Download and Analysis of Four Actuator IO Process (AIOP) Modules from Houma, LA Agusta AW139 Accident Aircraft Registration N385RH

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Approved by: _____

Jim Allen
Product Integrity

NTSB Identification: CEN13LA025
Accident occurred October 22, 2103 near Houma, LA
Aircraft: Agusta AW139, Registration: N385RH

Actuator IO Processor (AIOP) Investigation

Purpose:
This report, prepared on December 5, 2013 by Honeywell Aerospace, presents the findings of testing and examination conducted on 4 Actuator Input/Output Processor (AIOP) circuit cards used in the Primus EPIC system installed in an Agusta AW139. The investigation took place at the Honeywell Deer Valley facility (21111 N. 19th Ave) in Phoenix, Arizona, on December 3rd and 4th, 2013.

The inspection was conducted at the request of and under the cognizance of the National Transportation Safety Board (NTSB).

Attendees:
- Pam Sullivan – NTSB
- John Conrad – ERA Helicopters
- Jay Eller – Honeywell
- Dennis Hone – Honeywell
- Steve Yarborough – Honeywell
- Vathana Thirakul – Honeywell
- William Yee – Honeywell
- Dean Wilkens – Honeywell
- Robert Helmbrecht - Honeywell

Background:
The NTSB contacted Honeywell to help with this investigation as Honeywell was the manufacturer of the AIOP modules used in the Honeywell manufactured Primus EPIC system.

The AIOP modules were shipped to Honeywell by the NTSB. Upon arrival, the subject modules were secured, unopened, in a locked storage area until the AIOP testing which occurred in Phoenix, AZ between December 3, 2013 and December 4, 2013. After the testing in Phoenix, AZ, the units were packaged in their original shipping box and returned to Honeywell's secured and locked storage area.

Summary:
No pre-existing conditions were found that would have prevented proper operation of the AIOP modules and the AFCS functionality in the Primus EPIC system.

Process of the Investigation:

The AIOP units were transported from the secured and locked storage area at Honeywell's, Phoenix Sky Harbor facility to the Deer Valley facility in four separate shipping boxes, one unit per box.

The following general process was used to inspect, evaluate, and test each unit. Details of the investigation of each unit will be provided in the following sections.

1. Remove units from shipping boxes and document their physical appearance.
2. Install the unit into an engineering bench and download the following information (all files downloaded were in binary format):
    a. Functional software
    b. Boot software
    c. Fault history
3. Run the fault history file through a separate software program in order to decipher the binary file into a spreadsheet format for review by the investigative team.
4. Install all 4 units on a system bench, already loaded with the -107 Phase 5 software.
5. Verify the units are powered up and all processes are running fresh and valid.
6. Exercise the AFCS functionality (AP On and SAS engaged) to ensure the units are functioning and responding appropriately and the AFCS can stabilize after an upset. Perform this in level flight as well as in a hoover.
7. After system bench testing, re-install the units on the AFCS engineering bench and re-download and analyze the fault data within each unit.
8. Run a full Automated Acceptance Test Procedure (ATP) on each module and review the results for any failure conditions.
9. Re-evaluate if any tests need to be re-performed.

Investigation and Findings:

- The units were packaged in standard EPIC module shipping boxes. (Figure 1 through Figure 8)
- The shipping boxes appeared to be unopened and undamaged.
- After opening the shipping boxes, the AIOPs were found packaged within a standard Electro Static Discharge (ESD) safe bag. (Figure 9 through Figure 12)
- The AIOP modules appeared to be undamaged. (Figure 13 through Figure 20)
- One of the AIOP data plates identified the following information: (Figure 21 and Figure 22)
    - P/N: 7029194-1901
    - S/N: 07010735
    - Mod Status: A through L
- Another of the AIOP data plates identified the following information: (Figure 23 and Figure 24)
    - P/N: 7029194-1901
    - S/N: 05100394

