PFR-096 Title: EFI Y Current Monitor Unstable

Assembly : EFI	**SubAssembly : Y-Axis**	
Component : Unknown	**Units Affected:**	**Units fixed:**
Originator: John Bonnell	X 0 0 0 0 0	X 0 0 0 0 0
Organization: UCBSSL	**Date: 16 Sep 2005**	
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Failure Occurred During (Check one √)

X Functional test □ Qualification test □ S/C Integration □ Launch operations □ Other (Flight Assy)

Environment when failure occurred:

XAmbient	□ Vibration	□ Shock	□ Acoustic
□ Thermal	□ Vacuum	□ Thermal-Vacuum	□ EMI/EMC

Problem Description

(In this section it is important to document the specific symptoms which exhibited the problem. In the event we see it happen again, we would like to know as much as possible.)

The Y-axis +/- 10-volt floating supply current monitor (IMON_EFI_Y) for the THEMIS FM1 electric field instrument was observed to drift with time more than the X- and Z-axis IMONs during the post-TVAC Suite CPT (16 Sept 2006). This test was performed at ambient pressure and room temperature (approx. 25 C), and the Y-axis IMON recorded an increase in current consumption of approximately 1 mA over an 80 minute period, while the X- and Z-axis IMONs varied by less than 0.1 mA. Since the typical current consumption by the EFI preamp at room temperature is 2 to 3 mA per supply (+10 and –10 volts), this instability in current consumption was deemed significant, and an investigation opened to determine the source of the instability, and possible corrective action.

Analyses Performed to Determine Cause

(How do we know how the failure happened? Was it a bad part, bad handling, what?)

The X- and Y-axis spin plane boom (SPB) units were swapped on the FM1 Suite, and the unstable current consumption was found to follow the SPBs originally mounted on the Y-axis, indicating that the source of the instability most likely lay in the EFI preamps, rather than the low-voltage power supply (LVPS) in the THEMIS IDPU.

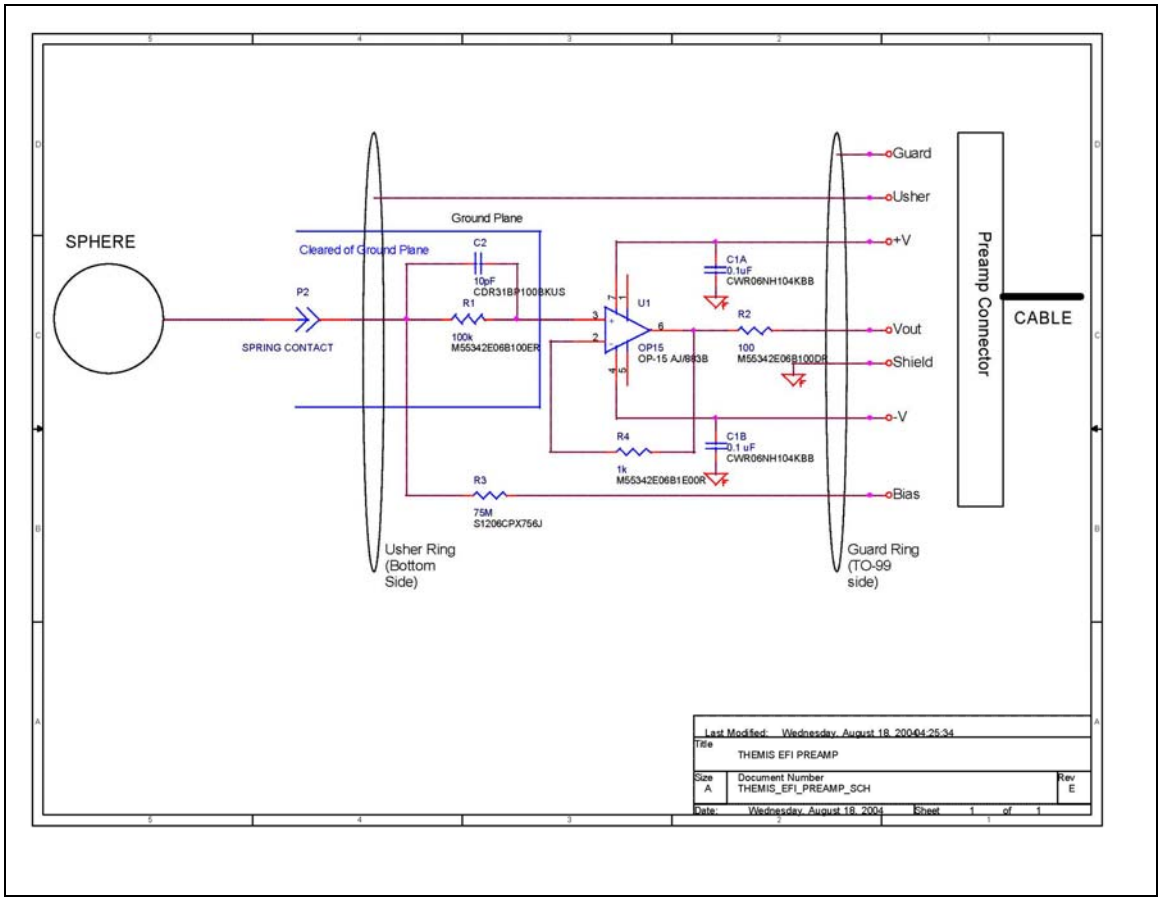
Power supply turn-on/turn-off sequence tests were performed on all three of the floating power supplies using passive loads (33-kohm || 0.1-uF to floating ground on both P10VF and M10VF supplies) on FM1 to determine if there were any time during the start-up or shut-down sequences where the EFI preamps could be exposed to out-of-specification voltages (e.g. reversed polarity or over-voltage conditions); no evidence of such anomalies were found, and the power supplies were observed to start up, maintain proper polarity, and achieve in-spec voltages (10 +/- 0.5 volts) according to design and past experience.

