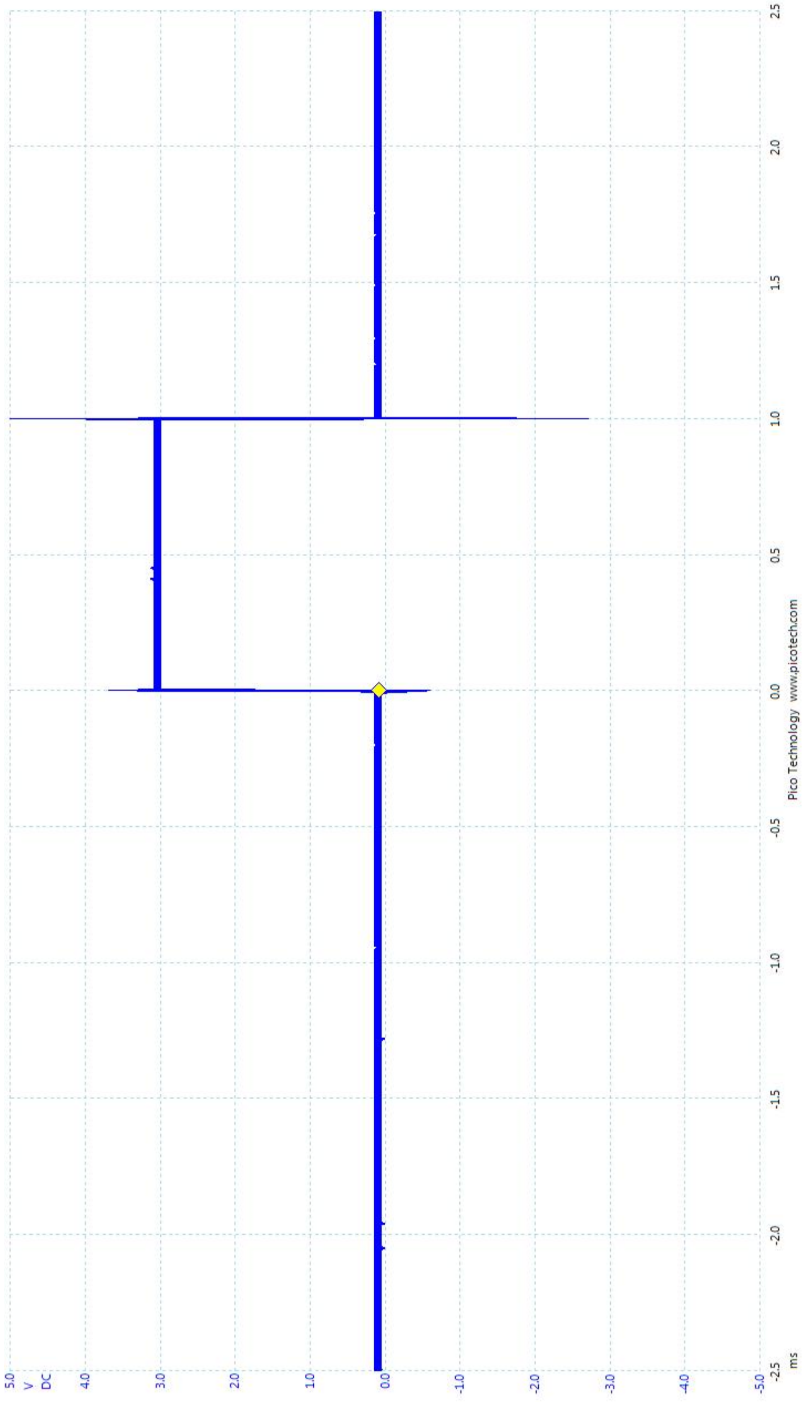


FIGURE B-4. Waveform Q4 30 mA 1 ms.

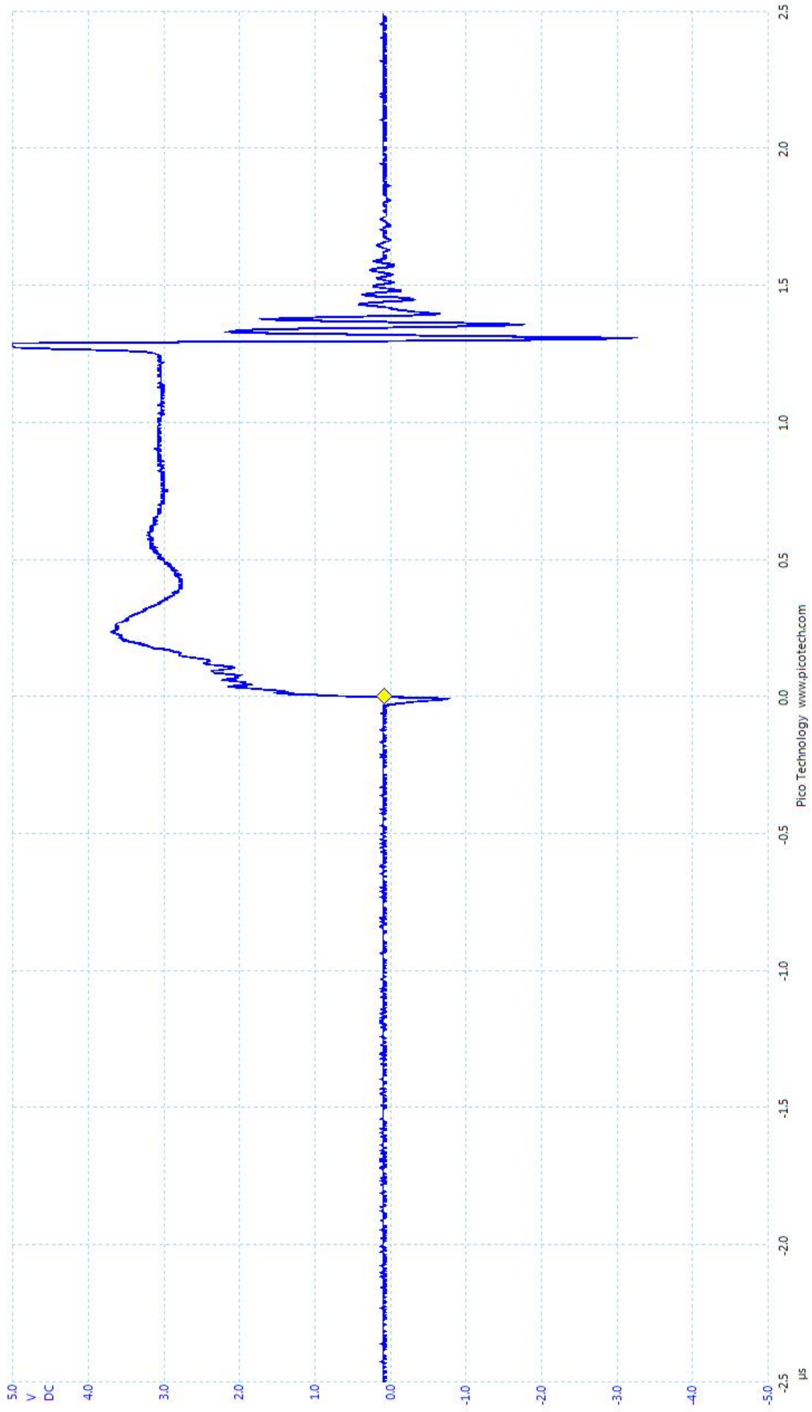


FIGURE B-5. Waveform Q4 30 mA 1 µs.

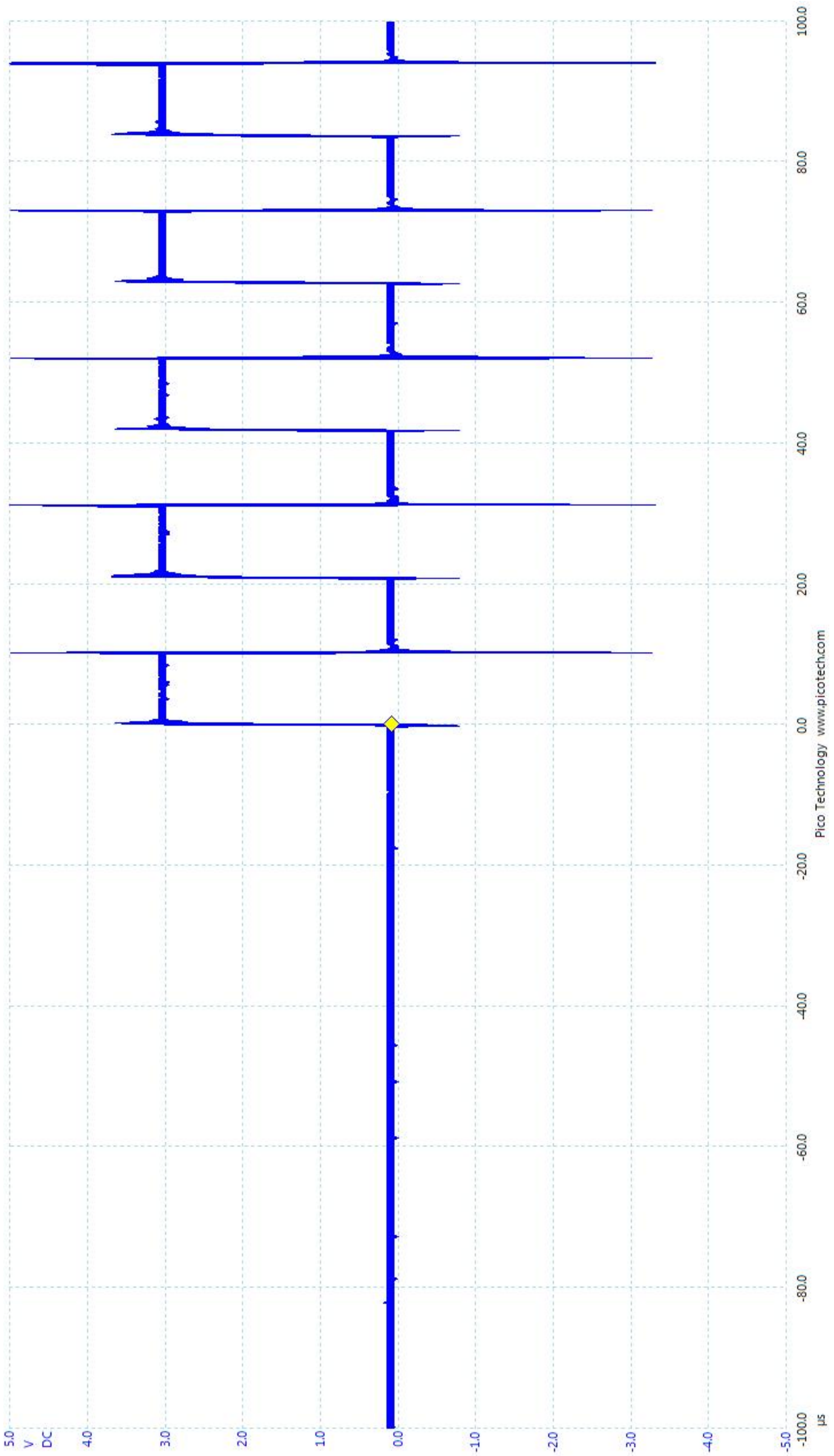


FIGURE B-6. Waveform Q4 30 mA 10 µs 5B.