  - Mod Status: A through L
- Another of the AIOP data plates identified the following information: (Figure 25 and Figure 26)
  - P/N: 7029194-1901
  - S/N: 07020813
  - Mod Status: A through L
- Another of the AIOP data plates identified the following information: (Figure 27 and Figure 28)
  - P/N: 7029194-1901
  - S/N: 06080596
  - Mod Status: A through L
- Each unit was connected to the AFCS engineering test bench (Figure 29). Communication was established with the test bench interface and the functional software, boot software, and fault history were successfully downloaded from each unit.
- Each unit's fault history binary file was successfully converted to spreadsheet format with the exception of S/N 06080596. See separate CSV files for fault history data. The S/N 06080596 fault history file appeared to be corrupted and was unable to be deciphered.
- An analysis of the fault history files was performed. While faults were logged before the accident, on the day of the accident, and after the accident none were felt to have any impact on the accident scenario. The faults were identified as nuisance faults clearing shortly after the startup sequence as evidenced by the "time since startup" of between 0 to 4 minutes when the faults occurred and were recorded.
  - Note: The EPIC system contains an internal clock which is used by all of the modules. These modules, such as the AIOP modules, use this time when reporting faults in the fault logs. The team was able to determine that the EPIC system internal clock was synced with the GPS time and was reporting Zulu (GMT) time in the logs. At the time of the accident, Louisiana was 5 hours behind GMT. Therefore, 5 hours was subtracted from the reported times in the logs in order to align with the accident location local time.
- An important feature about the Primus EPIC system is that each AIOP has a specific location within the system. The location of the units as removed from the accident aircraft was not known to the investigative team assembled during this investigation. As such, a read of the log files was used in order to try to determine the location of each unit. The team was unable to definitively determine the location from the log files.
  - Note: The Primus EPIC system has a software function called the Aircraft Configuration Management System (ACMS) which is always running when the system is powered. Its purpose is to monitor the configuration of the system (software installed, location of modules installed, etc) and to verify that everything is in the correct location and running the correct version of software. If one of the modules is identified as being in the wrong location or has the wrong software installed, the ACMS function will automatically shut down the offending module, not allowing it to function within the system until the issue is corrected and a power cycle is reapplied.

- The units were then installed into the system bench (Figure 30, red arrows). The system bench was preloaded with the Agusta AW139 107 Phase 5 TSO certified software to match the accident aircraft. The accident units contained the software from the accident hardware (as received) and were not reloaded for this testing (IE: They were run as received). Initially upon power-up, the unit in MAU1 slot 7/8 and MAU2 slot 7/8 were shut down by the ACMS system. After some analysis, the team determined that these two modules needed to be swapped with one another. After swapping the offending units and repowering the bench, all units powered up and were determined to be "fresh and valid" on the data bus.
- With the system bench aircraft simulation model running, the helicopter was placed in level flight with a forward speed of approximately 80 knots and an altitude of approximately 2100 feet.
- The autopilot and Stability Augmentation System (SAS) were engaged. The system held attitude appropriately.
- While flying, the SAS was turned off and the attitude of the aircraft would slowly roll to one side, indicating SAS was not operating to stabilize the aircraft (as it was disconnected).
- Re-engaging SAS, the flight control system would properly re-capture the appropriate attitude and continue level flight.
- With SAS engaged, upsets were introduced to the system by making abrupt input changes to the trim actuators as if cyclic inputs were being made. The system bench showed attitude changes and a slow damping/settling back to controlled level flight as expected.
- With a significant cyclic upset/input, the system was able to "runaway" and not have the attitudes recaptured. The team felt that this input that created the uncontrollable FCS response was greater than what could have been generated in the aircraft and therefore was not deemed a failure.
- The system was then brought to a hover condition and the same tests as above were repeated. The FCS was able to capture and control the aircraft back to level flight in each of the tests while in the hover condition. Even the test with the large upset input was successfully passed in that the system was able to recapture and control a level hover.
- The units were then removed from the system bench, brought back to the engineering bench, and the fault logs downloaded again for analysis. Downloading and deciphering of the fault logs was performed as previously mentioned.
- An analysis of the fault history files was performed after the system bench testing. While faults were logged during the system bench testing, all were identified to be associated with bench related issues, simulation issues, or nuisance faults.
- A full Automated Acceptance Test Procedure (ATP) was run on each module. All modules passed ATP with the exception of S/N 07020813 which failed one test. An analysis of the failure led the team to identify a damaged diode (Figure 31) on the circuit card that is used in a 3.3V pull down circuit. This circuit is only used for ATP testing and has no impact on the functionality of the software.
- As a final check, the S/N 07020813 was reloaded with the TSO'd functional software and placed back onto the system bench. It powered up properly and behaved as expected.
- After ATP was completed, the fault history file from S/N 06080596 was downloaded and properly deciphered. This supported the assertion of a previously corrupted file due to

