HESSI ADP Software Requirements
1999-May-25 D. W. Curtis

1. Introduction

This document describes the requirements for the software to be developed for the HESSI Aspect Data Processor DSP. This document will not attempt to describe the hardware environment or how the software interacts with it.

1.1 Related Documents

These documents are available on the web at:

ftp://apollo.ssl.berkeley.edu/pub/hessi/

[1] HESSI IDPU to ADP Interface Control Document (HSI_IDPU_013)
[2] HESSI Telemetry Formats Document (HSI_SYS_007)
[3] HESSI ADP Telemetry Formats (HSI_SYS_032)
[4] HESSI IDPU to Spacecraft Interface Control Document (HSI_SYS_001)

2. Requirements

2.1. *Power-on initialization*

On reset the system initializes the hardware, and waits for instructions (in Idle state). The ADP will start a data collection routine by command, not automatically on reset. This state is also entered by an ADP_STOP command.

2.2. *Memory Management*

The ADP will store one or more versions of the processing software in EEPROM. On command, the system will verify that the requested program is valid (checksum?), load it into RAM, and start execution.

In addition to the program, the EEPROM contains one or more versions of a Parameter table, Hot Spot table, and RAS Threshold table. These tables can be loaded from the EEPROM into the 'current' location in RAM by command. Tables should only be changed while in Idle State so that the system gets configured correctly on starting up the processing software. The ADP will dump a copy of the current tables into the science telemetry stream when starting up the processing software. The current program and tables can also be dumped via diagnostic SOH telemetry by command.

Each table will include an embedded version number. The version number of the current version of each table will be included in each packet header (see reference 3) and the SOH telemetry.

The current program and tables can be loaded or modified by command (see reference 1). A copy of the current program or a current table can also be written to EEPROM by command.

It is probably best to have different programs for generating the unusual diagnostic formats to keep the 'normal mode' software from getting cluttered with special cases.

2.3. *Single Event Upset Management*

The FPGA and RAMs have some sensitivity to single event upset due to penetrating particles in space. FPGA control registers should be periodically refreshed by the DSP to restore the correct value in case of upset. RAM tables and code space should include a checksum that is checked periodically, with an error flag being sent in the State Of Health telemetry if any checksum fails.

2.4. *IDPU Interface*

Reference 1 describes the IDPU interface to the ADP. The ADP must respond to messages, including:

- State Of Health (SOH) collect
- SAS Aspect Solution collect
- Memory dump
- Memory load
- Commands Execution

The ADP must also place completed science telemetry packets into the FIFO where it will be automatically collected by the IDPU.

2.5. *RAS/SAS Interface*

When the data collection program starts, it must configure the RAS/SAS sensors and the interface FPGA in the ADP according to the information in the current Parameter Table. Some of these parameters are discussed in reference 3. Once data collection has started, the DSP must collect the partially processed data from the RAS/SAS interface FPGA, extract the desired data, format it into telemetry packets per reference 3, and pass it to the IDPU Interface FIFO.

2.5.1. SAS Processing

The 3 SAS sensors each collect one image 128 times a second (ignoring the double exposure taken in the sensor to mitigate problems associated with the long time interval between exposures). The RAS/SAS interface FPGA collects up these images and puts them into a memory accessible by the DSP. It also determines "limbs" in each image, based on a programmable threshold value; the locations of these limbs are also put in the RAM for the DSP. The DSP is notified when the image collection is complete.

2.5.1.1 SAS Limb Processing

The DSP shall be programmed to process only every Nth set of limbs, where N is a programmable parameter, from 1 to 16. This gives a limb sampling rate between 8Hz and 128Hz.

There should be at most 2 limbs per SAS detector image. There may, however, be multiple limbs identified by the RAS/SAS interface FPGA. Bad limbs may be due to hot spots outside the sun image, or cold spots inside the sum image. A hot spot table shall be used to remove any limb that is located at a known hot/cold spot on the CCD. In addition, any limb which is followed by another opposite limb less than N pixels later shall be ignored (N can be a programmable value, but it is probably sufficient to set N to 1). If, after these constraints are applied, there are still more than 2 limbs for a SAS sensor, the limbs closes to each end of the CCD shall be used, and an error flag shall be set in the SOH telemetry.

Each limb identified as described above is then formatted into telemetry, along with the selected number of surrounding pixels, as specified in reference 3.

2.5.1.2 SAS Image Processing

Complete images from the SAS detectors shall be sent periodically and by ground command, as described in reference 3. Periodic images shall be collected every N accumulation intervals, where N is programmable (in the parameter table). The DSP must collect the image data for all 3 SAS sensors from the RAS/SAS interface memory, format it into packets as required, and pass the results into the IDPU interface FIFO.

2.5.2. RAS Processing

The RAS/SAS Interface collects RAS image data at a programmable cadency. Images are placed into the memory accessible by the DSP. In addition, the RAS/SAS FPGA performs space and time averages, and compares each averaged pixel with a threshold value. The threshold values are different for each pixel, and are set from a programmable table. The pixel numbers for averaged pixels that exceed threshold are also placed in the interface memory (up to a maximum number of pixels). The DSP is notified when a RAS image has been collected.