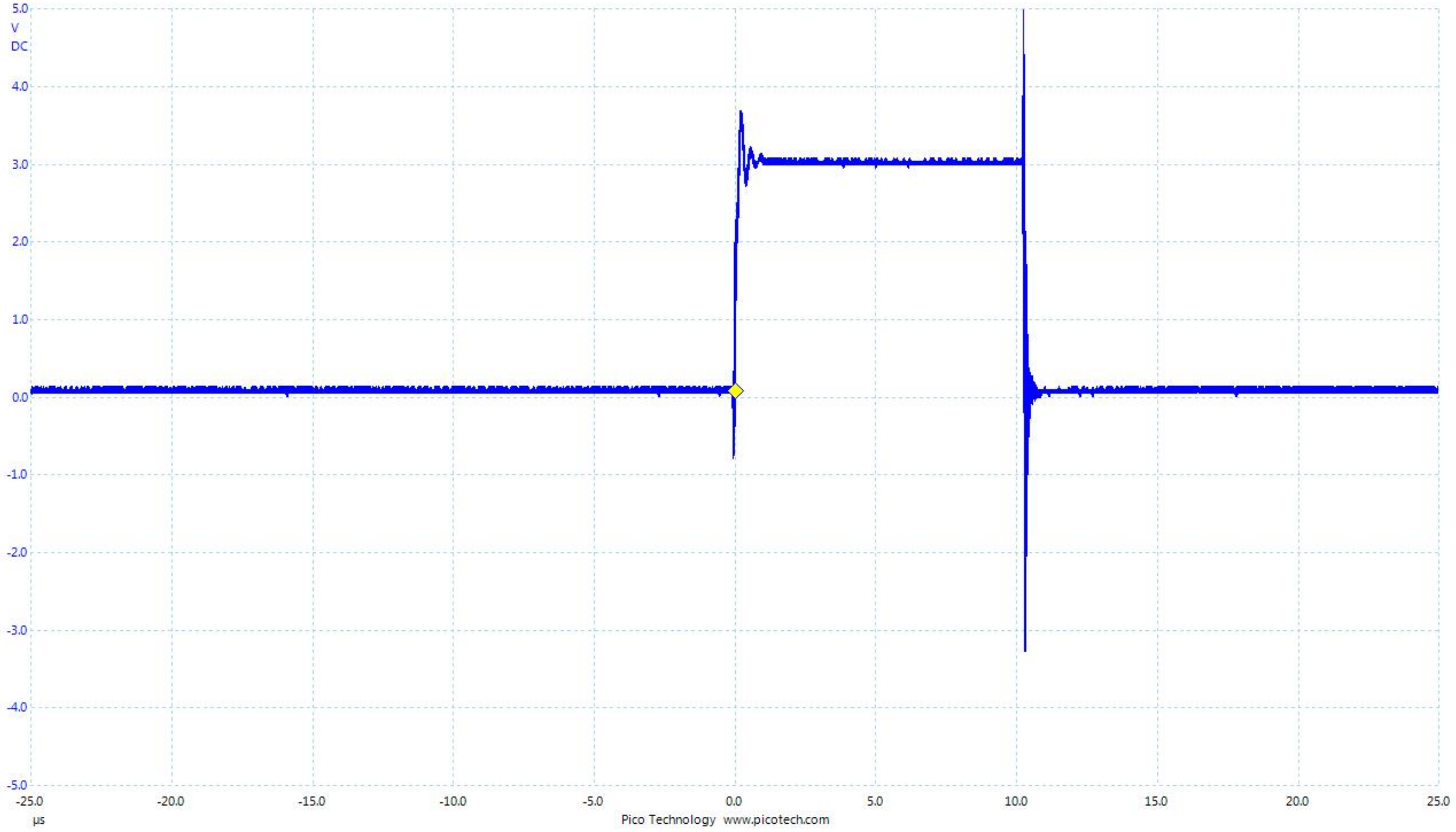


FIGURE B-7. Waveform Q4 30 mA 10 µs.

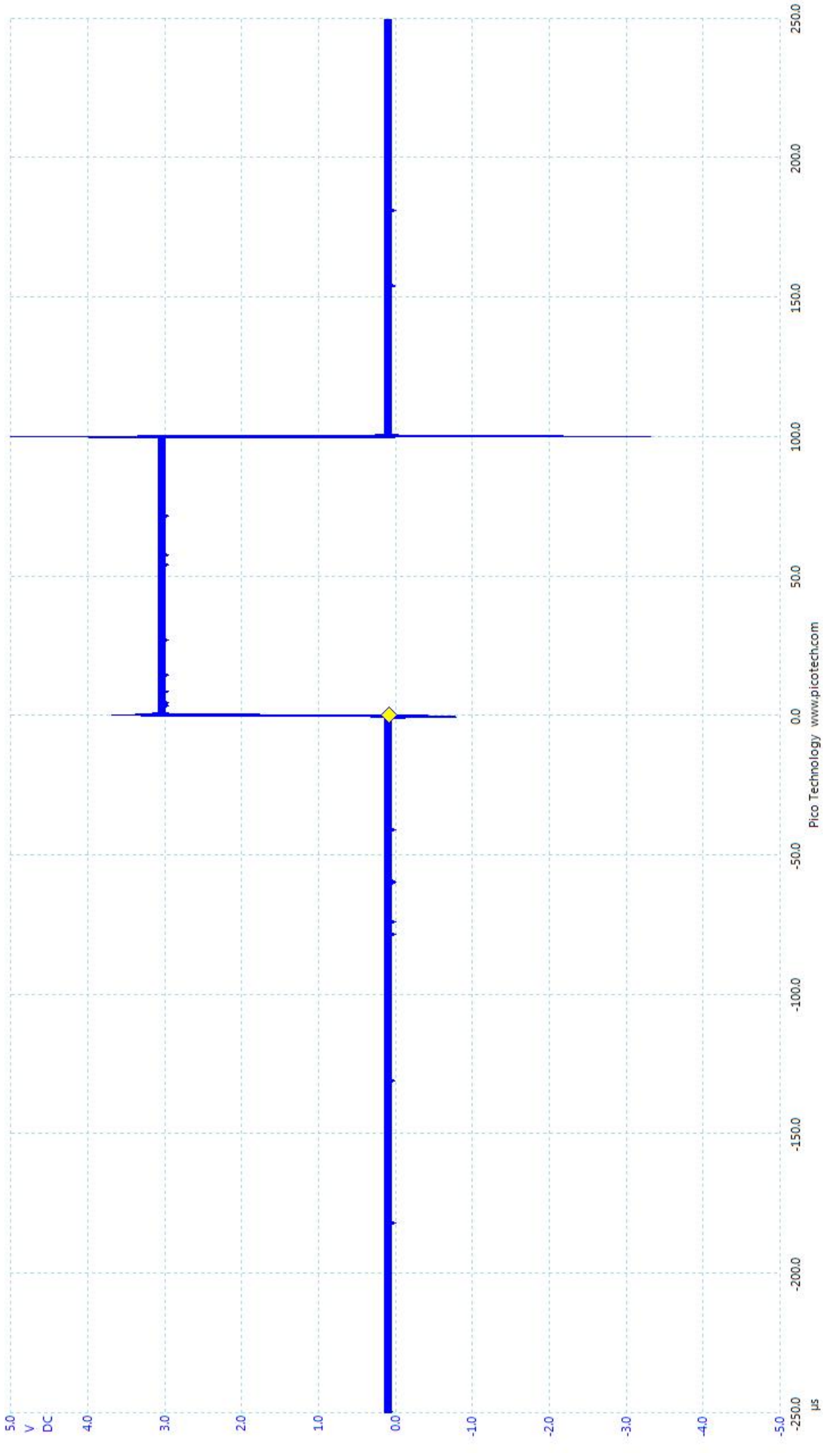


FIGURE B-8. Waveform Q4 30 mA 100 µs.

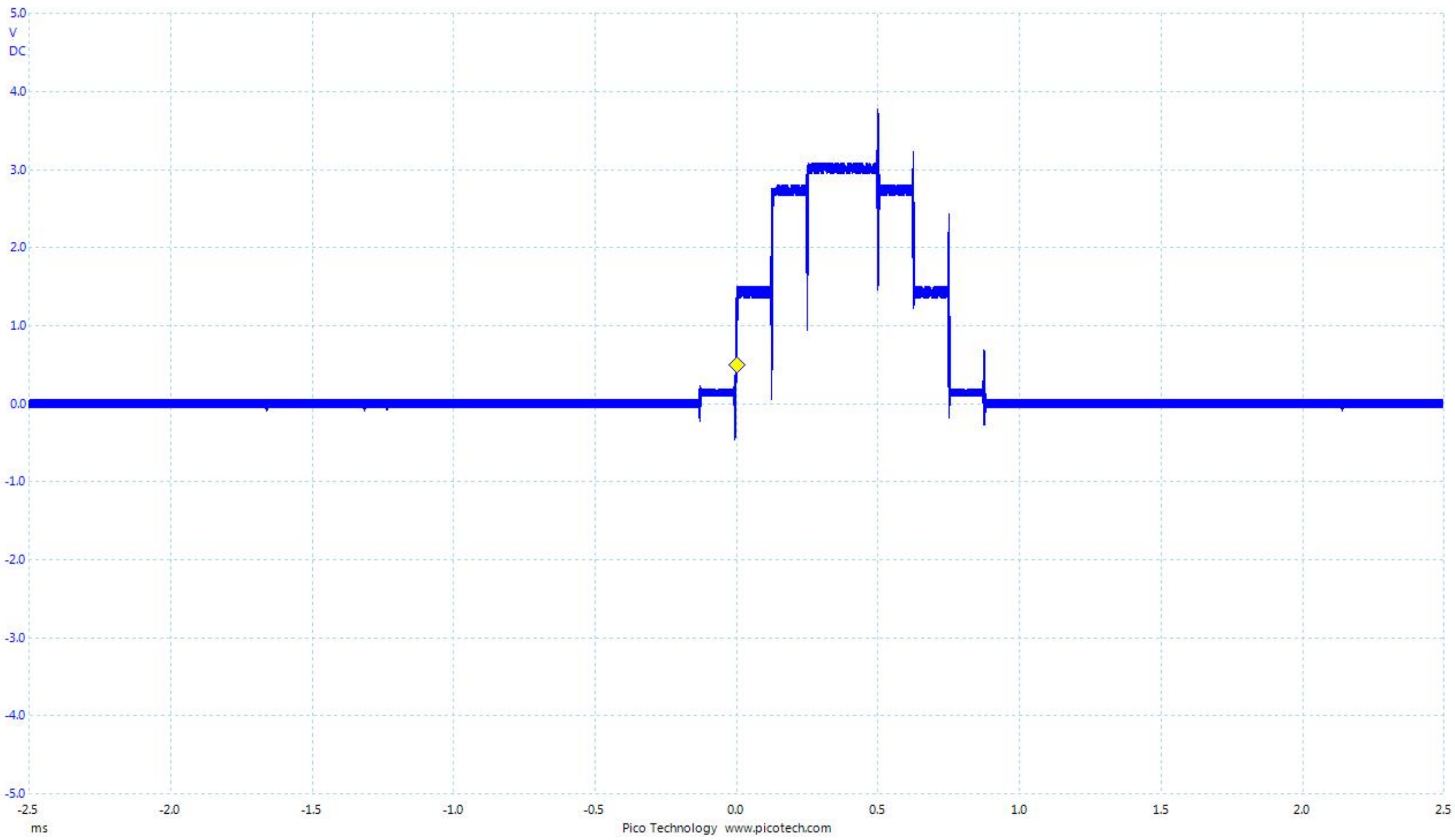


FIGURE B-9. Waveform R4 3 mA 1 ms.