the fact that the ATP test wipes the module's memory locations clean and recreates a new fault history file which was then readable after ATP testing.

Conclusion:

No pre-existing conditions were found that would have prevented proper operation of the AIOP modules and the AFCS functionality in the Primus EPIC system.

Figure 1. S/N 07010735 Shipping Box as Received

Figure 2. S/N 07010735 Shipping Box as Received

Figure 3. S/N 05100394 Shipping Box as Received

Figure 4. S/N 05100394 Shipping Box as Received

Figure 5. S/N 07020813 Shipping Box as Received

Figure 6. S/N 07020813 Shipping Box as Received

Figure 7. S/N 06080596 Shipping Box as Received

Figure 8. S/N 06080596 Shipping Box as Received

Figure 9. S/N 07010735 Within It's ESD Bag as Received

Figure 10. S/N 05100394 Within It's ESD Bag as Received

Figure 11. S/N 07020813 Within It's ESD Bag as Received

Figure 12. S/N 06080596 Within It's ESD Bag as Received

Figure 13. S/N 07010735 After Removal From ESD Bag

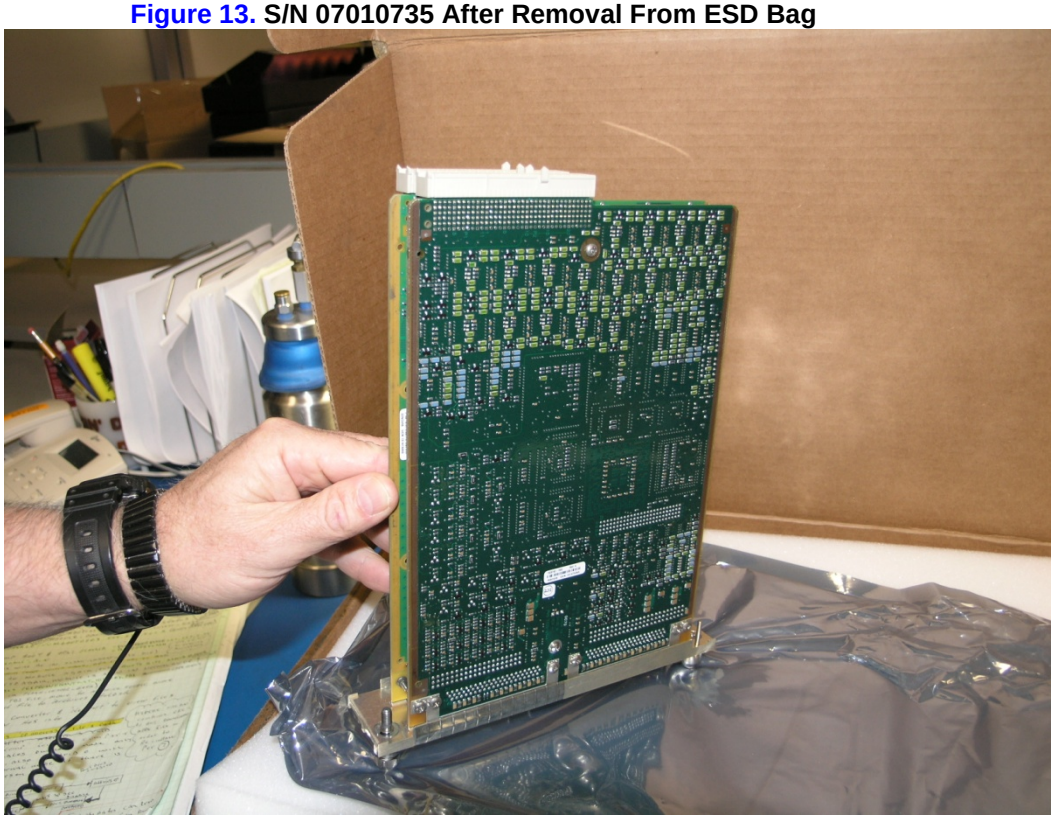

Figure 14. S/N 07010735 After Removal From ESD Bag

Figure 15. S/N 05100394 After Removal From ESD Bag

Figure 16. S/N 05100394 After Removal From ESD Bag

Figure 17. S/N 07020813 After Removal From ESD Bag

