MIDDLE EAST TECHNICAL UNIVERSITY

SMALL SPACE SYSTEMS LABORATORY

ON-BOARD COMPUTER TEAM

Testing Guide for Raspberry Pi Compute Module 5 as METUCube OBC

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Contents

1   Introduction

In this document, the Raspberry Pi Compute Module 5 with a 2GB SDRAM and 16GB eMMC will be referred as the hardware.

2   Power Consumption Tests

The hardware is running on a 5V connection. During the power up, it expects a monotonical rise to at least 4.75V, then runs.

2.1   Needed Equipment for Testing

For testing, a **Programmable Bench Power Supply** with following requirements is needed:

- minimum 5V Voltage Capability

- minimum 2A Current Capability

- maximum ± 25mV Voltage Error

- maximum ± 10mA Current Error

- minimum 5 Hz Logging Rate

2.2   Testing Conditions

The OBC should be tested under following conditions.

- IDLE

- Typical Operational Load

- Stress Conditions

- High Stress Conditions

2.2.1   IDLE Test

The OBC will run nothing except its OS in flight settings.

2.2.2   Typical Operational Load

The OBC will run its flight software as expected, but there will be no active communication, nor use of payload. This case simulates the in orbit activity where satelitte can not be reached by ground stations, and satelitte is not ordered to do any tasks via its payload.

This condition represents the lowest and most common power consumption expected in flight envelope.

2.2.3 Stress Conditions

The OBC will run its flight software as expected, while actively communicating with ground station. The OBC will also perform telecommand requests, such as sending files downlink, or performing config changes.

This condition represents the highest power consumption expected in flight envelope.

2.2.4 High Stress Conditions

The OBC will run an additional app inside its flight software, which will simulate high stress conditions. The additional app will perform all of the given tasks in sync.

- Prime Number Sieve Test

- Memory Thrashing

- Perihepral Loopback Test

3 Thermal Vacuum Chamber Tests

In order to obey with the standarts mentioned in **NASA LSP-REQ-317.01** - given in [2] - , the OBC should be tested for vacuum thermal cycling and vacuum thermal balance. The GSFC ([1]) states the operating temperatures as in the Figure 1.
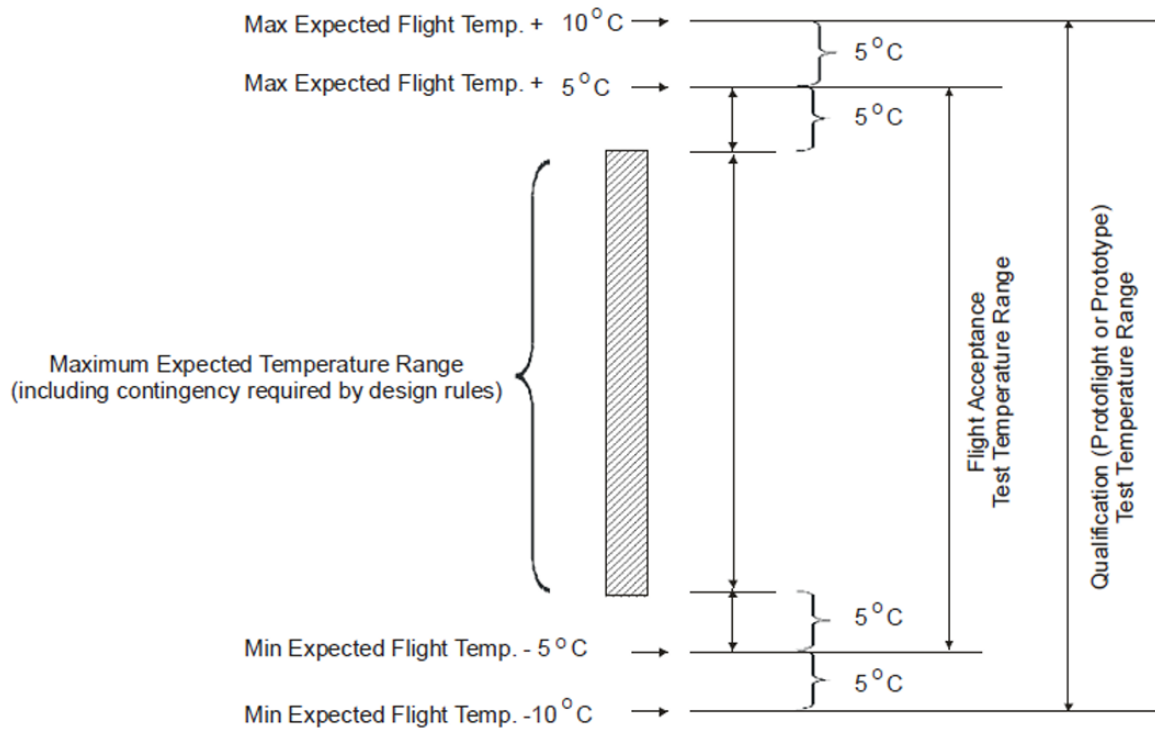