The EFI preamp boards on the two affected SPBs (SPB-901 and –902, S/N 023 and 035, respectively) were removed, and Flight spares integrated in their place (S/N 022 and 033, respectively). SPB-901 and –902 were reintegrated to the FM1 suite, and a one-hour current consumption test was performed. The replacement units were in-family during this test, and showed the stable (less than 0.1-mA of variation over a 90-minute test interval) evidenced by the other two axes of units.

In parallel with the preamp replacement on the affected SPB units, the suspect preamp boards (S/N 023 and 035) were subjected to long-duration current consumption tests on the bench in order to characterize the problem, and isolate the possible sources of the unstable current consumption.

In order to more clearly describe the testing and rework done on the suspect preamp boards, we have included a copy of the as-built Flight schematic for the THEMIS EFI preamp in Figure 1.

Figure 1: Schematic of THEMIS EFI Flight preamp.



In flight configuration, the EFI preamp is located approx. 25 meters away from the THEMIS spacecraft on a radial wire boom. The preamp input couples to the ambient medium through a spherical electrode, and the preamp output drives a 25-meter coaxial cable that returns the signal to the THEMIS IDPU for analog and digital signal processing.

The EFI preamp circuit is essentially a high-input-impedance, unit-gain amplifier circuit used to buffer between the high-source-impedance voltage fluctuations picked up by the EFI antenna element (marked SPHERE in the schematic) and the significant, primarily capacitive load (30-ohm series resistance, approx. 1700-pF capacitance to analog ground) of the coaxial antenna cable. Power (+/- 10-volt analog, with floating ground) is supplied to the unit via the +V, –V, and SHIELD connections. C1A and C1B are 0.1-uf, polarized tantalum capacitors included as power supply noise bypass capacitors.

The preamp uses the Analog Devices OP-15 operational amplifier, with ESD input protection and bypassing provided by R1 and C2, and output stabilization under the significant capacitive load is provided by R2. R3 is part of a current-biasing circuit for the input electrode, and R4 is a modest (1-kohm) resistor provided to stabilize the feedback path.

Bench tests of the long-duration (3- to 15-hour test runs) current consumption of both suspect preamps were performed using a test setup that monitored both the positive and negative supply current consumptions (auto-logging using Fluke-189 DMMs and an Agilent E3631A Triple-Output DC Supply), and the following results were found (in the following, P10VF is the +10-volt supply, and M10VF is the –10-volt supply):

1. In both tests with both preamps, the current consumption on the M10VF supply was nominal and stable, while that on the P10VF supply increased with time and was somewhat spiky as well.