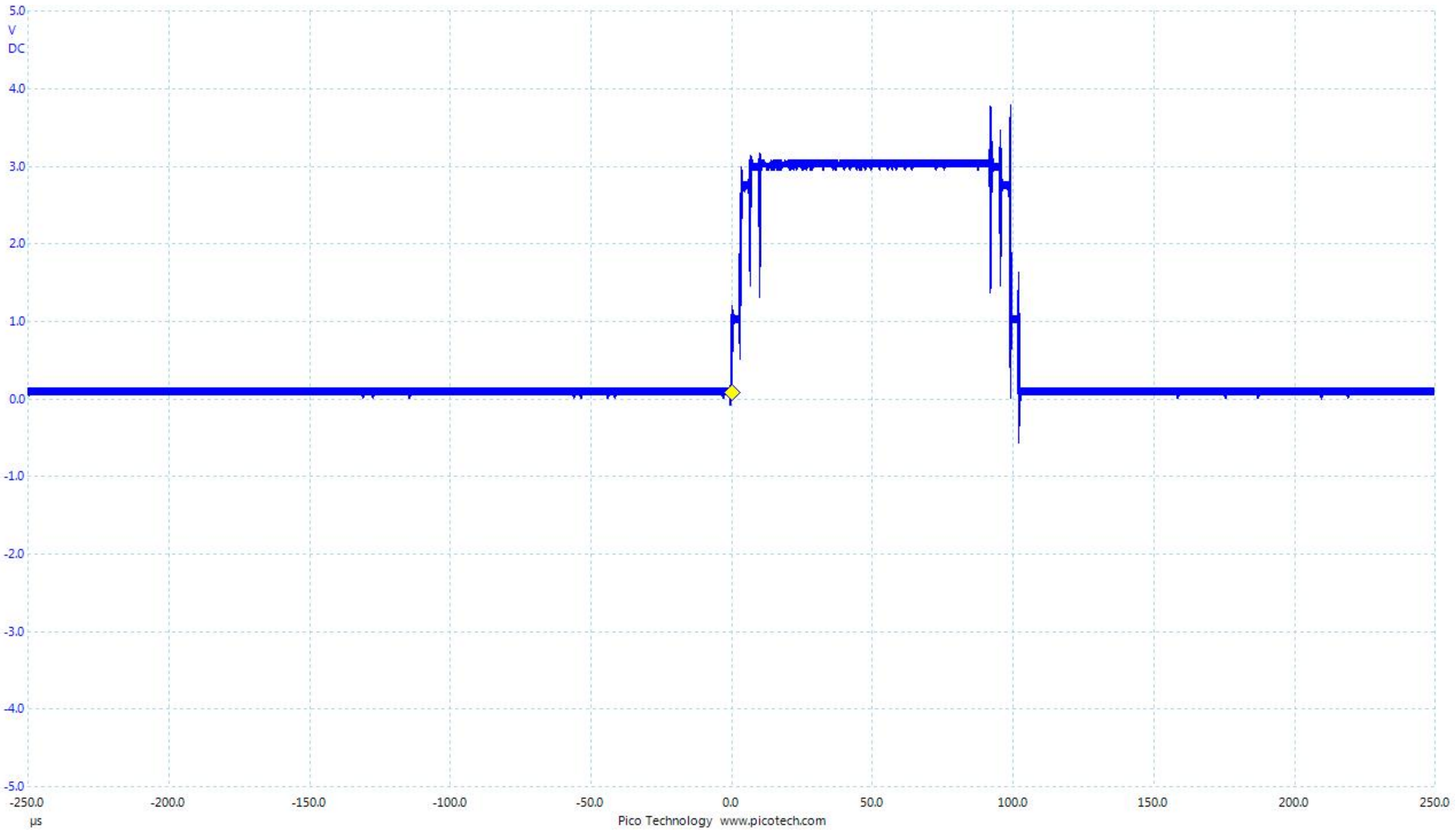


FIGURE B-10. Waveform R4 30 mA 100 µs.

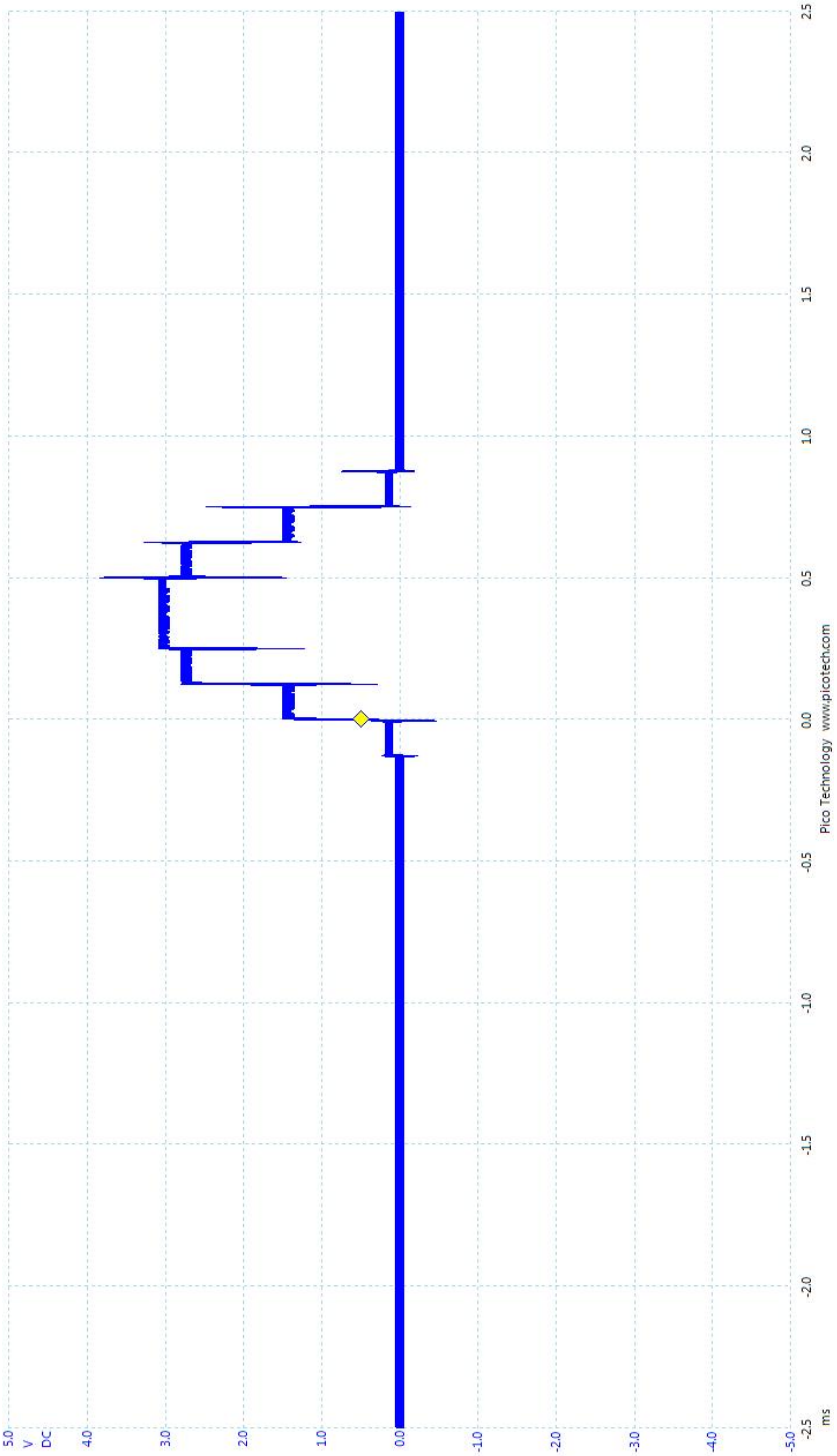


FIGURE B-11. Waveform S4 3 mA 1 ms.

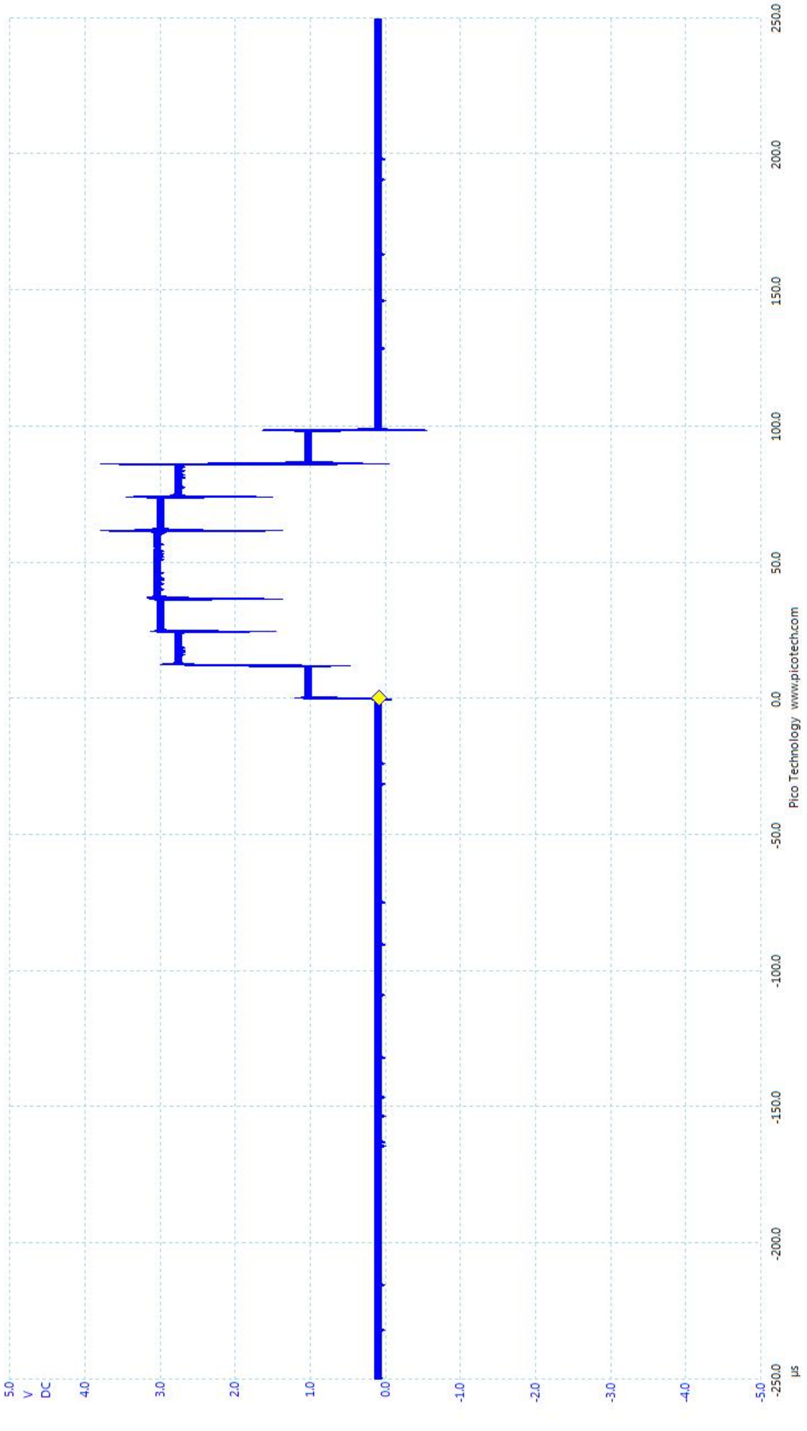


FIGURE B-12. Waveform S4 30 mA 100 µs.