Figure 1: Thermal Vacuum Temperatures

For METUCube, operating temperature range is from 50° C to −10° C. Tests will be conducted in flight acceptance temperature range, which corresponds to from 55° C to −15° C.

3.1   Needed Equipment for Testing

For testing, a **Thermal Vacuum Chamber** with following requirements is needed:

- Temperature Range from $-20°$ to $60°$

- Vacuum Levels Below 10^{-4} torr

- Slowest Transition Speed of $5°C/min$

3.2   Thermal Vacuum Bake out

The NASA LSP document [2] clearly states that for acceptance testing, the hardware should be tested under these conditions:

- $60°C$

- 6 Hour Dwell Time

- Transition speed below $5°C/min$

- Vacuum should be 10^{-4} Torr

3.3   Thermal Vacuum Balance Test

This test is not mandatory by [2], however still appreciated. Testing conditions are given below:

- $-20°C$

- 3 Hour Dwell Time

- Transition speed below $5°C/min$

- Vacuum should be 10^{-4} Torr

Also, the test should be conducted under following conditions too (If 6 hours test in bake out is completed without KIO before 3 hours, no need for that):

- $60°C$

- 3 Hour Dwell Time

- Transition speed below $5°C/min$

- Vacuum should be 10^{-4} Torr

3.4 Thermal Vacuum Cycling

The NASA LSP document [2] clearly states that for acceptance testing, the hardware should be tested under these conditions:

- 2 Cycles

- 1 Hour Dwell Time

- Transition speed below $5°C/min$

- Vacuum should be 10^{-4} Torr

3.5 Test Performance Measurements

Under testing conditions, OBC is expected to perform its tasks, in addition to some more. These additional tasks are:

- Heartbeat test

- Voltage & Current Logging

- Memory & CPU Performance Logging

- Memtest86 Test Under Stabilized Conditions

4 Radiation Testing

4.1 Total Ionizing Dose Testing

Gamma Irradiation with Co-60 is preferred. With around 5 krad/hr, the target dose should be 20 krad. When target dose achieved, force 24 hours of of testing under this condition. The dose can be released after that.

Following test objectives needs to be analyzed.

- Heartbeat test

- Memory & CPU Performance Logging

- Memtest86 Test

- Watchdog reboots

References

[1] NASA, Goddard Space Flight Center. *GSFC-STD-7000A: General Environmental Verification Standard (GEVS)*. Technical Standard GSFC-STD-7000A. Approved April 22 2013; revalidated April 22 2019. Greenbelt, MD, USA: NASA Goddard Space Flight Center, Mar. 2018. URL: https://explorers.larc.nasa.gov/2019APSMEX/MO/pdf_files/gsfc-std-7000a_final_3-28-18.pdf.

[2] NASA, Launch Services Program. *LSP-REQ-317.01RevisionB: Program-Level Dispenser and CubeSat Requirements*. Technical Requirement Document LSP-REQ-317.01RevB. Defines program-level requirements for CubeSat dispensers on NASA ELV missions; Revision date January 30, 2014. Kennedy Space Center, FL, USA: NASA Launch Services Program, Jan. 2014. URL: https://www.nasa.gov/wp-content/uploads/2018/01/627972main_lsp-req-317_01a.pdf?emrc=4e0f87.