2. PRE-023 misbehaved most; its P10VF current consumption increased by 0.6 mA over the 3-hour test (from 2.9 mA up to 3.5 mA, or about 20%), and stabilized at around 3.75 mA 7 hours into the 15-hour test. Spikes of a few tenths of a mA lasting for several minutes were also present in the P10VF record.

3. PRE-035 showed similar, but more modest current consumption increases. Over the 3-hour test, its M10VF consumption was stable, and its P10VF consumption increased by 0.2 mA, from 3.2 to 3.4 mA. Its behavior was similar during the 15-hour test, ramping up from 3.2 to 3.4 mA on the P10VF, while the M10vF consumption remained stable. PRE-035 also showed episodes of increased current consumption, with spikes up to 3.5 mA that lasted for several minutes at a time.

On the basis of these results, it was decided to remove and replace individual parts on at least one of the two suspect preamp boards and rerun the current consumption tests on the reworked units in order to localize the source of the unstable current consumption to a particular part on the preamp board. Since the most likely sources of the unstable current consumption were deemed to be the power supply bypass capacitors (C1A, C1B) and the OP-15 itself, those items on PRE-023 were slated for replacement, with the C1A-C1B replacement to occur first. PRE-035 was left untouched to act as a control.

C1A and C1B were replaced on PRE-023, and packaged for possible DPA (see ***Assembly_Repair-Rework_THM_rev4-thm-efi-pre-023-revA.doc*** for details of the rework procedure); the 15-hour current consumption test was run, and it was found that current consumption was nominal and very stable, with less than a 0.01-mA (10-uA) change in current consumption over the test, and no evidence of the sporadic increases in current consumption observed with the original pair of tantalum bypass capacitors in the circuit. Charts showing the current consumption test results are included in Appendix A below.

On the basis of these results, it was deemed that the source of the current consumption instability lay in the original tantalum bypass capacitors, and that those units should be sent out for DPA in order to determine what, if any, physical damage was present on the units, and if such physical damage produce changes in the electrical properties of the capacitors that would lead to the observed unstable current consumption.

Two rounds of differential DPA analysis were performed on C1A and C1B from PRE-023 and a pair of capacitors pulled from the same part lot by RIGA Analytic Lab, Inc. (Analyses #27535 and 27535A). The results of this DPA were discussed informally with a representative of the capacitor manufacturer as well (Doug Twomey at Vishay).This DPA included electrical testing (measurement of leakage resistance); sectioning; X-ray, SEM and photomicrography; composition measurement using X-ray energy dispersion spectroscopy. The DPA and subsequent discussion had the following findings:

1. The affected units did show out-of-spec leakage currents when out of the circuit (3.2 uA at 20 volts for C1A; 15 nA at 20 volts for C1B), with C1A having higher leakage than C1B. The relative magnitudes of leakage current between C1A and C1B were consistent with, but of significantly less magnitude than the variations in in-circuit current consumption observed on the affected units (hundreds of uA); the control units were in spec for the part (2 nA at 20 volts).

2. The affected units showed reduced leakage current (order of magnitude) after soaking in acetone, suggesting that the leakage was due to a superficial leakage path, rather than one passing through the deeper bulk of the tantalum dielectric material.
3. micrographic comparison of the affected and control units found no obvious physical evidence of a leakage path between the two electrodes of the affected capacitor, although apparent differences in the structure of affected and control units could be perceived in the photomicrographs. In particular, the affected units showed evidence of an additional layer of differently-colored material interposed between the epoxy structures surrounding the tantalum stud that forms the anode of the capacitor. Discussion with the Vishay representative did not place any significance on this additional layer, however, and so the possible mechanism for enhanced leakage within the affected units remains unclear.
4. Note that the X-ray energy dispersion results reported in Analysis #27535A suggest that the imposed material in the affected units (the so-called red layer) has a different composition than the surrounding epoxies. Subsequent discussion and reference to VISHAY's "Style 194D/CWR06 Solid Tantalum Capacitor Assembly Process," document suggests that the XED probed one of the nearby layers of the tantalum dielectic slug, rather than the epoxy, and so this apparent compositional different is not significant.