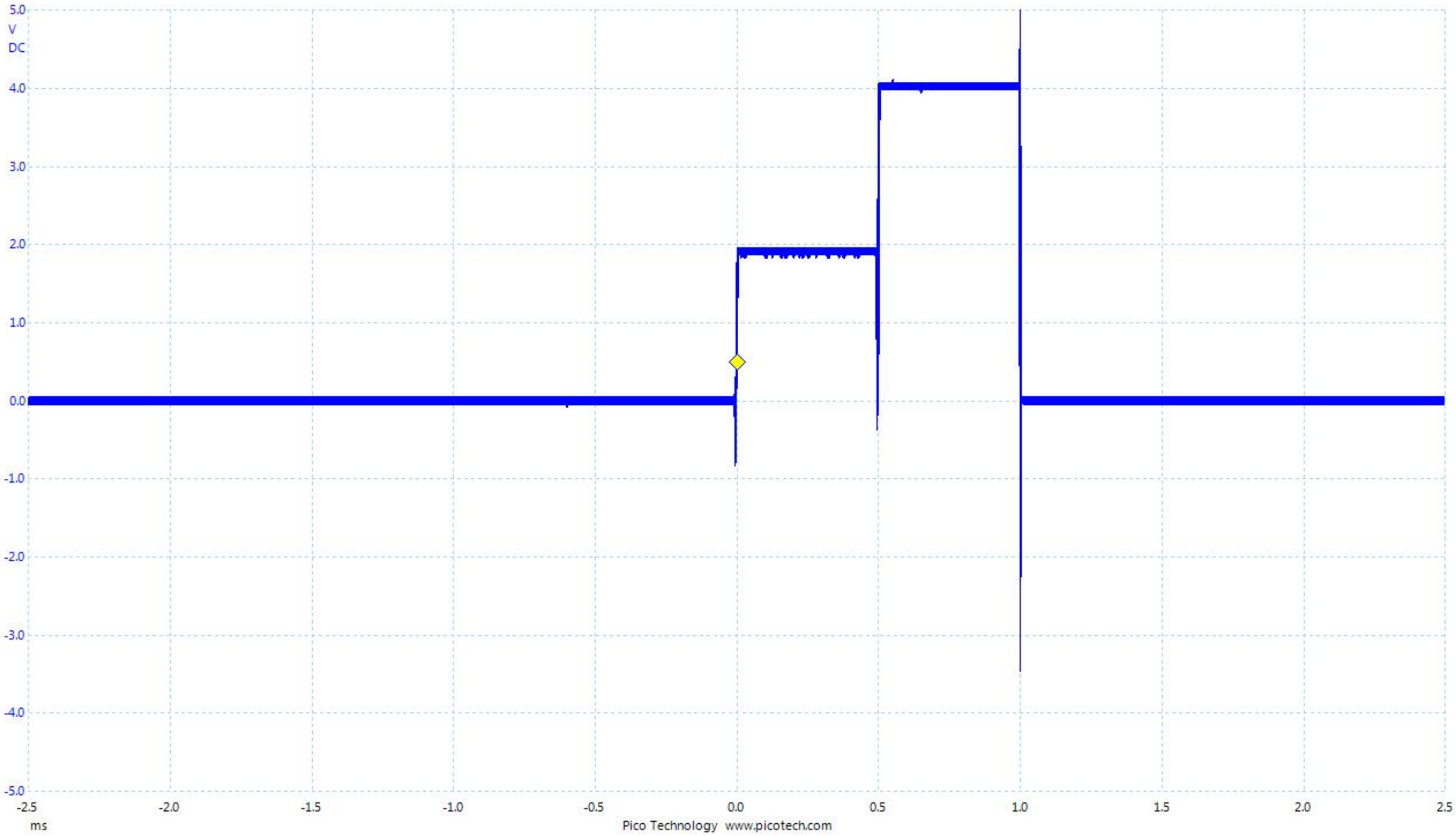


FIGURE B-13. Waveform T4 3 mA 1 ms.

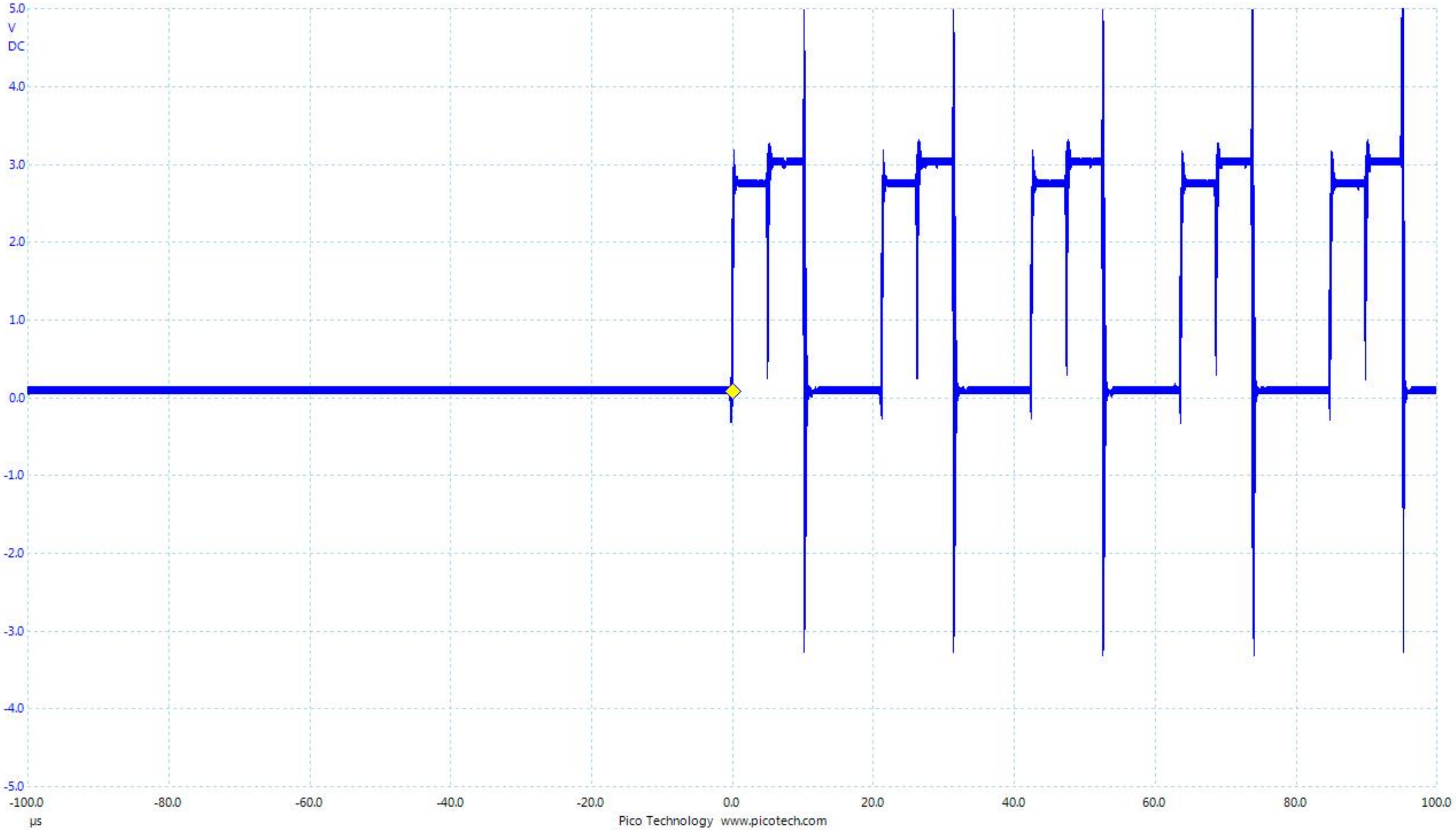


FIGURE B-14. Waveform T4 30 mA 10 µs 5B.

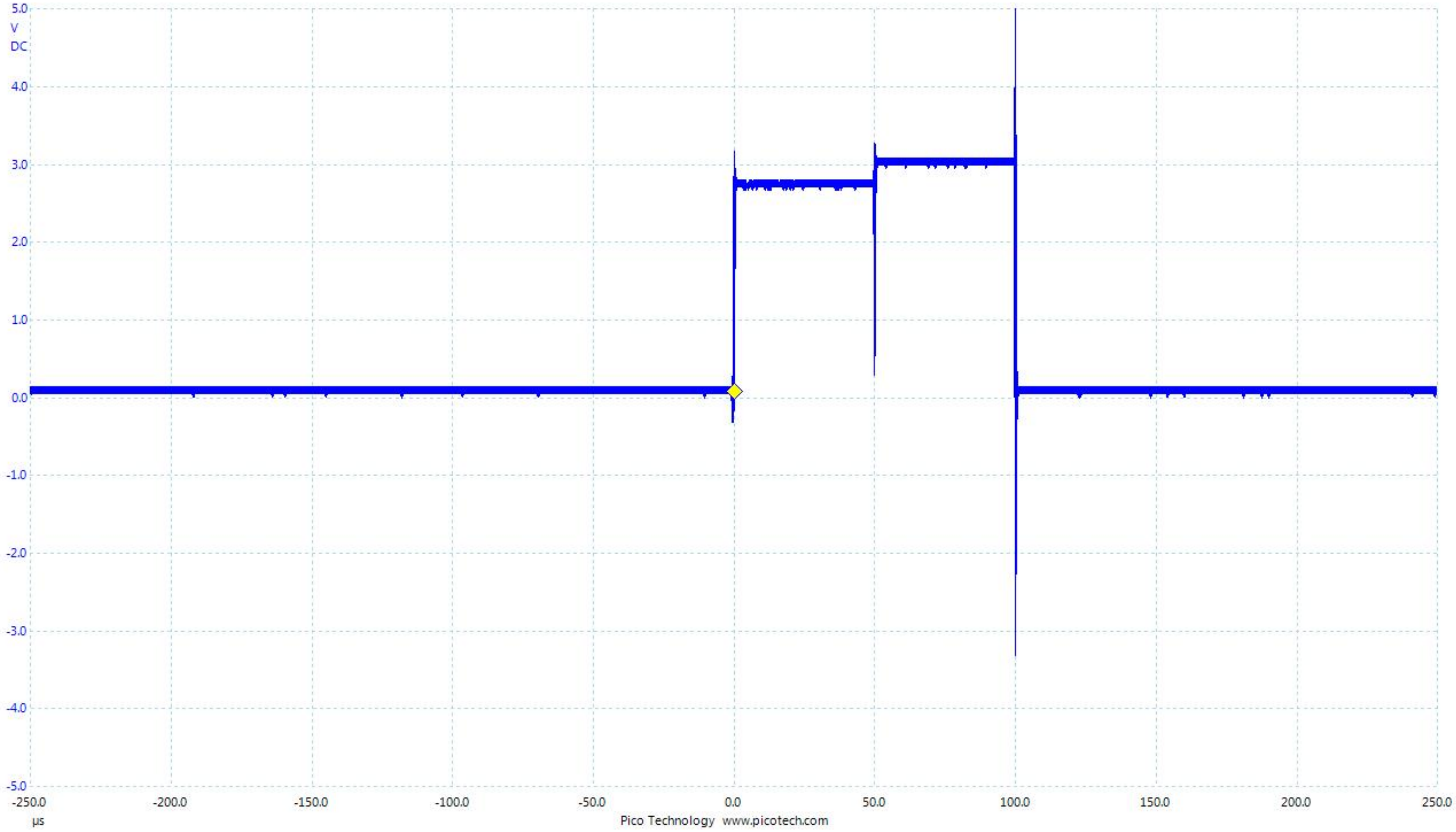
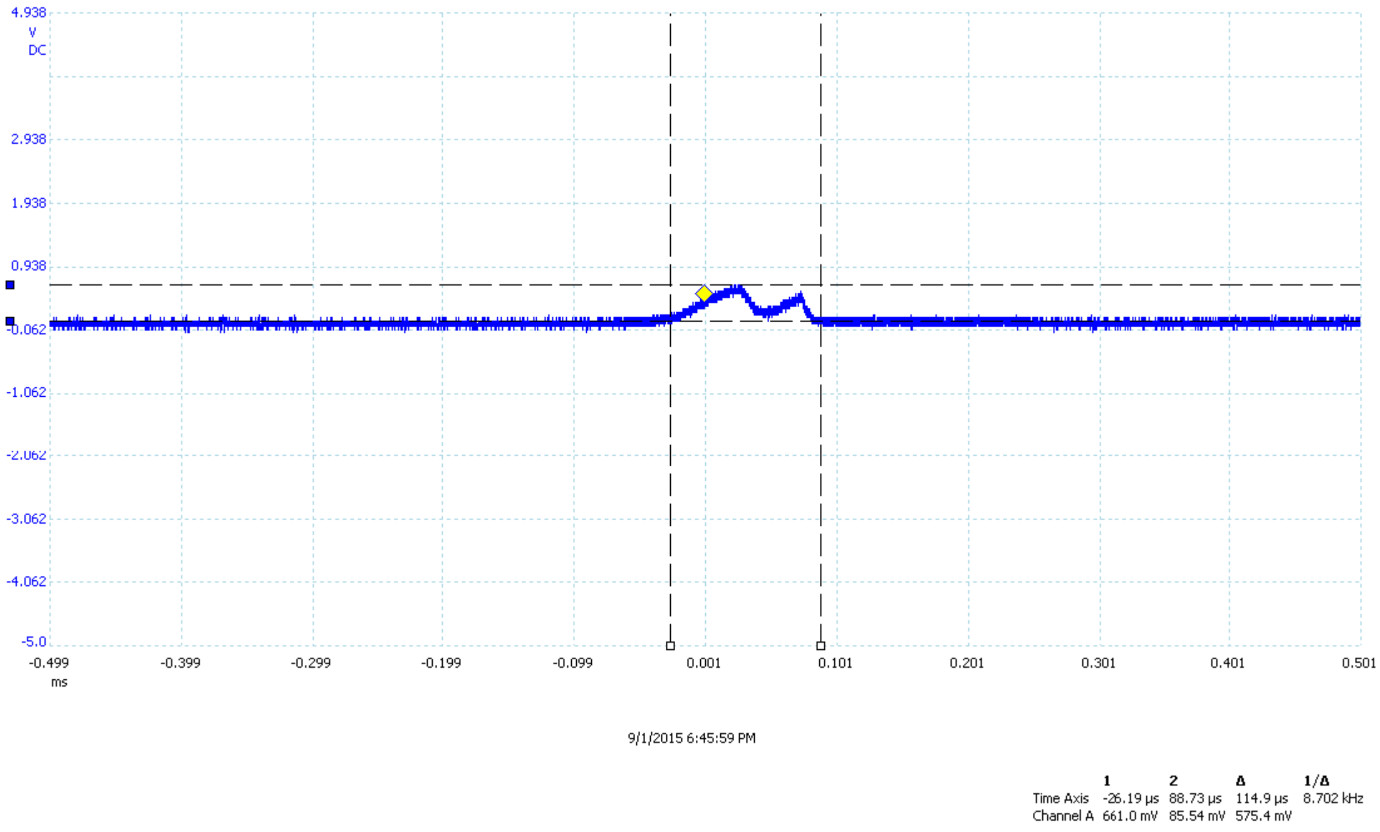


