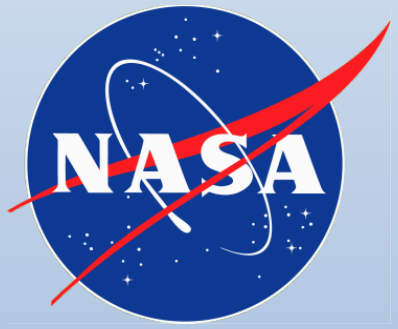
Arduino/Raspberry Pi: Hobbyist Hardware and Radiation Total Dose Degradation



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To be presented by Daniel P. Violette at the EEE Parts for Small Missions, Greenbelt, MD, September 10-11, 2014.

Acronyms

Acronym	Definition
COTS	Commercial Off The Shelf
CPU	Central Processing Unit
DUT	Device Under Test
EEE	Electrical, Electronic, and Electromechanical
GPU	Graphics Processing Unit
HDMI	High-Definition Multimedia Interface
I/Os	Input/Outputs
IDE	Integrated Development Environment
IR	Infrared
LED	Light-Emitting Diode
NASA	National Aeronautics and Space Administration
NEPP	NASA Electronic Parts and Packaging
TID	Total Ionizing Dose
USB	Universal Serial Bus

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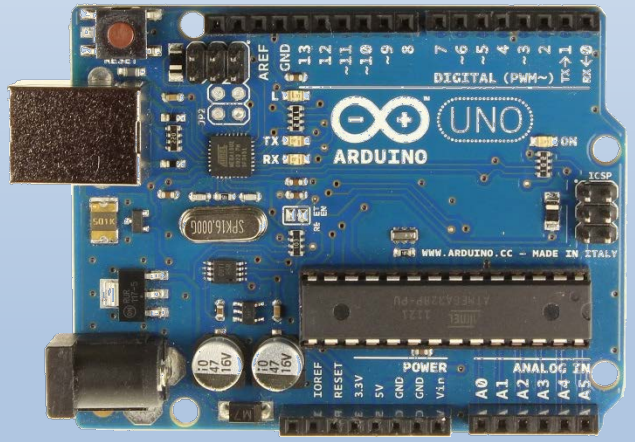
Outline

Why Hobbyist Hardware?

Component Introduction

TID Testing

TID Results



http://arduino.cc/en/Main/ArduinoBoardUno

http://www.raspberrypi.org/product/model-b/

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Why Hobbyist Hardware?

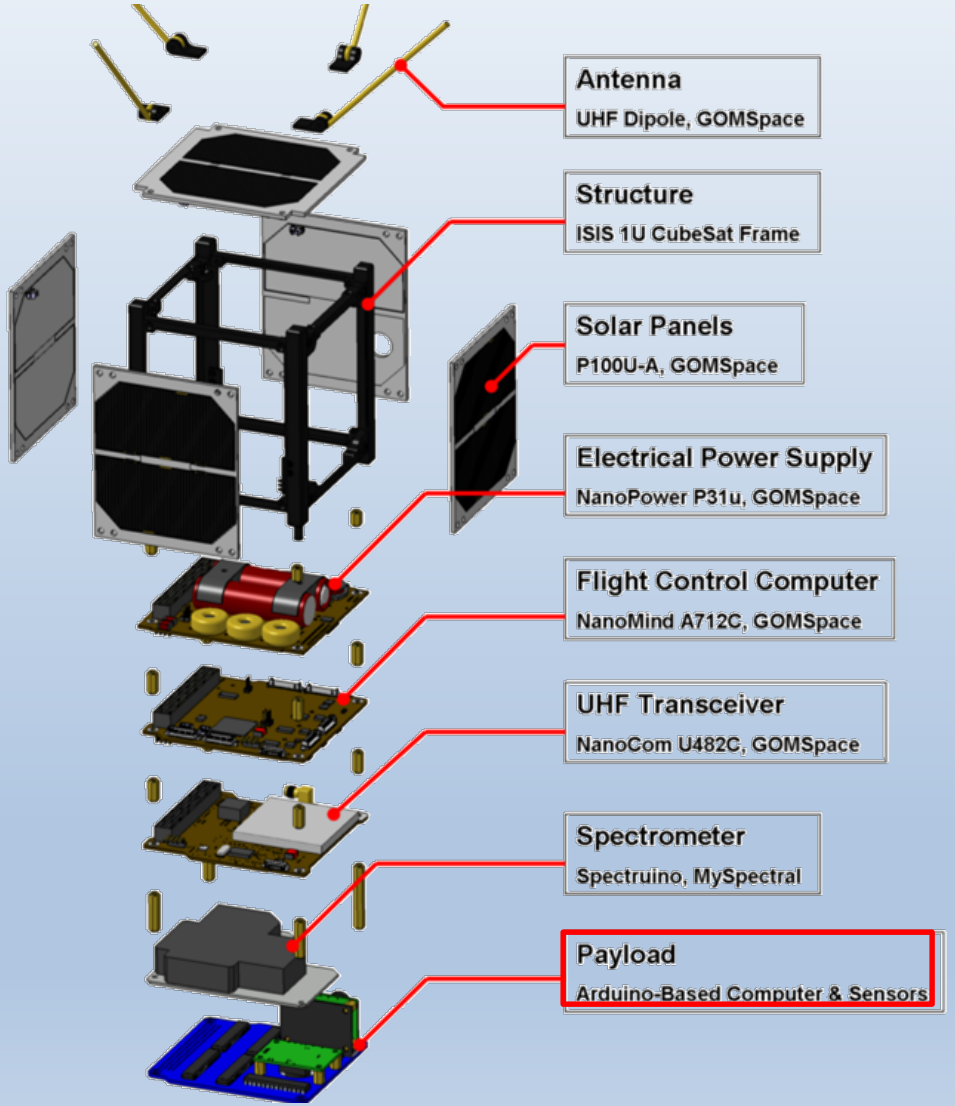
CubeSAT design allows for lower cost threshold for design, construction and launch