Because no significant differences between the internal physical properties of the affected and control capacitors could be found, the exact cause of the unstable current consumption of the affected units remains unknown at this time.

Since the failure of the first two units, there have been no other observed failures of this type in the entire flight build integrated to-date (FM1 through FM5, 30 units total). As noted below, additional tests have been added to both Suite- and Probe-level integration so as to monitor the population of preamps for this failure.

Corrective Action/ Resolution

(How do we fix the unit? And how do we make sure it doesn't happen again?)
As noted above, the flight spares integrated into the F1 SPBs have performed in-spec and in-family, and so the original fault has been repaired. An additional long-duration current monitor test has been added to the Suite level CPT procedure so as to catch the failure of any other units in the flight build.

It should be noted that the increased current consumption of the affected units had no apparent affect upon the DC or AC functionality of the preamps. The floating supplies themselves can easily handle the increased current demands of the affected units with only a modest (few tenths of a volt) droop in their output. In addition, each of the three axes of EFI sensors on each probe has an independent floating supply. If the unstable current consumption were to crop up in other elements of the flight build, either in I&T or on-orbit, it would neither cause a failure of the floating supply, nor undue restriction of the dynamic range of the preamp itself.

. Thus, while the source of the increased current consumption in the affected units remains unknown, its possible impact upon the fulfillment of mission science requirements is minimal, and thus benign.

Acceptance:
MAM: Ron Jackson_____; MSE: Ellen Taylor_____

PM: Peter Harvey_____; Cognizant Engineer_____

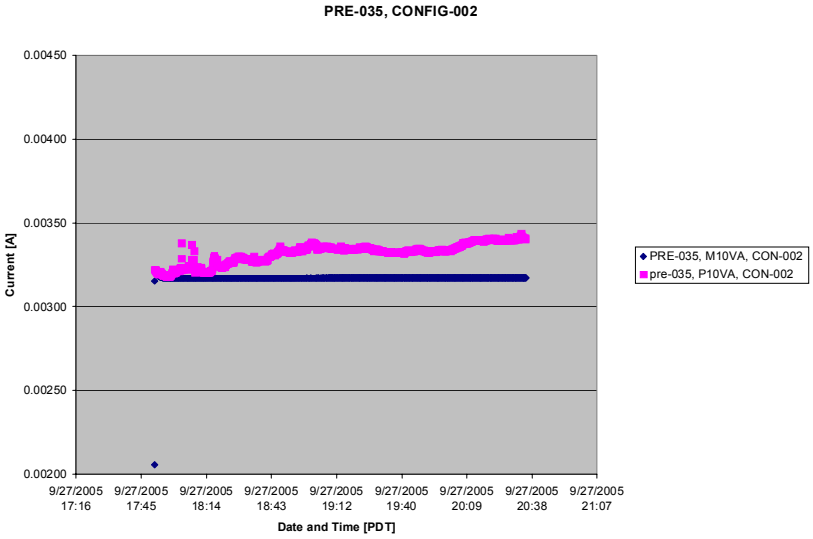
Date of Closure_____

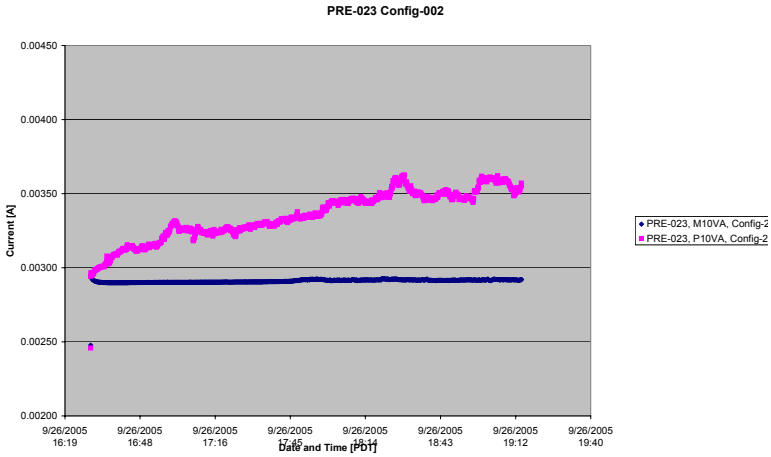
Appendix A: Current-Consumption Test Results.