Figure 18. S/N 07020813 After Removal From ESD Bag

Figure 19. S/N 06080596 After Removal From ESD Bag

Figure 20. S/N 06080596 After Removal From ESD Bag

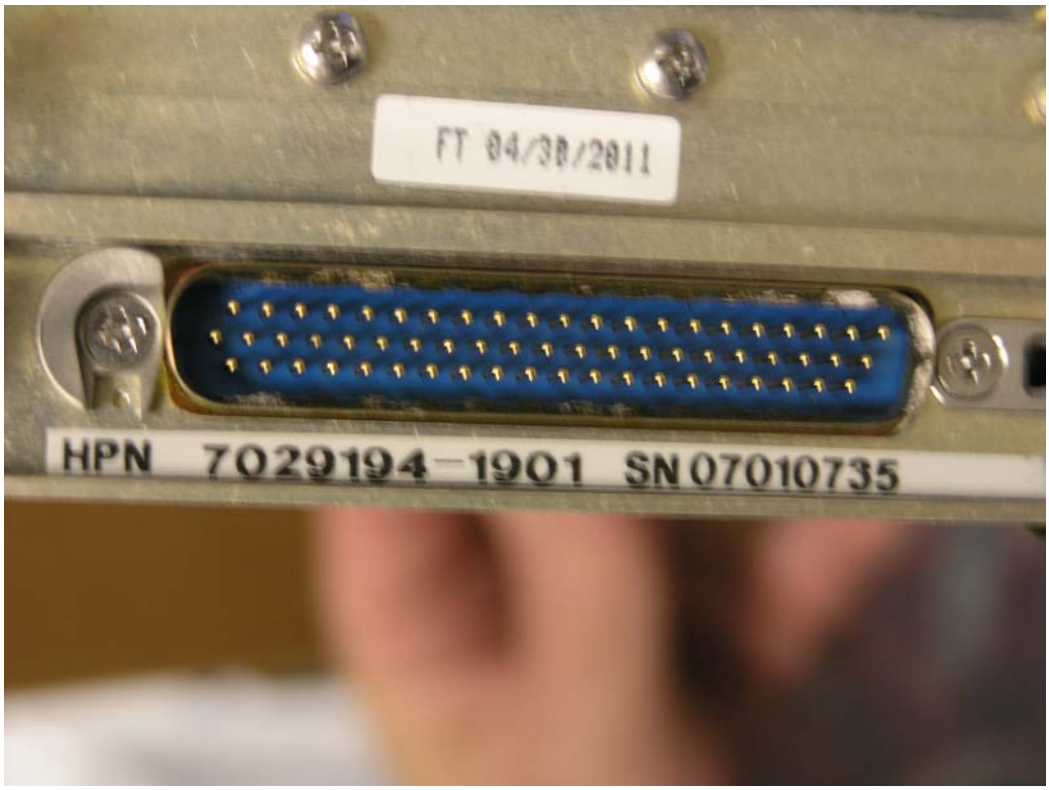

Figure 21. S/N 07010735 Data Plate Information

Figure 22. S/N 07010735 Data Plate Information

Figure 23. S/N 05100394 Data Plate Information

Figure 24. S/N 05100394 Data Plate Information

Figure 25. S/N 07020813 Data Plate Information