Cheaper COTS equipment costs can be seen as desirable in low-risk missions

Arduino-based CubeSATs launched in 2013, Raspberry Pi CubeSAT in development

http://www.ardusat.com/

http://www.lunarsail.com/



https://www.kickstarter.com/projects/575960623/ardusat-your-arduino-experiment-in-space

Raspberry Pi Single-Board Computer

http://www.raspberrypi.org/product/model-b/

Raspberry Pi Model B

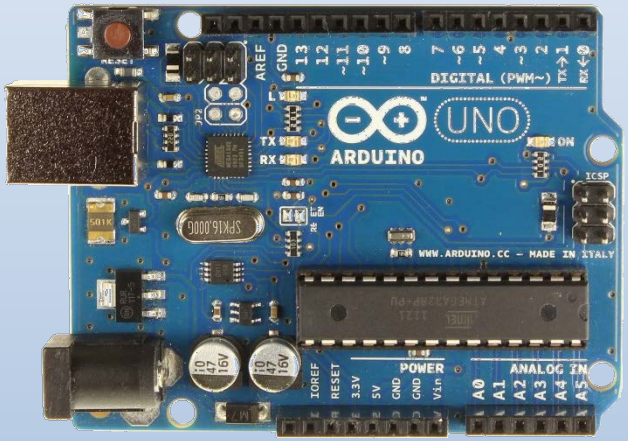
Broadcom BCM 2835 Chipset
CPU – 700 MHz ARM 1176JZ
GPU – Dual Core VideoCore IV Multimedia Co-Processor
26 General Purpose I/Os

Input Voltage	5V
Input Current	750-1200 mA
Storage	4 GB Micro-SD
SDRAM	512 MB
Clock Speed	400 MHz