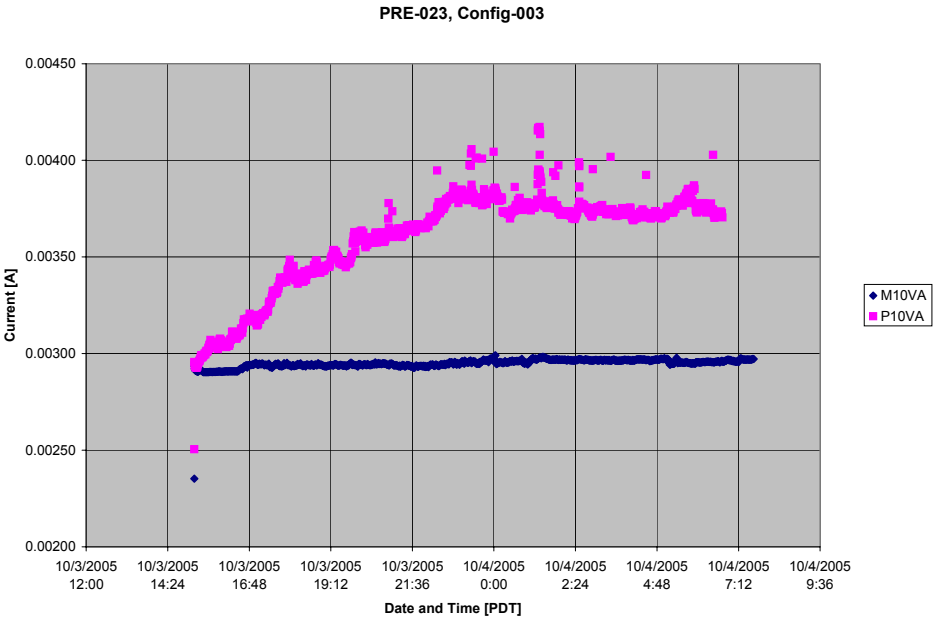
"PRE-023, CONFIG-002" and "PRE-035, CONFIG-002" are 3-hour current consumption tests, with the preamp output (VOUT) terminated to AGND via a 100-kohm resistor, and preamp input directly terminated to AGND.

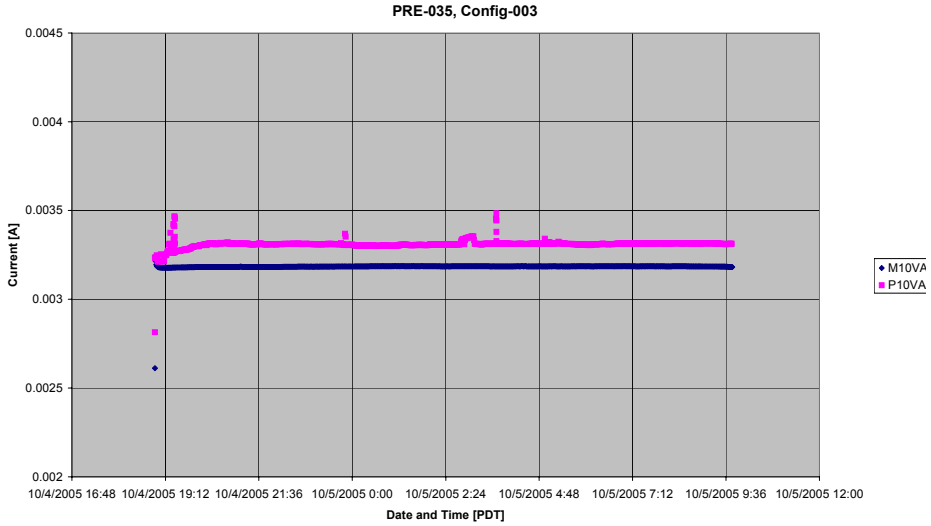
"PRE-035, CONFIG-003" and PRE-035, CONFIG-003" are 15-hour current consumption tests, with the preamp output (VOUT) terminated to AGND via a 100-kohm resistor, and preamp input terminated to AGND via the on-board 75-Mohm bias resistor (R4).