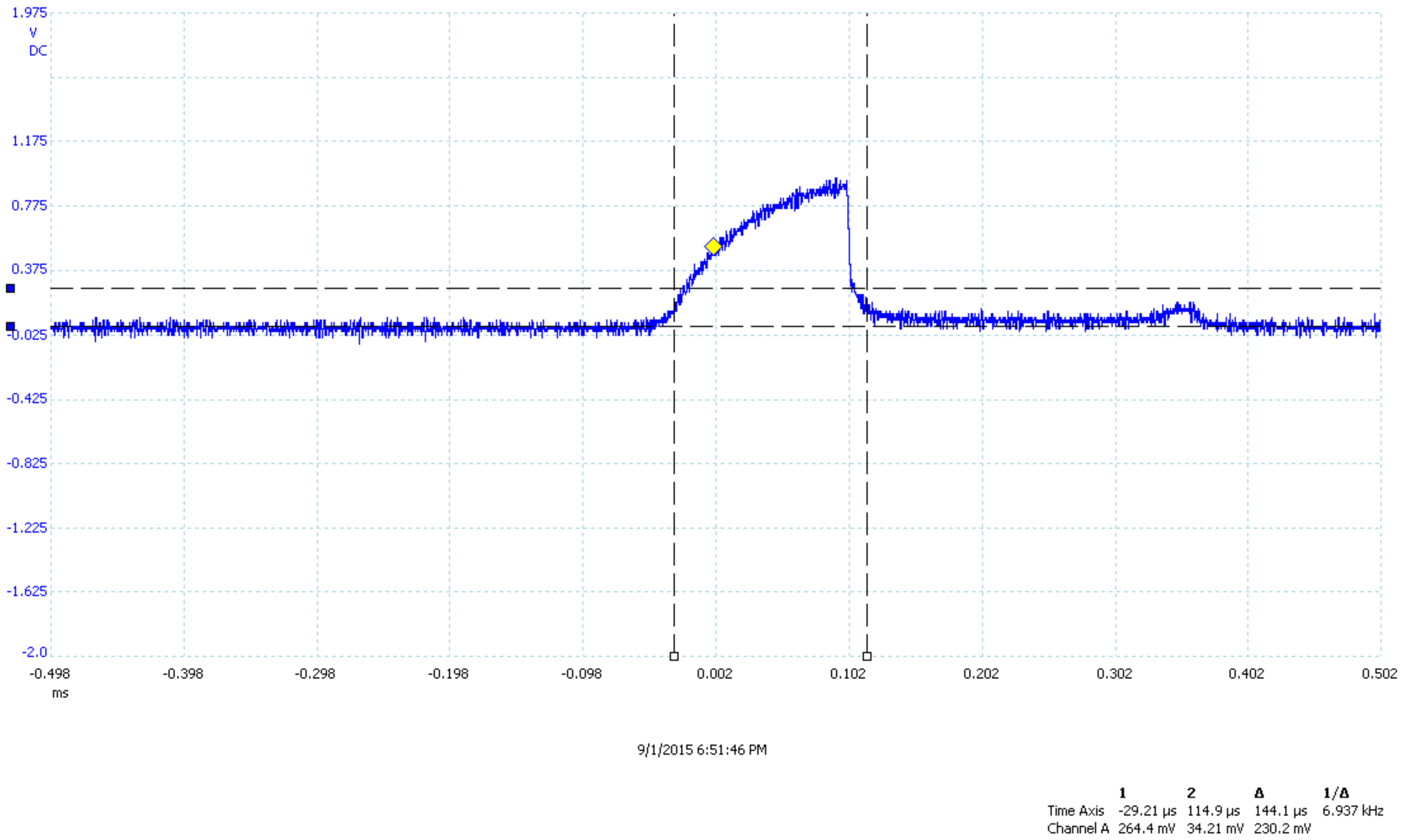
FIGURE B-15. <u>Waveform T4 30 mA 100 µs</u>.

B.5 F/A-18 generator converter unit waveform examples. Figures B-16 through B-21 are examples of waveforms taken from an F/A -18 Generator Converter Unit (GCU). These intermittent faults were detected by Intermittent Fault Diagnostic Equipment and the waveforms were captured on an oscilloscope. All of the waveforms are of different amplitudes and durations, but coming from the same test point. These examples illustrate the importance of testing all circuits simultaneously. Figures B-16 through B-21 also show that intermittent faults do not follow a specific pattern from minute to minute during testing, which is one reason that intermittent faults are difficult to capture and detect. These waveforms are provided only as examples. Waveform duration, amplitude, and shape will vary depending on the piece of equipment and the nature of the intermittent fault (fatigue fracture, cold solder joint, poor crimp, etc.).



	1	2	Δ	1/Δ
Time Axis	-26.19 µs	88.73 µs	114.9 µs	8.702 kHz
Channel A	661.0 mV	85.54 mV	575.4 mV	

FIGURE B-16. GCU waveform example 1.



```
              1           2          Δ          1/Δ
Time Axis   -29.21 µs   114.9 µs   144.1 µs   6.937 kHz
Channel A   264.4 mV    34.21 mV   230.2 mV
```

FIGURE B-17. GCU waveform example 2.