Operating System: Linux Raspbian

Connections: Ethernet, USBx2, HDMI, Stereo Audio/Composite

Arduino Microcontroller



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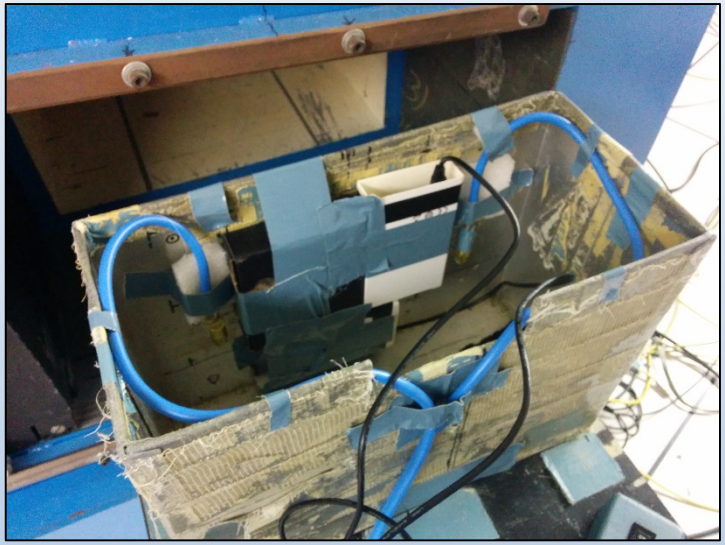
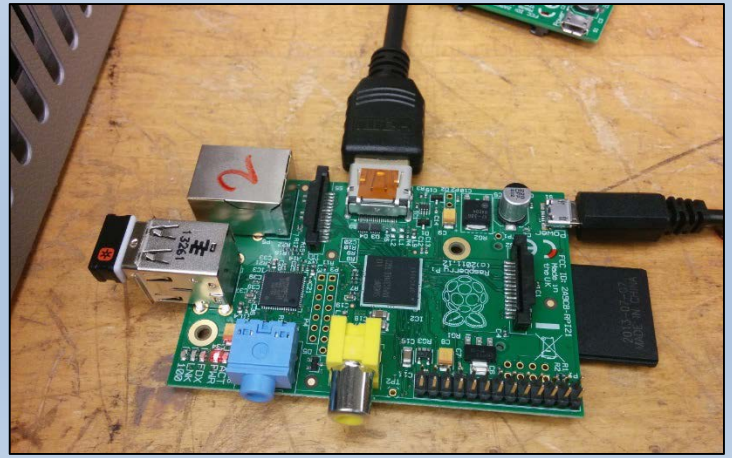
Arduino UNO v3.0 Microcontroller Board

ATMEL Atmega 328 8-bit microcontroller
RISC-based ATMEL Atmega 16U2 USB-to-serial converter
16 Digital I/Os
6 Analog Inputs

Operating Voltage	5V
Input Voltage	7-12V
Voltage Limits	6-20V
Flash Memory	32 KB
SRAM	2 KB
Clock Speed	16 MHz

Raspberry Pi TID Testing Set-up & Verification





Testing Set-up

Devices under test (DUTs) mounted within Pb-Al shielding box and tested 2 at a time.

Dose rate remained consistent for all tests at 1 krad(Si)/minute of gamma irradiation.

Dose rate and accumulation measured by two probes mounted on each side of DUTs.

DUTs biased by 5V 1200mA and 5V 1000mA power adapters.

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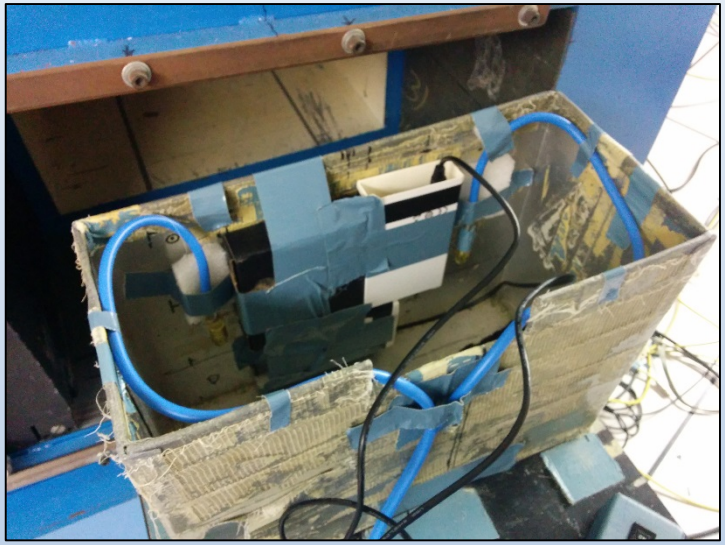
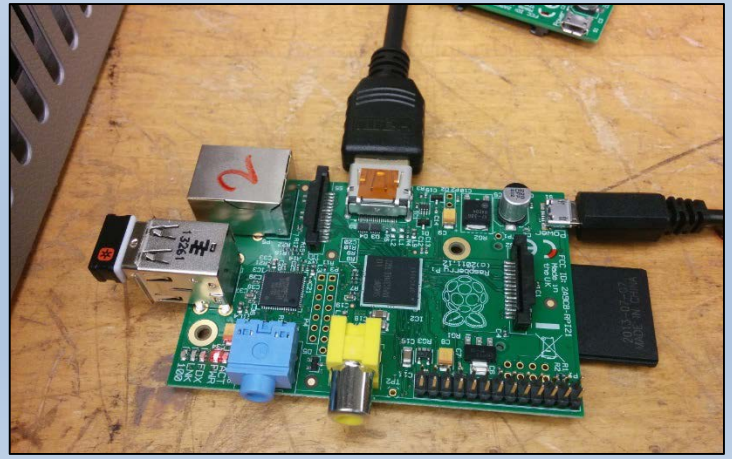
Raspberry Pi TID Testing Set-up & Verification





Verification Hardware

After an irradiation step, DUTs were connected to a display set-up including an HDMI-compatible monitor, power, and wireless mouse and keyboard.