The RAS sensor generates an 'earthshine' signal when an extended bright object, such as the Earth, is seen by the RAS. Earthshine in the detector precludes measuring stars.

2.5.2.1 RAS Star Processing

The DSP shall process the start candidate data (pixels that exceeded threshold, as indicated in the RAS/SAS interface memory) every image collection time. However, if the DSP gets over-burdened, an occasional dropped RAS image shall be acceptable, provided that the system knows that it has skipped an image.

Images collected while the earthshine signal is active shall be dropped (no star processing shall be performed).

If the number of start candidates has reached the hardware limit, an error flag shall be set in the SOH telemetry.

The list of star candidates shall first be weeded by removing any pixel that is indicated as a hot spot in the hot spot table. Next, the pixels around the star candidate shall be extracted from the image data as described in reference 3. Since pixels from images both before and after the time of the threshold crossing are included, the system must maintain previous images, and must wait for the following data before the data associated with the star candidate can be collected). The star candidate data must then be formatted into the current RAS packet as indicated in reference 3.

Overlapping star candidates may be combined as indicated in reference 3, but this is a low priority requirement.

2.5.2.2 RAS Image Processing

Complete images from the RAS detector shall be sent periodically and by ground command, as described in reference 3. Periodic images shall be collected every N accumulation intervals, where N is programmable (in the parameter table). The DSP must collect the RAS image data from the RAS/SAS interface memory, format it into packets as required, and pass the results into the IDPU interface FIFO.

2.6. *SAS Aspect Solution*

The spacecraft can use the SAS data as a backup to the Fine Sun Sensor for pointing the spacecraft at the Sun. The desired format for the aspect data is described in reference 4. The data is to be collected 8 times a second synchronous with the 1Hz clock, buffered up into a block of 8 samples taken between 1Hz clock ticks, and transmitted during the following 1 second interval in response to an IDPU message. The IDPU will pass the data on to the spacecraft unchanged.

The SAS aspect solution is based on the limb locations. 2 limbs from 2 sensors are required. If this information is unavailable (for example, too few limbs found), a special code is placed in the SAS aspect solution for that sample. The aspect solution consists of the X and Y location of the sun center as seen by SAS sensors 1 and 2. Note that SAS1 is aligned along the spacecraft X-axis.

First the sun-center on each of the 2 SAS sensors, C1 and C2, is computed as the average of the two limb locations, minus the center pixel number (so that the 0 is at the center of the image). C1 and C2 shall be inverted as required (depending on the pixel-numbering scheme) so that C1 is positive for pixels in the -Y direction (indicating the object imaged is in the +Y direction), and C2 is positive for pixels in the -X direction (indicating the object imaged is in the +X direction).

The X and Y values, in pixel units, are calculated as:

$X = C1$
$Y = (2*C2-C1)/\sqrt{3}$

These values must then be scaled as indicated in reference 4, to 1 degree of displacement equals a scaled value of 128 (the scaling constant depends on the SAS optics and CCD pixel size.

This module is low priority requirement, because it is a backup function for the spacecraft. However, the system must be capable of responding to the SAS Aspect Solution Block request from the IDPU even if this module is not coded. In that case, the value returned shall indicate no solution.

2.7. *RAS Dark Level Determination & Threshold Updating*

If the RAS dark levels vary with time or temperature, it may be desirable to have an automatic system for updating the threshold values used in the RAS/SAS interface FPGA star determination. The dark levels can be computed by averaging periodic RAS images (excluding images with the earthshine signal active). The image cadency should programmable, and if necessary, data formatting for the RAS image that is used can be skipped to save processor time). A method for doing this averaging is described in reference 3. After N RAS images have been averaged into the dark level (N shall also be programmable), the new threshold can be computed. This involves first summing up the pixel dark levels in the same way the RAS/SAS Interface FPGA averages the RAS data for star detection, and then adding a fixed offset to all values (from the parameter table). Different offset values will be required for pixels having different numbers of pixels summed together. Thresholds for known hot pixels, based on the HotSpot table, (and their neighbors that get averaged in) should be set high to avoid having them trigger the star determination hardware.

This module is low priority requirement, because it is uncertain that it will be needed, and it is likely that if it is needed, the algorithm will need to be tweaked in response to what actually see.

2.8. *SOH Telemetry Formatting*

Once a second the IDPU shall collect a State Of Health (SOH) block for the ADP via the message interface described in reference 1. The DSP must format the data and have it available when requested. The SOH data is passed to the ground in real time during contacts. When not in contact, SOH data is sub-sampled at about once every 10 seconds and saved to be downloaded during the next ground contact. Unlike science data, SOH data does not have long delays associated with the Solid State Recorder (which may back up data transmission by as much as 2 days). SOH data should include all data needed for determining the general health of the instrument, and verifying commands have been received. A list of candidate SOH information follows.

- Command verification (most recent command received code, and a count of commands received).
- Error code/counter
- Program/table version numbers
- Memory dump address
- Average, minimum, and maximum RAS Dark level

- Number of starts seen (this second)
- Earthshine time/duration (most recent)
- Number of solar limbs found (most recent)
- Number of telemetry packets made (this second)