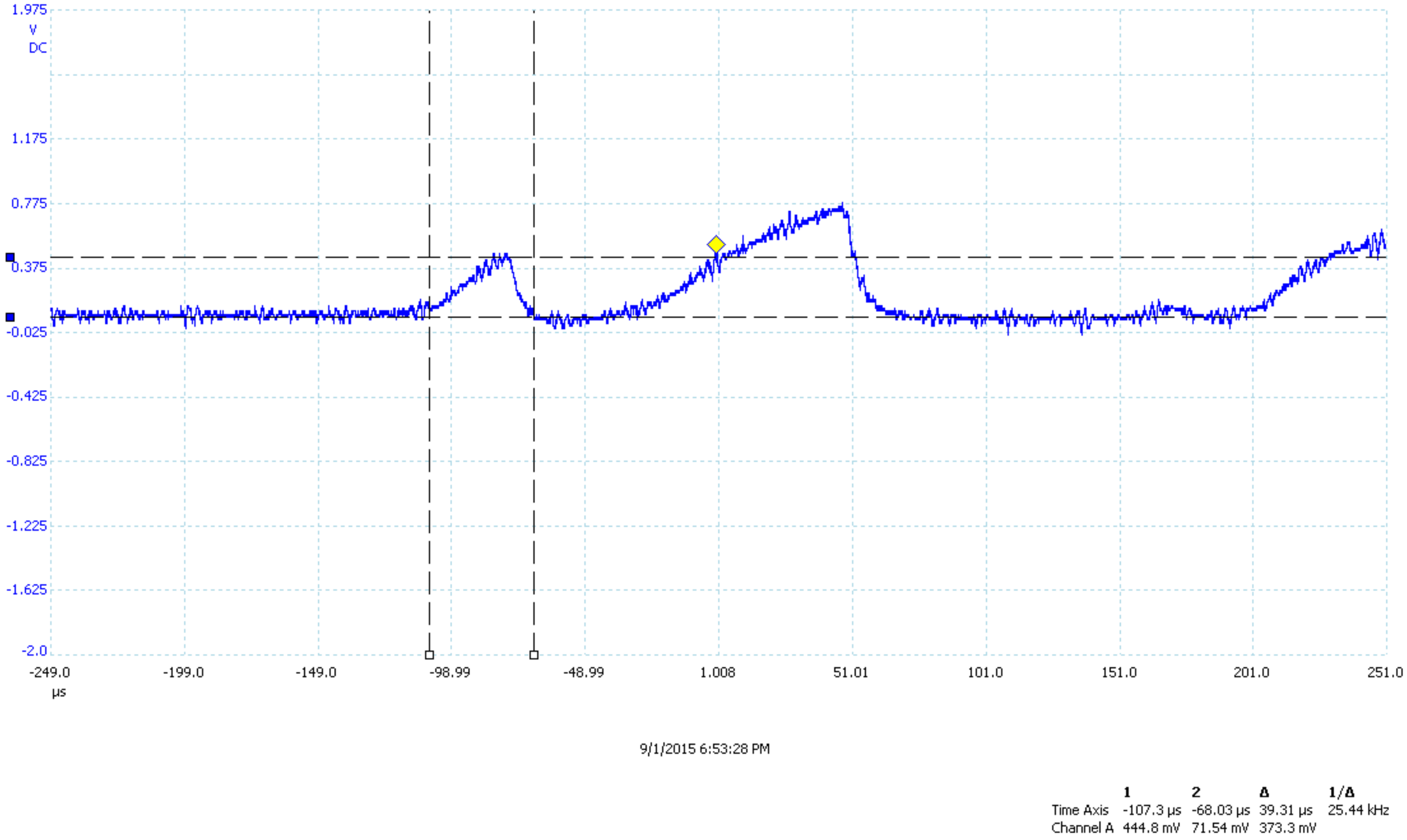
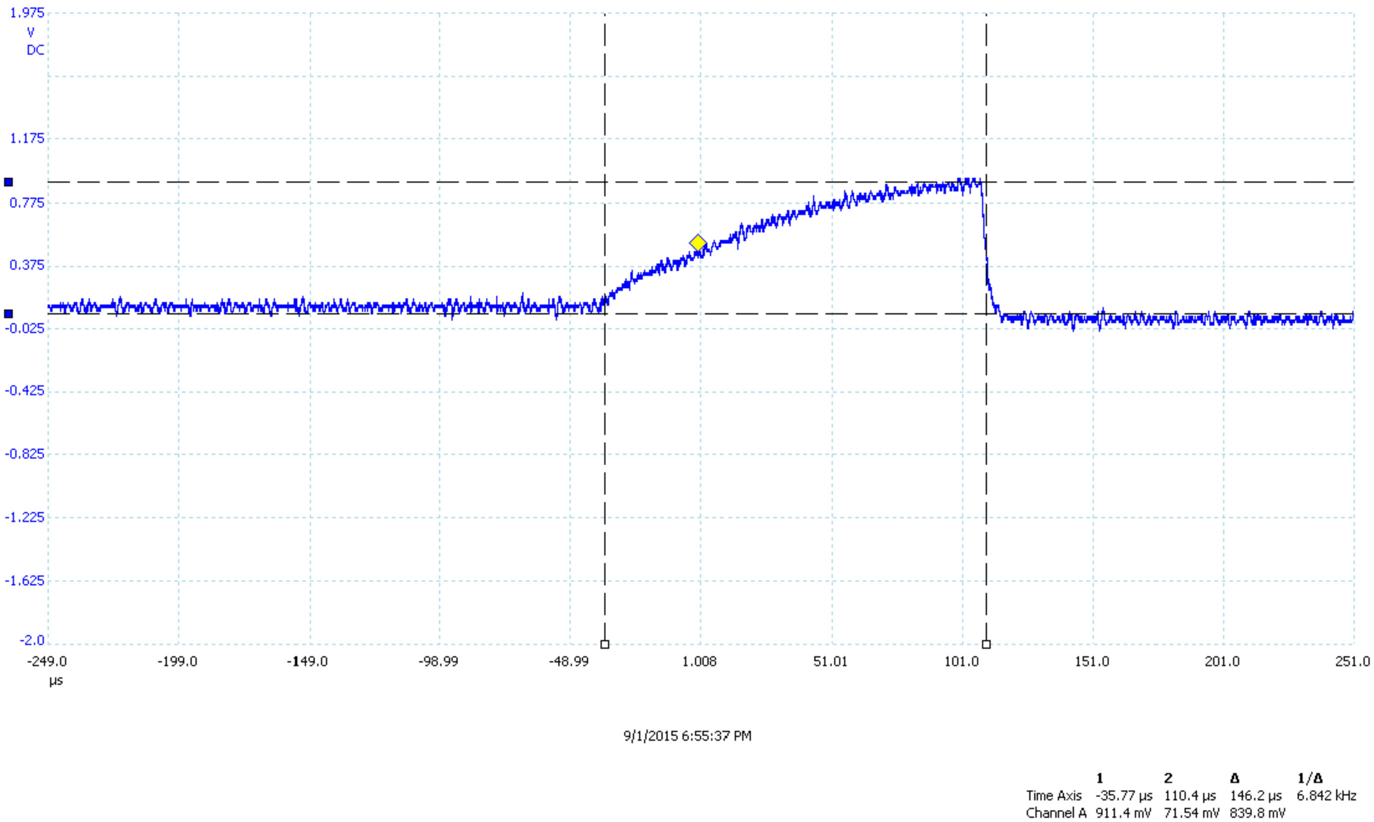
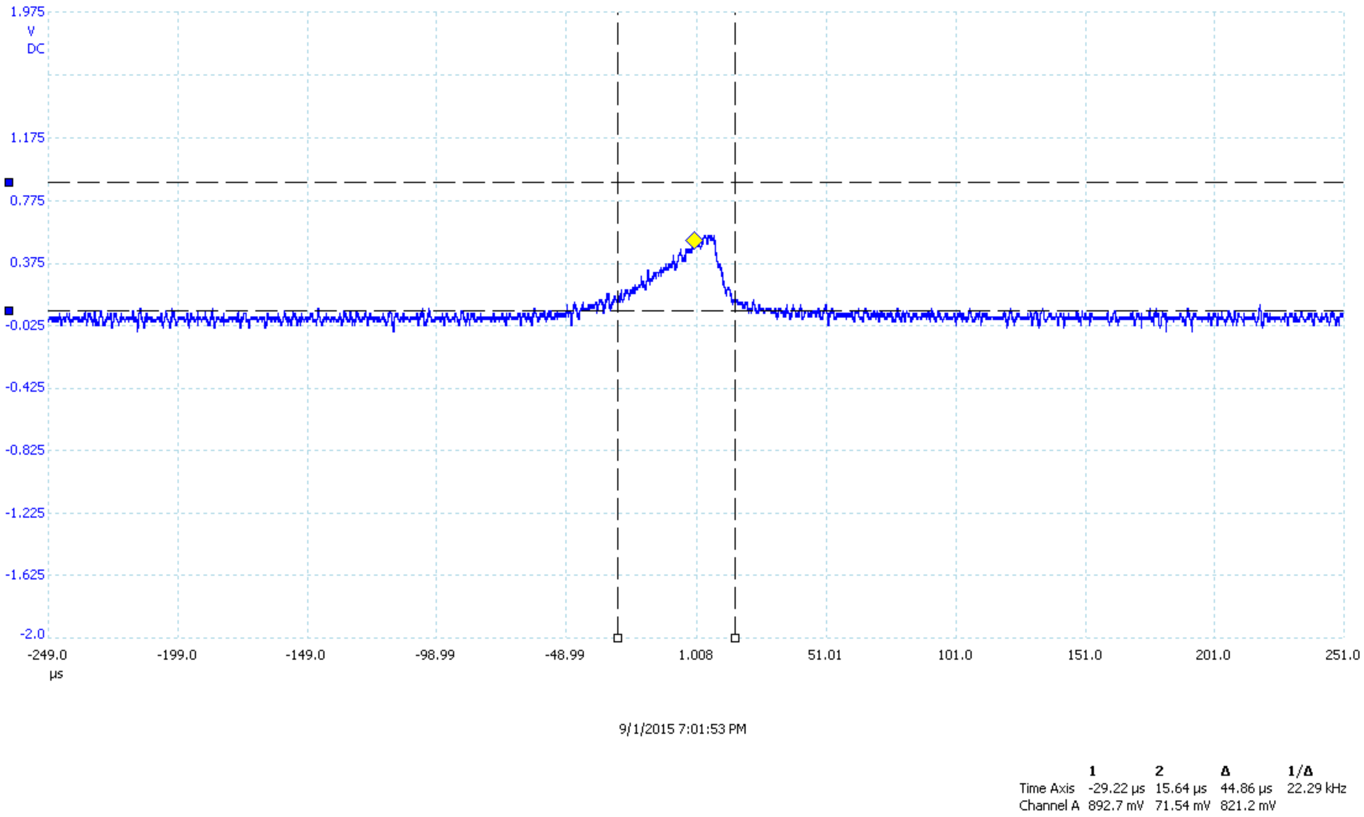


FIGURE B-18. GCU waveform example 3.



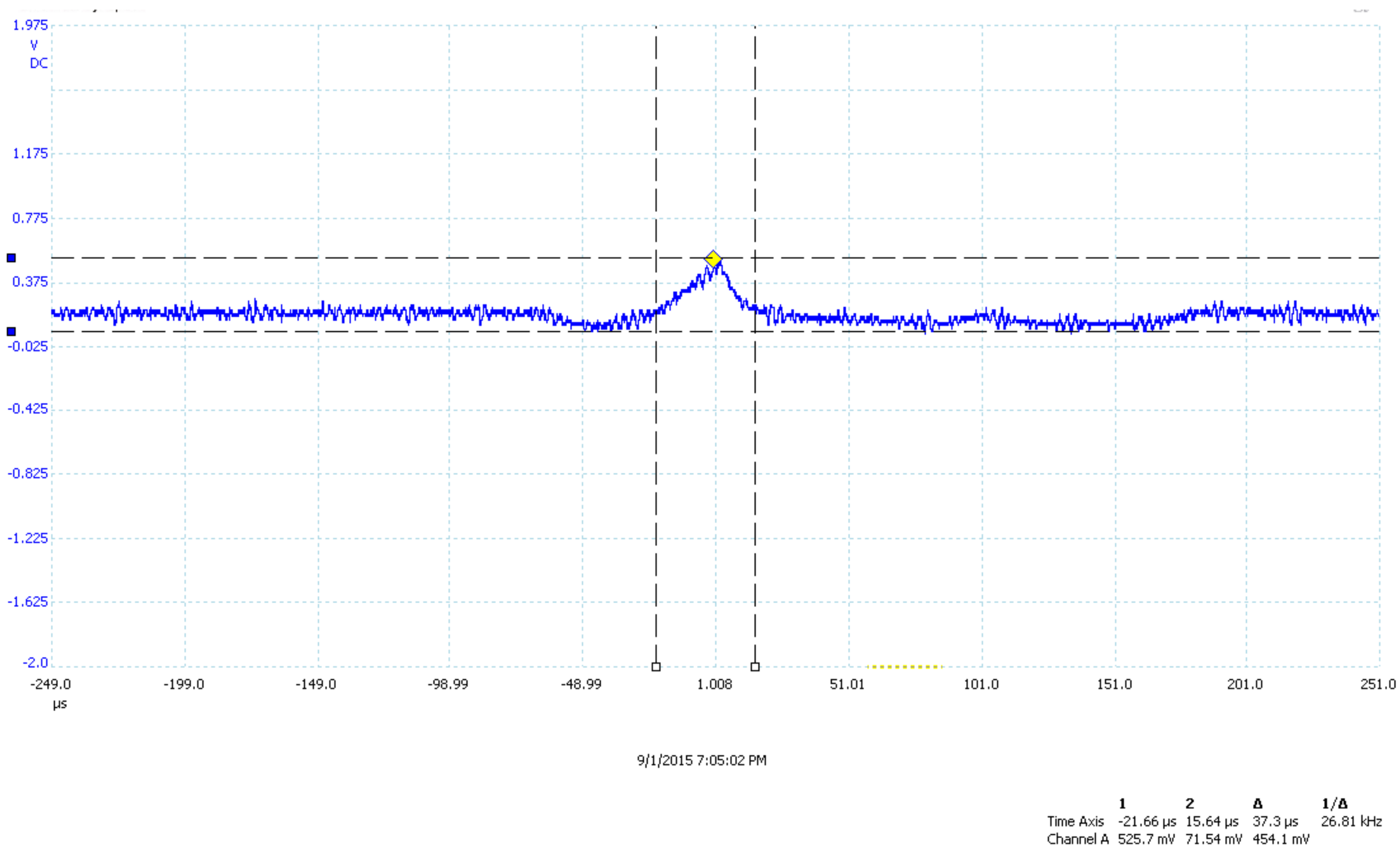
	1	2	Δ	1/Δ
Time Axis	-35.77 µs	110.4 µs	146.2 µs	6.842 kHz
Channel A	911.4 mV	71.54 mV	839.8 mV	

FIGURE B-19. GCU waveform example 4.