The Raspbian Linux-based operating system was installed and run off of a 4 GB micro-SD card (the card was not irradiated).

Verification was performed by booting the DUT and running benchmarking tests to check bus speed, memory speed, and drive speed.

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Raspberry Pi TID Testing Results

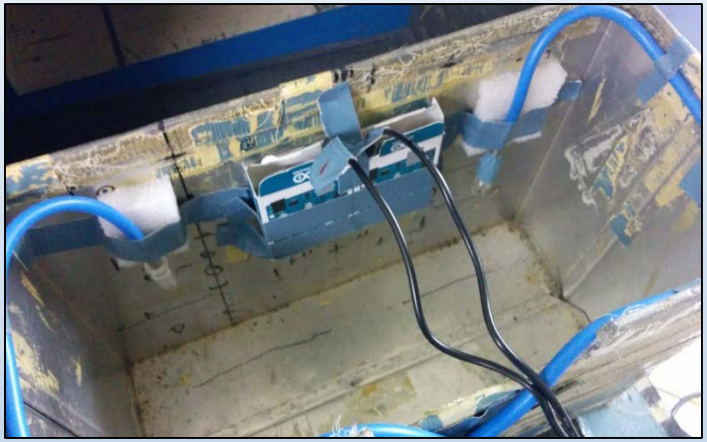
TID (krad(Si))	Condition DUT 2	Condition DUT 3	Condition DUT 4	Condition DUT 5	Condition (DUT 1 – Control)
10	Nominal	Nominal	Nominal	Nominal	Nominal
20	Nominal	Nominal	No Logon	Nominal	Nominal
30	Nominal	Nominal	Nominal	Nominal	Nominal
40	Nominal	Nominal	Nominal	Nominal	Nominal
50	No Logon	No Logon	No Logon	Nominal	Nominal
60	No Test	No Test	No Logon	No Logon	Nominal
70	No Test	No Test	No Logon	No Logon	Nominal
80	No Test	No Test	No Logon	No Logon	Nominal
100	No Test	No Test	No Logon	No Logon	Nominal
120	No Test	No Test	No Logon	No Logon	Nominal
150	No Test	No Test	No Logon	No Logon	Nominal

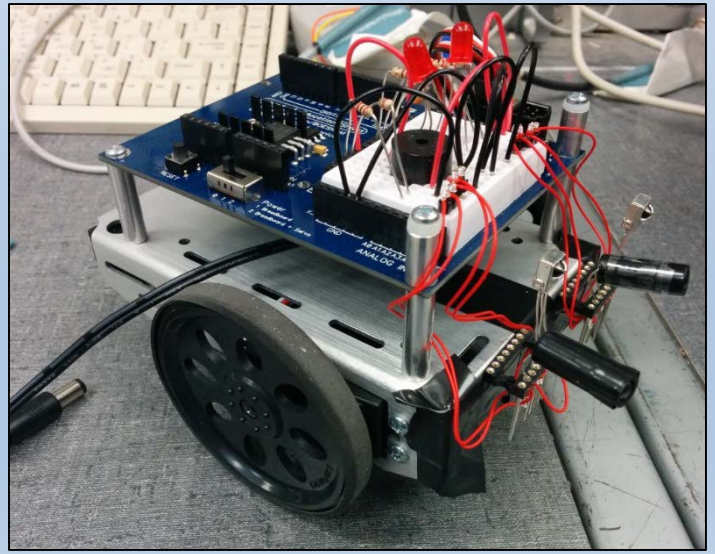
All DUTs booted and ran normally up through 40 krad(Si). Benchmarking tests all were completed successfully up through 40 krad(Si).

From 50-60 krad(Si) all DUTs lost the ability to detect the attached USB and keyboard, preventing log-in. At 20 krad(Si), DUT 4 had a similar problem. Switching from 1A to 1.2A power supply solved it temporarily.

DUTs continued to fully boot to log-in screen up through a TID of 150 krad(Si).

