Optical Inspection of Analog Device (ADI OP 284 FS) Packages Before and After Thermal Cycling in an Extreme Temperature Range (-125°C to 90°C)

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Objective: The objective of this test is to evaluate the SOIC package of Analog Devices Operational Amplifier model OP 284 FS via thermal cycling tests and inspection by optical microscopy.

Introduction: This product has been proposed to use in the control electronics package of an actuator for Mars Exploration Rover Project. There could be some problems associated with the driver electronics package boards associated with the actuators that are available commercially under extreme environments. The board was redesigned and the new package will be built for MER. Therefore, parts group at JPL has undertaken an effort of upscreening the parts required to build such a package board. There are several parts in the package board. One of the parts is Analog Devices OP 284 FS. There are several steps involved in upscreening the plastic parts for any NASA project. Thermal cycling is one of the steps in upscreening the parts to choose the reliable parts to build the final board.

Features of OP 284 (Ref.: Website of Analog Devices): The features of this part are single supply operation, wide bandwidth (4 MHz), Low offset voltage (65 μV), unity gain stable, high slew rate (4 V/μs), and Low noise (3.9 nV/(Hz)$^{1/2}$). The OP184/OP284/OP484 are single, dual and quad single-supply, 4 MHz bandwidth amplifiers featuring rail-to-rail inputs and outputs. They are guaranteed to operate from +3 to +36 (or ±1.5 to ±18) volts and will function with a single supply as low as +1.5 volts. These amplifiers are superb for single supply applications requiring both ac and precision DC performance. The combination of bandwidth, low noise and precision makes the OP184/OP284/OP484 useful in a wide variety of applications, including filters and instrumentation. Other applications for these amplifiers include portable telecom equipment, power supply control and protection, and as amplifiers or buffers for transducers with wide output ranges. Sensors requiring a rail-to-rail input amplifier include Hall effect, piezo electric, and resistive transducers. The ability to swing rail-to-rail at both the input and output enables designers to build multistage filters in single-supply systems and to maintain high signal-to-noise ratios. The OP184/OP284/OP484 are specified over the HOT extended industrial (-40°C to +125°C) temperature range. The single and dual are available in 8-pin plastic DIP plus SO surface mount packages. The quad OP484 is available in 14-pin plastic DIPs and 14-lead narrow-body SO packages.

Figure 1 shows the optical photographs of the ADI OP 284 that were taken before thermal cycling. Inspected the parts/packages (#621, 622, and 623) using optical microscopy and digital camera in the inspection laboratory of JPL.

Applications: Battery powered instrumentation, power supply control and protection, telecom, DAC output amplifier, and ADC input buffer etc. These parts may be used for space applications.

Package: The package type of this part is the standard 8-pin SOIC (Small Outline Integrated Circuit).

Absolute Maximum Ratings (Ref. Analog Devices Website):

Supply voltage =	±18 V
Input voltage =	±18 V
Differential input voltage =	±18 V
Storage temperature =	-65^{o}C to 150^{o}C
Operating temperature =	-40^{o}C to 150^{o}C
Junction temperature =	-65^{o}C to 150^{o}C
Lead temperature range (soldering 60 Sec) =	300^{o}C

Test objective: Based on the technical features of the devices provided above the part maximum operating temperature is -40^{o}C to 150^{o}C. This part has been proposed to use in the actuator electronics that is to be used in a temperature range of –125^{o}C to 90^{o}C. Therefore, an assessment of the package is necessary prior to employ in such extreme low temperature environment.

Thermal Cycling Tests:

A thermal cycling chamber was used to assess the parts for their package robustness in a temperature range of –125^{o}C to 90^{o}C. This chamber has the capability to perform thermal cycling in a temperature range of –196^{o}C to 200^{o}C. After optical inspection of the parts, which were loaded for thermal cycling. Figure 2 shows the optical photograph while loading the parts into the chamber. We have prevented the condensation by bringing the hardware to a warm temperature before opening the chamber. Dry nitrogen was continuously passed into the chamber to avoid condensation. Thermal cycling was performed using LabView in a remote mode. We have performed 10 thermal cycles from –125^{o}C to 90^{o}C as per the thermal profile (ramp rate of 7^{o}C/min, dwell time ~12 minutes). Finally, the test was stopped at ~ 45^{o}C. Optical inspection was performed after thermal cycling and unloading the parts. Figure 3 and 4 show the optical photographs of the parts (top side and bottom side) taken after thermal cycling in the inspection laboratory using optical and digital camera. The packages were intact (#621, 622, and 623) that are inspected. No cracking was observed even after 10 thermal cycles from –125^{o}C to 90^{o}C. This is based on external inspection of the packages only. Electrical and Non-destructive Analysis (NDE) analysis will provide substantial input on the characteristics of the parts. Figure 5 shows the close-up of the copper exposed area around the lead on one of the packages. The surface seems tarnished/black after thermal cycling test. This study requires an analysis of the copper surface by using Auger/XPS before and after thermal cycling. If there is any oxidation the signal corresponding to oxygen should increase. It may be worthwhile to implement the analysis of the exposed areas of the leads before and after thermal cycling in the future test runs on any packages.

In Summary – Analog Devices operational amplifiers were subjected to ten thermal cycles in the range of –125^{o}C to 90^{o}C. This temperature range is appropriate for a package where no thermal control was provided in a subsystem of the project. No cracks or damage was observed in the packages (number of packages/parts inspected: 3) after ten thermal cycles in an extreme low temperature range. Surface analytical techniques may be used in the future to characterize the surface of the leads before and after thermal cycling to learn more about the surface characteristics. X-ray and C-SAM may be used before and after thermal cycling in such extreme temperature range to learn more on the inside of packages that are being inspected using optical microscopy which is good only for external features.

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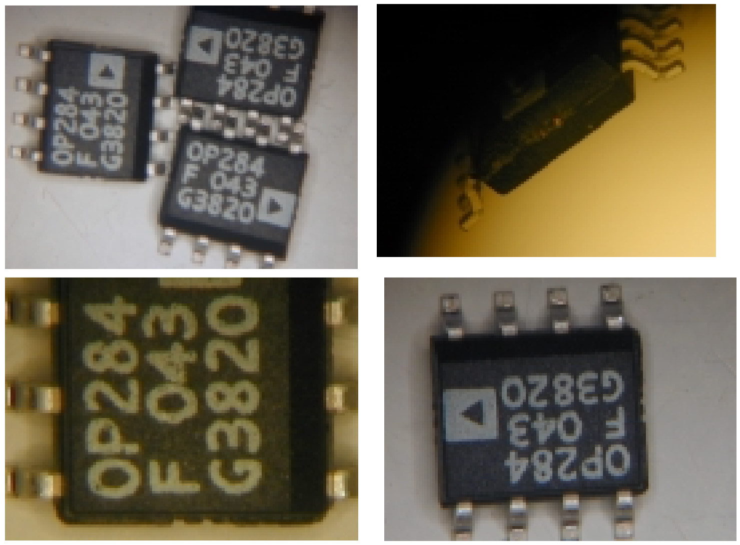

Figure 1: Optical photographs of the devices before thermal cycling

Figure 2: Loading of parts in the thermal chamber