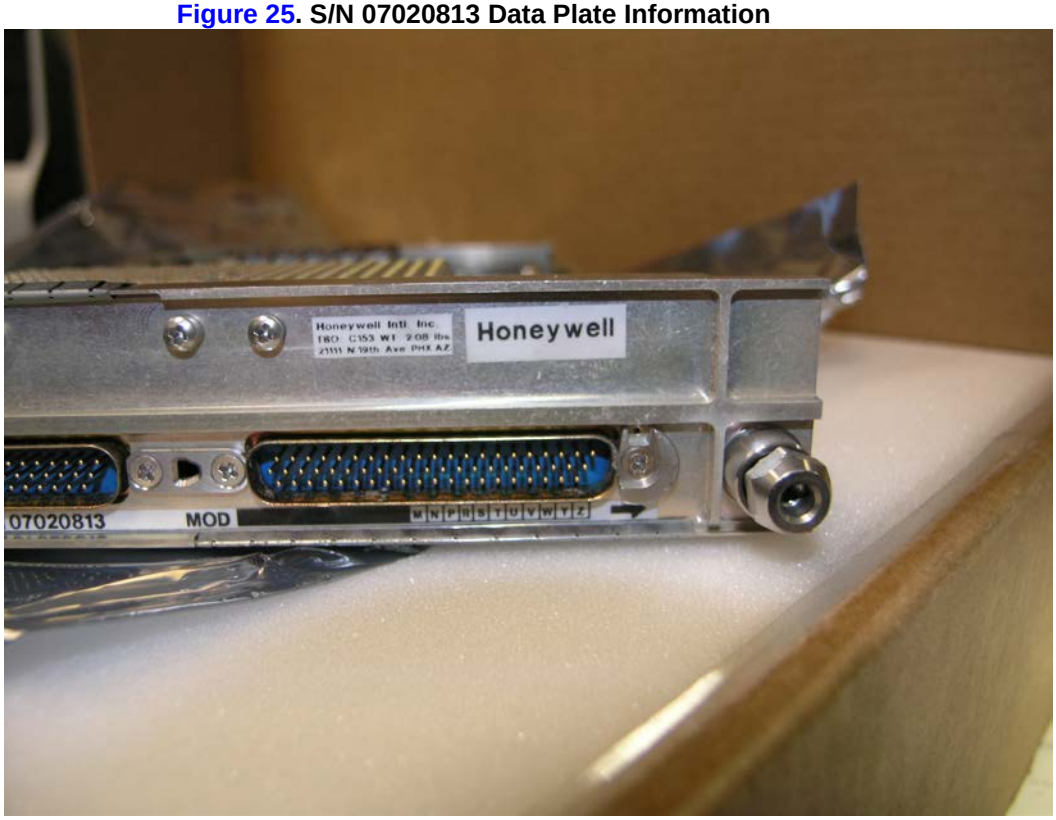

Figure 26. S/N 07020813 Data Plate Information

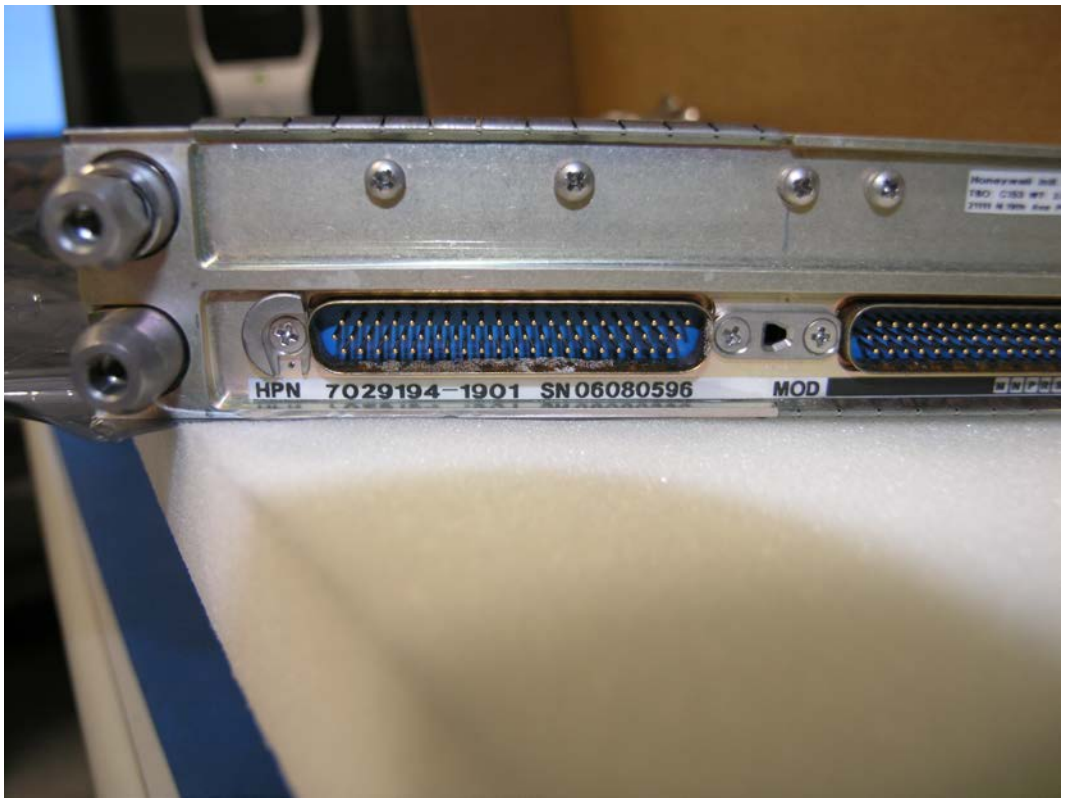

Figure 27. S/N 06080596 Data Plate Information

Figure 28. S/N 06080596 Data Plate Information

Figure 29. Installation on AFCS Engineering Bench

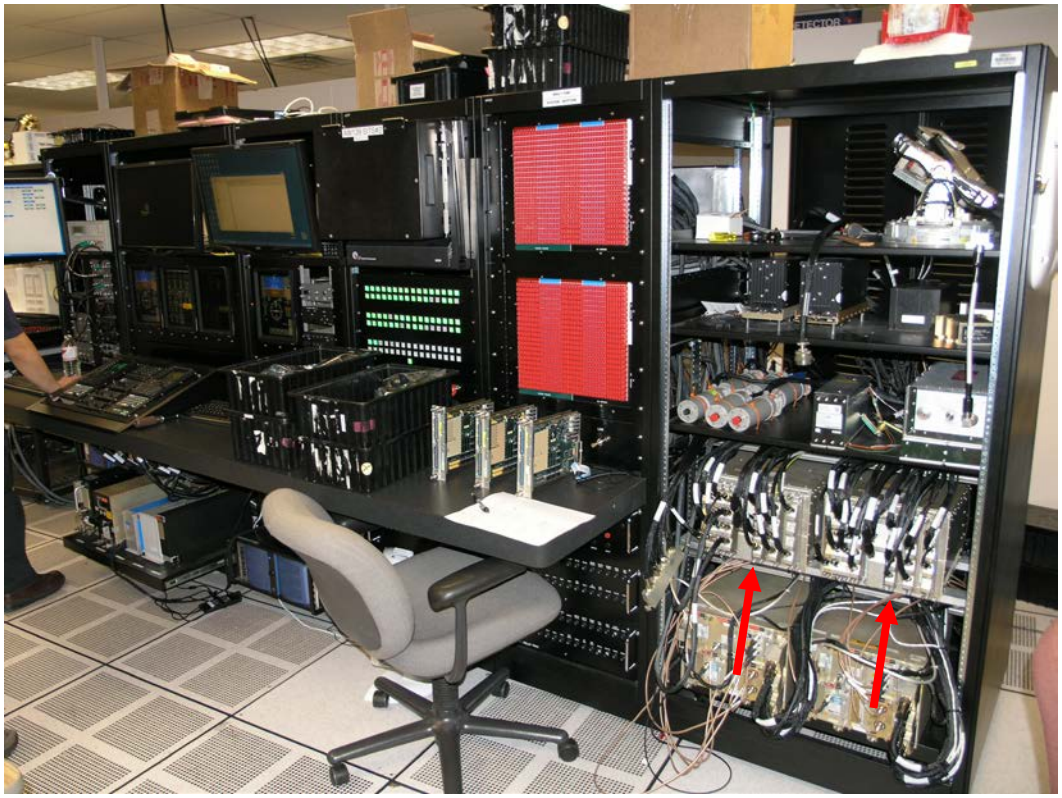

Figure 30. System Bench

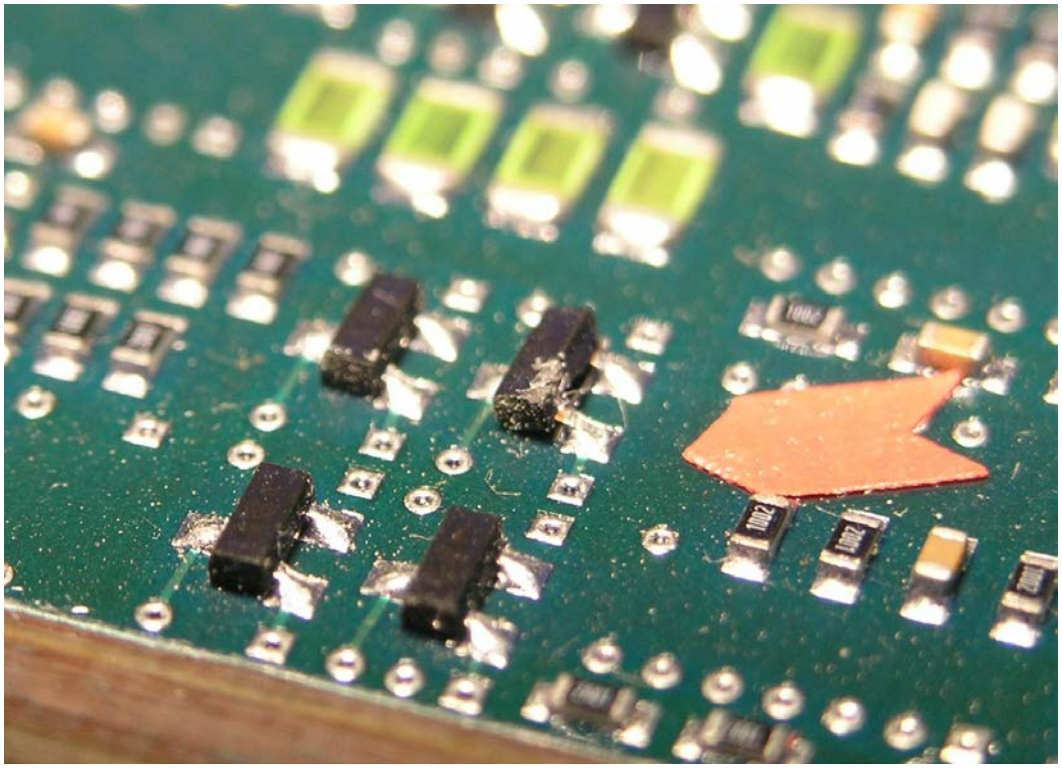

Figure 31. SN 07020813 With Damaged Diode