Arduino TID Testing Set-up & Verification





Testing Set-up

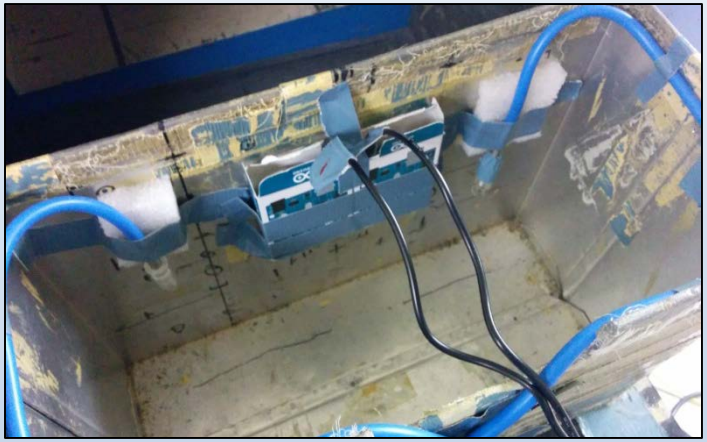
Devices under test (DUTs) mounted within Pb-Al shielding box and tested 2 at a time.

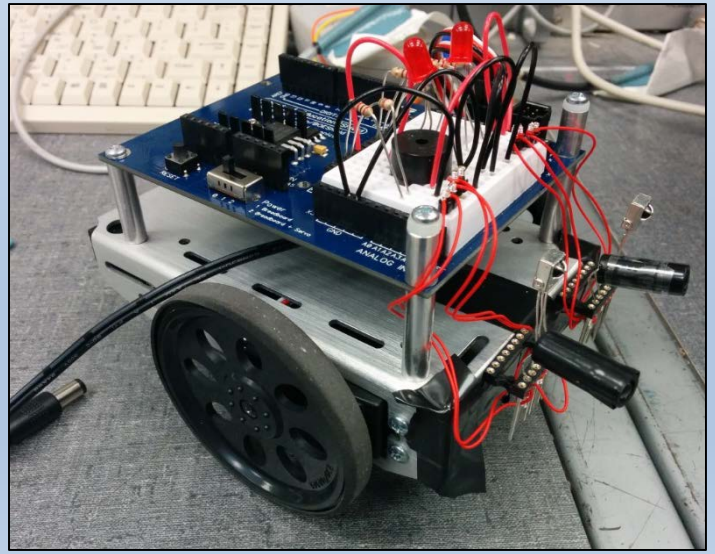
Dose rate remained consistent for all tests at 1.8 krad(Si)/minute of gamma irradiation (step sizes varied).

Dose rate and accumulation measured by two probes mounted on each side of DUTs.

DUTs biased by 9V 1000mA power adapters

Arduino TID Testing Set-up & Verification





Verification Hardware

After an irradiation step, components mounted on a specialized servo-controlling extension board called a “shield.”

This robotic shield performs a set of programmed instructions utilizing two servo-controlled wheels, a piezoelectric element, IR LEDs and photo resistors.

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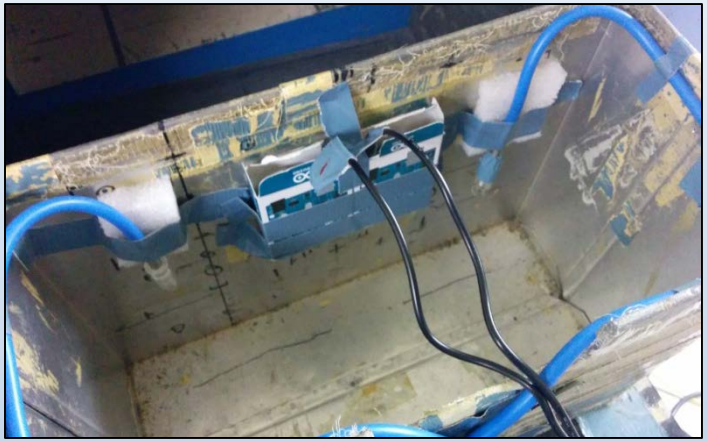
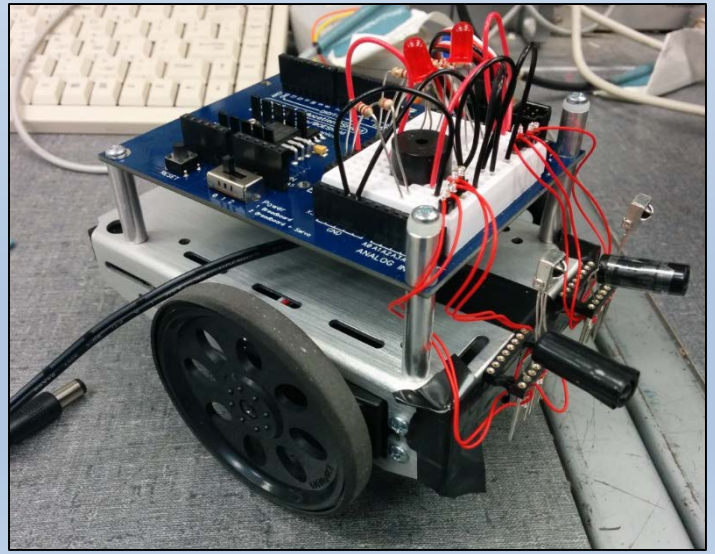
Arduino TID Testing Set-up & Verification