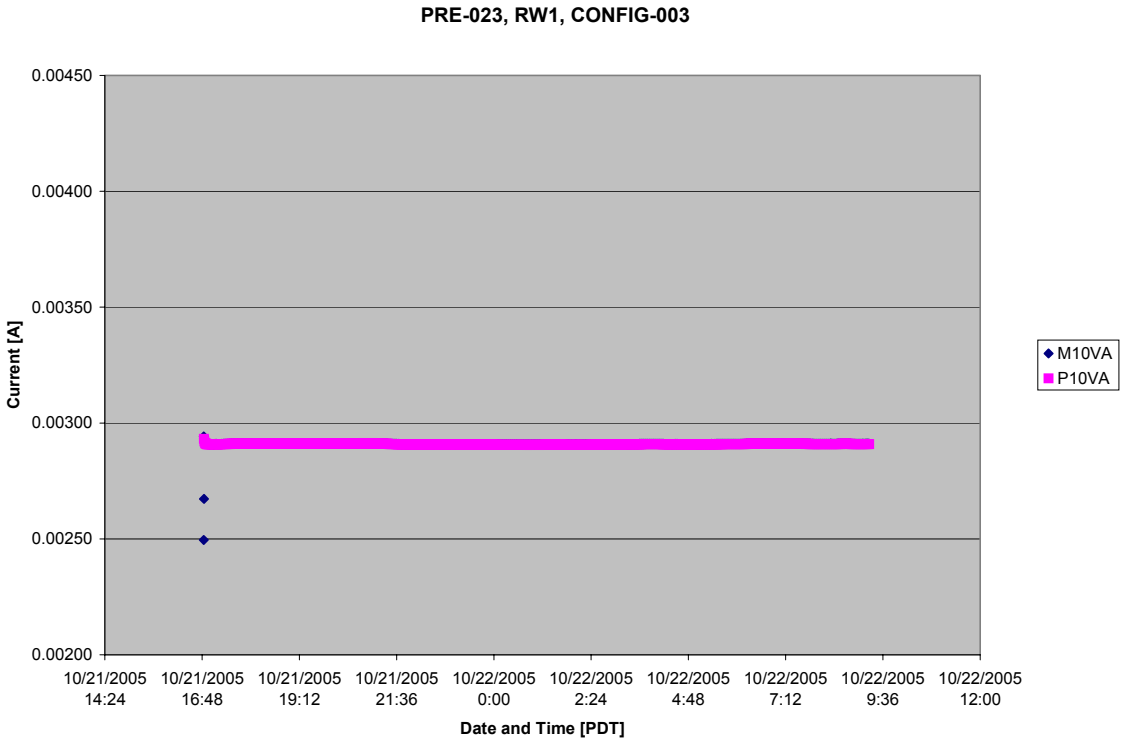
"PRE-023, RW1, CONFIG-003" is a 15-hour current consumption test using the PRE-023 unit with replacement tantalum bypass capacitors. Input and output termination is as in the preceeding CONFIG-003 tests.






PRE-023, Config-003
0.00450
0.00400
0.00350
0.00300
0.00250
0.00200
Current [A]
10/3/2005 12:00
10/3/2005 14:24
10/3/2005 16:48
10/3/2005 19:12
10/3/2005 21:36
10/4/2005 0:00
10/4/2005 2:24
10/4/2005 4:48
10/4/2005 7:12
10/4/2005 9:36
Date and Time [PDT]
M10VA
P10VA


PRE-035, Config-003
0.0045
0.004
0.0035
0.003
0.0025
0.002
Current [A]
10/4/2005 16:48
10/4/2005 19:12
10/4/2005 21:36
10/5/2005 0:00
10/5/2005 2:24
10/5/2005 4:48
10/5/2005 7:12
10/5/2005 9:36
10/5/2005 12:00
Date and Time [PDT]
M10VA
P10VA


PRE-023, RW1, CONFIG-003
Current [A]
0.00450
0.00400
0.00350
0.00300
0.00250
0.00200
10/21/2005 14:24
10/21/2005 16:48
10/21/2005 19:12
10/21/2005 21:36
10/22/2005 0:00
10/22/2005 2:24
10/22/2005 4:48
10/22/2005 7:12
10/22/2005 9:36
10/22/2005 12:00
Date and Time [PDT]
M10VA
P10VA