	1	2	Δ	1/Δ
Time Axis	-29.22 µs	15.64 µs	44.86 µs	22.29 kHz
Channel A	892.7 mV	71.54 mV	821.2 mV	

FIGURE B-20. GCU waveform example 5.



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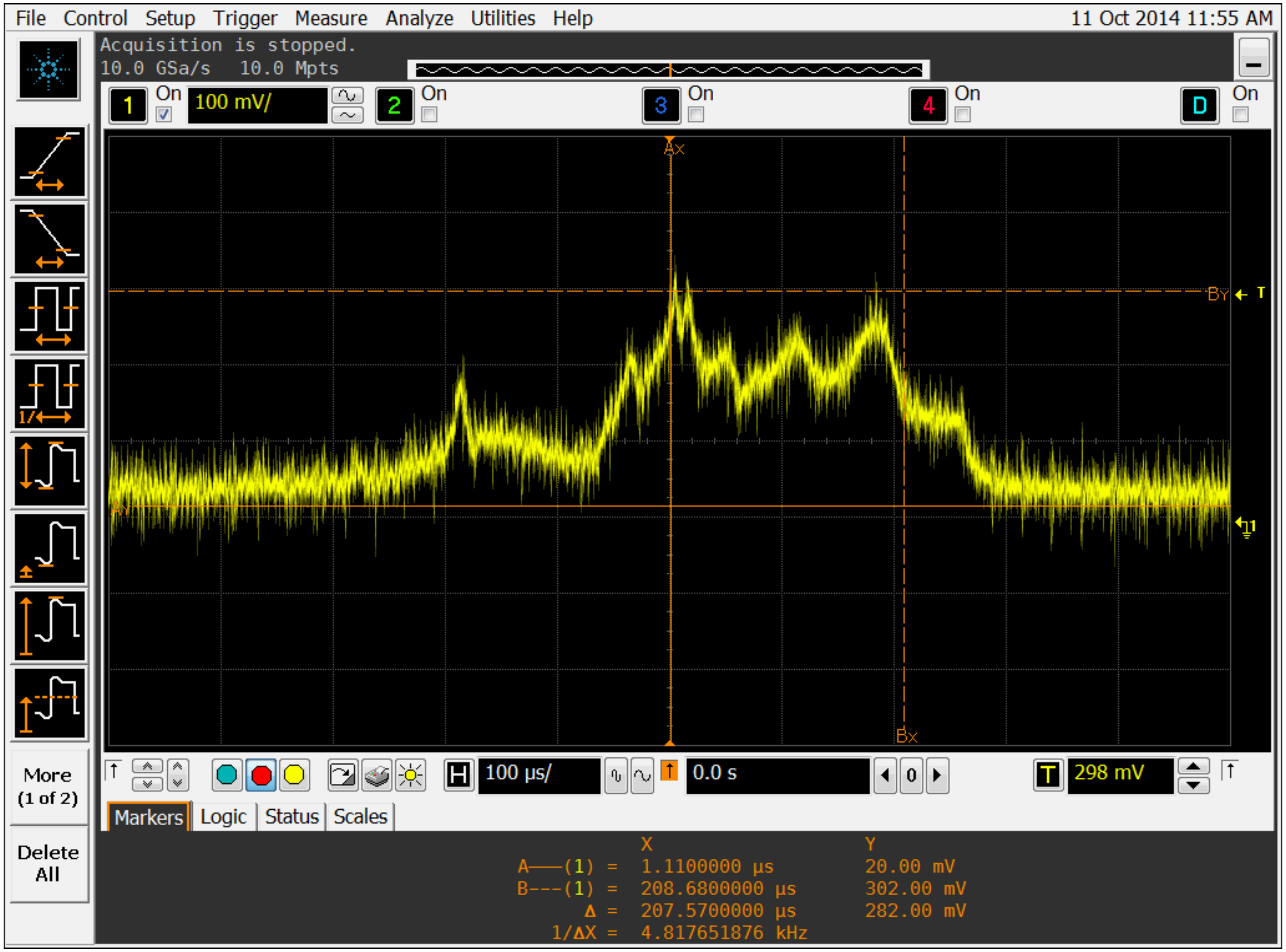
	1	2	Δ	1/Δ
Time Axis	-21.66 µs	15.64 µs	37.3 µs	26.81 kHz
Channel A	525.7 mV	71.54 mV	454.1 mV	

FIGURE B-21. GCU waveform example 6.

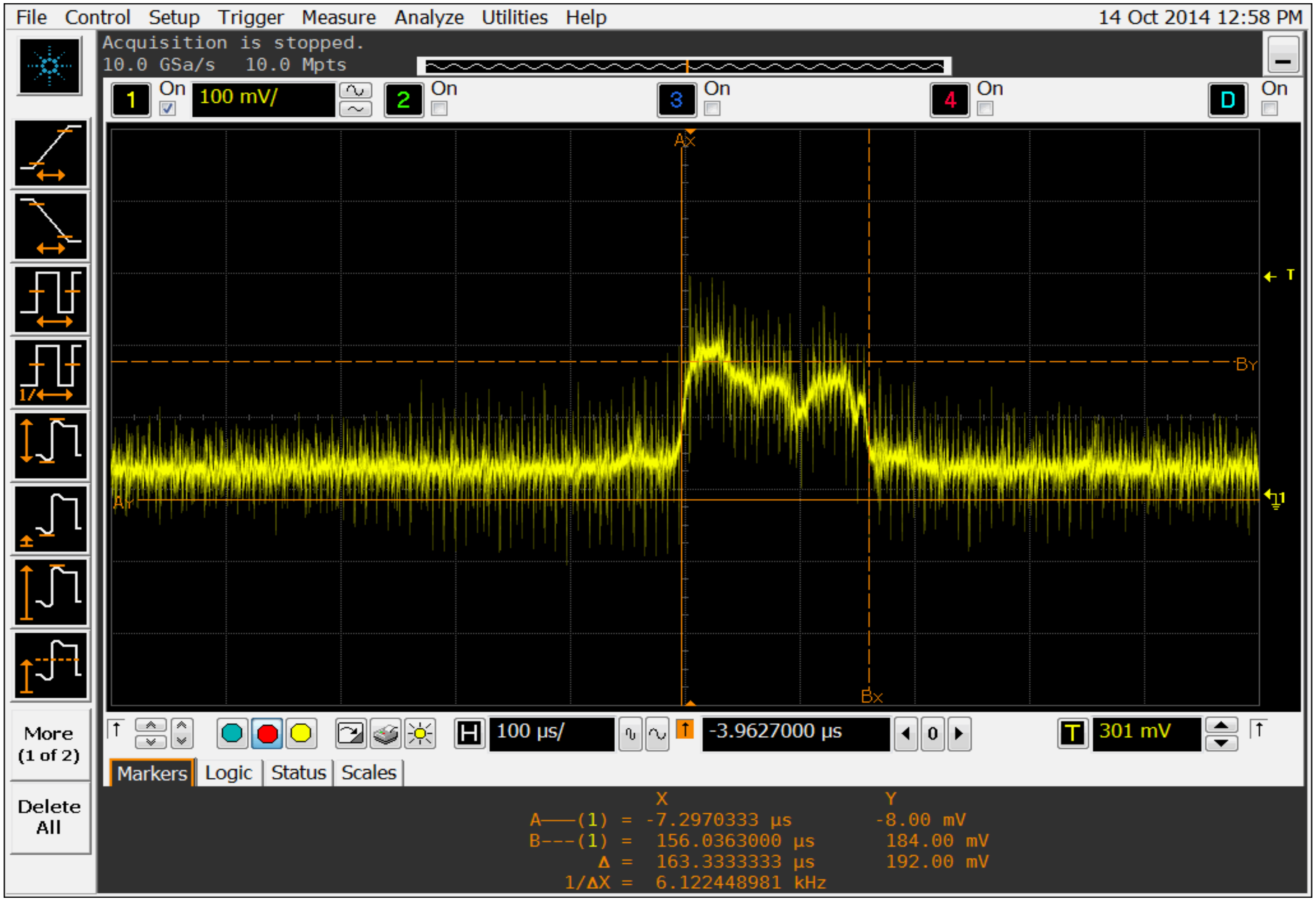
B.6 AN/APG-68 radar system programmable signal processor (PSP) waveform examples. Figures B-22 through B-26 are examples of waveforms taken from an AN/APG-68 Radar PSP. These intermittent faults were detected by Intermittent Fault Diagnostic Equipment and the waveforms were captured on an oscilloscope. All of the waveforms were detected on the same pin within the PSP and demonstrate the same intermittent event at different durations. Again as was seen in F/A-18 GCU (see B.5) example, this illustrates the importance of testing all circuits simultaneously. Figures B-22 through B-26 also demonstrate that intermittent faults do not follow a specific pattern from minute to minute during testing, which is one reason that intermittent faults again are difficult to capture and detect. These waveforms are provided only as examples. Waveform duration, amplitude and shape will vary depending on the piece of equipment and the nature of the intermittent fault (fatigue fracture, cold solder joint, poor crimp, etc.).



```
Acquisition is stopped.
10.0 GSa/s   10.0 Mpts
```

```
                     X                        Y
    A——(1) =   1.1100000 µs         20.00 mV
    B---(1) =   208.6800000 µs       302.00 mV
          Δ =   207.5700000 µs       282.00 mV
       1/ΔX =   4.817651876 kHz
```