Verification "Sketch"

Setup Commands:

1. Access servo library and connect servos.
2. Produce a 3000Hz tone.

Repeating operating commands:

3. Cycle IR LED light frequency and detect changes with photoresists to identify objects.
4. If object is only on left, rotate to face object.
5. If object is only on right, rotate to face object.
6. If object is too close, move back.
7. If no other criteria are filled, move forward.

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Arduino TID Testing Results

TID (krad(Si))	Condition DUT 2	Condition DUT 3	Condition DUT 4	Condition DUT 5	Condition (DUT 1 – Control)
5	Nominal	Nominal	No Test	No Test	Nominal
10	Nominal	Nominal	No Test	No Test	Nominal
15	Nominal	Nominal	No Test	No Test	Nominal
20	Nominal	Nominal	Nominal	Nominal	Nominal
30	Nominal	Nominal	No Test	No Test	Nominal
40	Nominal	Nominal	Nominal	Nominal	Nominal
50	Nominal	Nominal	Nominal	Nominal	Nominal
52	No Test	No Test	Nominal	Nominal	Nominal
54	No Test	No Test	Nominal	Nominal	Nominal
56	No Test	No Test	Damaged	Damaged	Nominal
58	No Test	No Test	Damaged	Damaged	Nominal
60	No Test	No Test	Failure	Failure	Nominal
70	Failure	Failure	No Test	No Test	Nominal

DUT 1 (control) received no dose and was tested at each irradiation step after DUTs 2-5.

No degradation observed in Arduino performance prior to 56 krad(Si).

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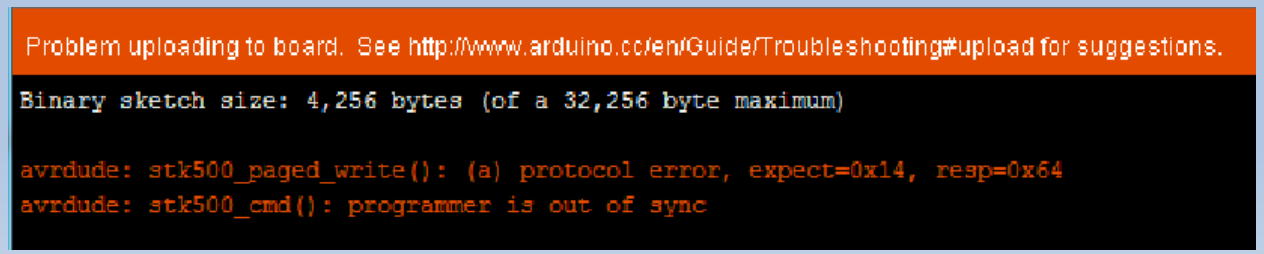
Arduino TID Testing Results

DUTs experiencing **damage** exhibited erratic behavior including repetitive reset of the “sketch”, failure to identify objects, producing tones of incorrect frequency upon start or reset, and freezing during different operations.

DUTs experiencing **failure** would no longer perform any operation on start or reset

Both damaged and failed DUTs would no longer interact with or receive commands from the Arduino Integrated Development Environment (IDE), citing programmer sync errors.

DUTs were annealed for 1-week under bias but did not regain any operational ability.



Summary

Arduino UNO v3.0 : After 56 krad(Si) of TID damage, DUTs displayed signs of errors and improper operation, with all DUTs receiving more than 60 krad(Si) failing completely.

Raspberry Pi Model B: After 60 krad(Si), no DUTs were able to identify the USB-connected mouse and keyboard, preventing log-in. However, the DUTs continued to boot successfully to the login prompt through 150 krad(Si).

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