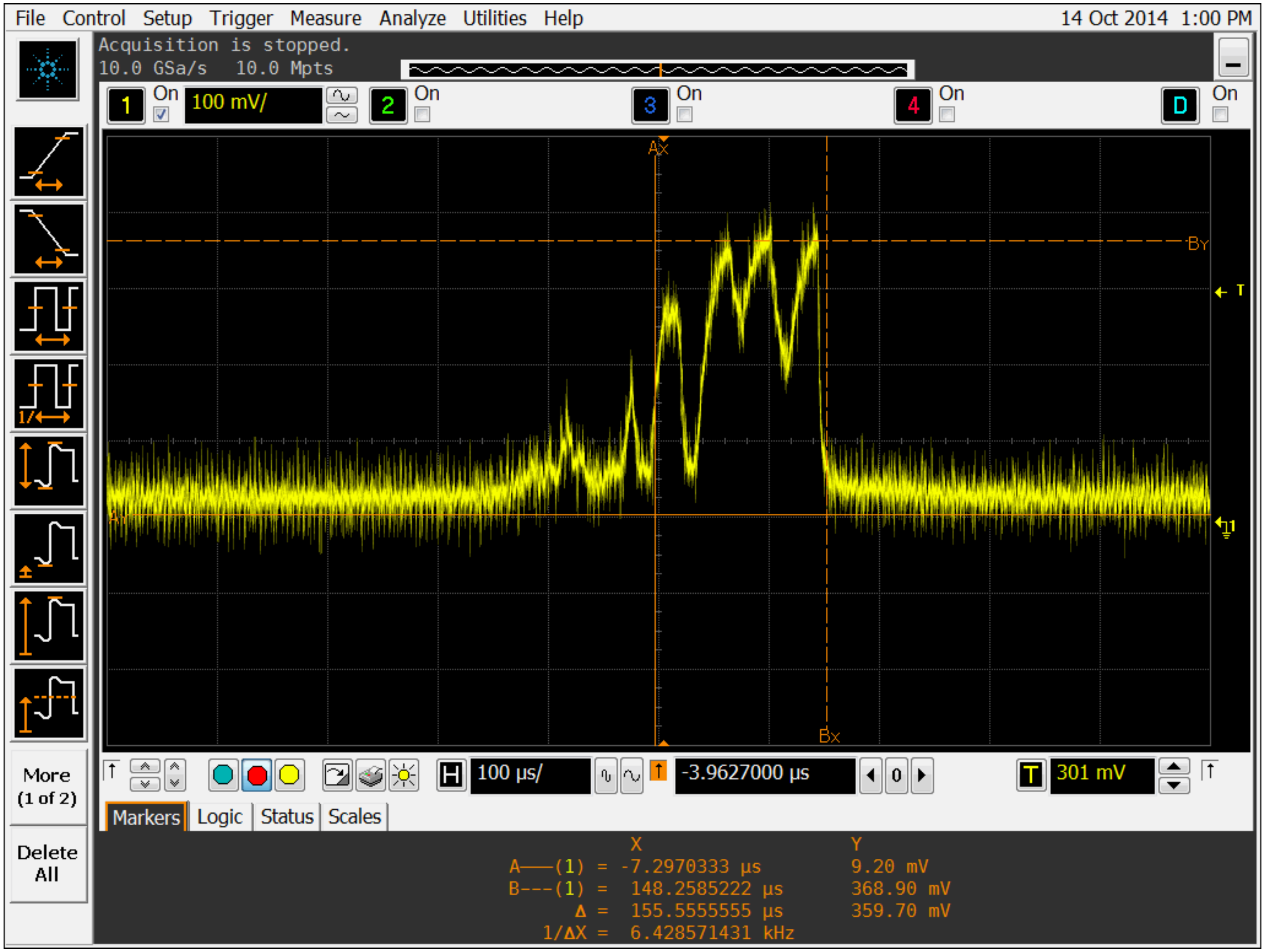
FIGURE B-22. PSP intermittent.
Duration approximately 207 microseconds



```
Acquisition is stopped.
10.0 GSa/s   10.0 Mpts
```

```
                      X                       Y
A——(1) = -7.2970333 µs          -8.00 mV
B---(1) =  156.0363000 µs        184.00 mV
     Δ =  163.3333333 µs        192.00 mV
  1/ΔX =  6.122448981 kHz
```

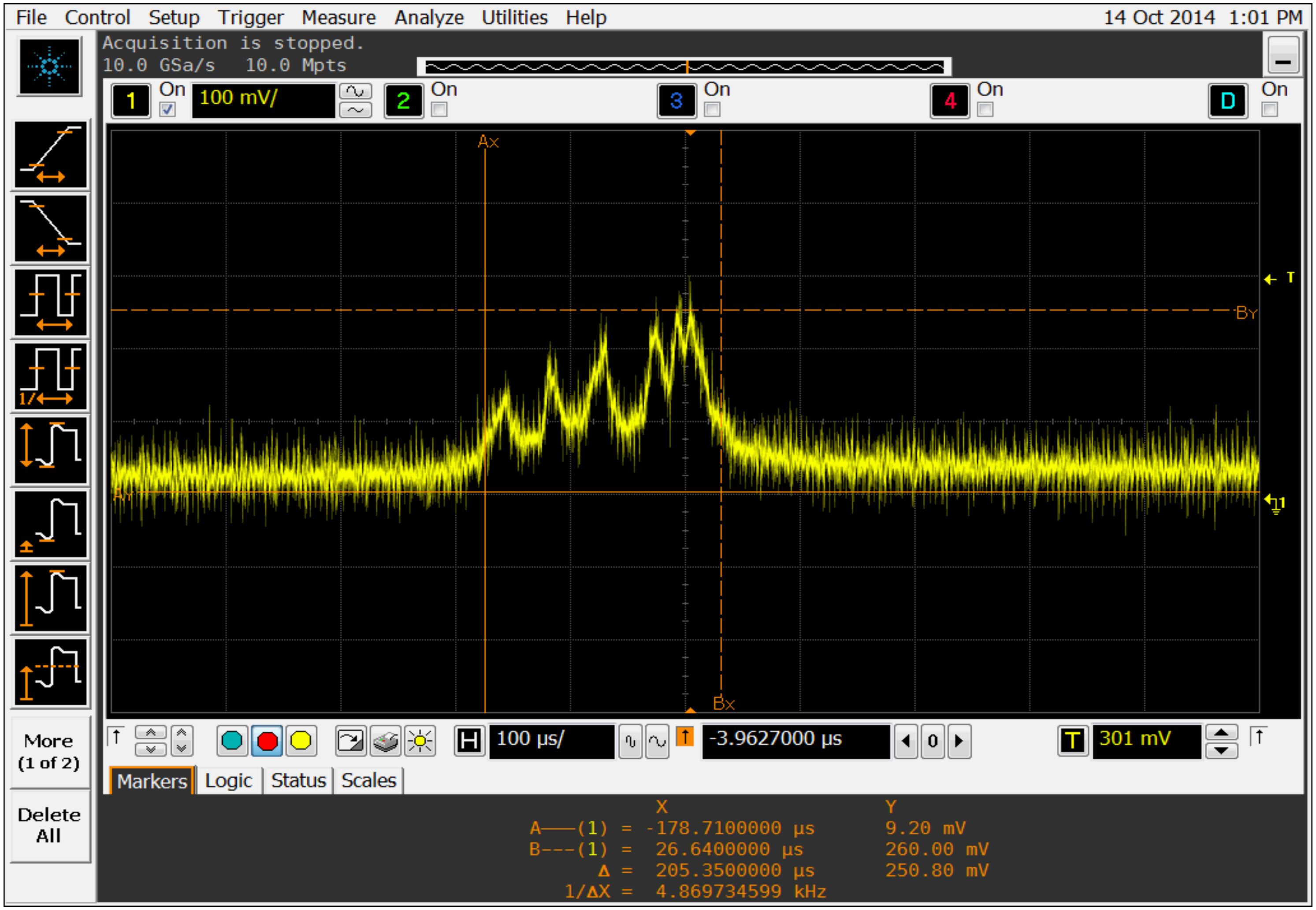
FIGURE B-23. PSP intermittent.
Duration approximately 163 microseconds



```
Acquisition is stopped.
10.0 GSa/s   10.0 Mpts
```

```
                    X                       Y
    A——(1) = -7.2970333 µs          9.20 mV
    B---(1) =  148.2585222 µs        368.90 mV
         Δ =  155.5555555 µs        359.70 mV
      1/ΔX =  6.428571431 kHz
```

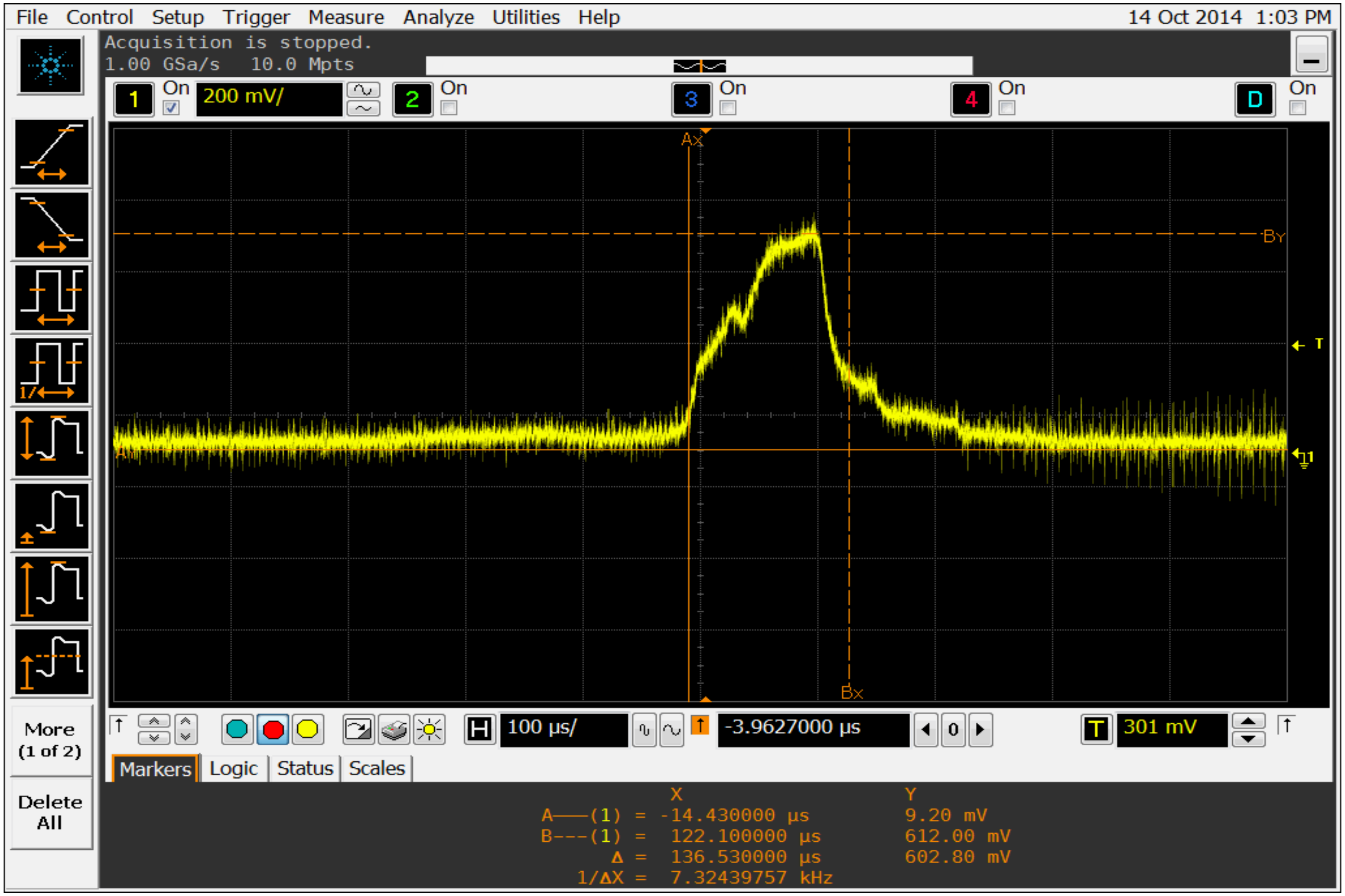
FIGURE B-24. PSP intermittent.
Duration approximately 155 microseconds



```
Acquisition is stopped.
10.0 GSa/s   10.0 Mpts
```

```
                    X                   Y
A——(1) = -178.7100000 µs      9.20 mV
B---(1) =  26.6400000 µs    260.00 mV
     Δ =  205.3500000 µs    250.80 mV
  1/ΔX =   4.869734599 kHz
```

FIGURE B-25. PSP intermittent.
Duration approximately 205 microseconds



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Acquisition is stopped.
1.00 GSa/s 10.0 Mpts

200 mV/

100 µs/

-3.9627000 µs

0

301 mV

```
              X                   Y
A——(1) = -14.430000 µs        9.20 mV
B---(1) =  122.100000 µs      612.00 mV
      Δ =  136.530000 µs      602.80 mV
   1/ΔX =  7.32439757 kHz
```

FIGURE B-26 .PSP intermittent.
Duration approximately 136 microseconds

CONCLUDING MATERIAL

Custodians:
Army - MI
Navy - AS
Air Force - 85

Review activities:
Army - AV
Air Force - 99

Preparing activity:
Navy – AS
Project 6625-2017-002

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