HESSI IDPU Software Specification
HSI_IDPU_006A
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1. Introduction

This document is a preliminary specification for the IDPU processor software. The processor controls the HESSI instruments, collects, monitors, and formats instrument State of Health (SOH) data, and communicates with the spacecraft over a serial interface. The processor does not directly interact with science telemetry – this is handled automatically by the hardware (FPGAs). The processor can control the flow of data via various control registers.

The HESSI IDPU processor is based on an 80C85RH processor (see reference 1). While the 8085 is a simple, low speed 8-bit processor, it is well matched to the HESSI requirements provided it is not overburdened with a complex operating system or higher level language. It is expected that HESSI software will be written in 8085 assembly language, and that the task manager will consist of a simple task list polled once a second, plus a few interrupt handlers.

1.1 Related Documents

These documents are available on the web at:

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

[1] HESSI IDPU Processor Specification.doc
[2] HESSI Telemetry Format (HSI_SYS_007)
[3] HESSI Command Format (Spectrum Astro document)
[4] HESSI IDPU Bus Controller FPGA Specification.doc
[5] HESSI IDPU Packet Formatter FPGA Specification.doc
[6] HESSI IDPU Detector Interface FPGA Specification.doc
[7] HESSI IDPU to Spacecraft ICD (HSI_SYS_001)
[8] HESSI IDPU Backplane Signals (HSI_SYS_019)

2. Software Architecture

The HESSI software is divided into tasks. Each task shall perform an independent function. Tasks shall be initialized on reset, and called once a second to perform their function. In addition, each task shall have commanding and telemetry entry points. Tasks shall be modular, with minimal interaction between them. Most variables shall be kept local to a task with as few variables shared between tasks as possible.

In addition to Tasks, there will be Interrupt Handlers. There are three interrupts:

- The 1Hz interrupt
- The 2^N Hz Interrupt
- The DMA EOP Interrupt

Care must be taken in the interrupt handlers to avoid race conditions in variable accesses and other reentrancy problems.

In general, hardware registers associated with each task should be refreshed once a second even if their value is not changed to protect against radiation-incuced hardware upsets (SEU).

3. Interrupt / Reset Handlers

3.1. *CLK1Hz Interrupt*

The 1Hz interrupt probably does not need to be enabled; it can be polled by the idle routine.

3.2. *DMA EOP Interrupt*

The DMA EOP interrupt handler shall call an entry in the Spacecraft Serial Interface Handler.

3.3. *2^N Hz Timing Interrupt*

The Timing Interrupt is provided to allow for fast timing for some tasks. The rate is programmable from 16Hz to 1024Hz by the processor. The rate shall be selected to meet the worst case task's requirement (TBD). The interrupt handler shall call an entry point in each task that requires high-speed polling.

3.4. *Reset Initialization*

On reset, the processor will be running out of PROM. The first task is to copy the PROM to the RAM and power off the PROM. Next each of the tasks is initialized. Finally the Idle task is entered, waiting on the first 1Hz interrupt.

4. Tasks

4.1. *Idle Task*

When the task list is complete, the idle task shall be executed until the next 1Hz interrupt. The idle task shall consist of a timing loop that counts the time in the idle task. This information is included in the SOH segment of the Telemetry Block as a diagnostic on the processor load. The loop polls a flag set by the 1Hz interrupt handler (or the interrupt flag if the interrupt is not enabled) to determine when to restart the task list.

4.2. *Spacecraft Serial Interface Handler*

The spacecraft serial interface is described in the IDPU ICD (reference 7). Once a second the spacecraft and instrument exchange fixed-length blocks of data over a serial interface. This instrument side of the serial interface is connected to the processor via an 82C37 Direct Memory Access (DMA) chip. The DMA chip transfers the data directly from/to processor memory. This driver should configure the DMA chip to handle the transfer of the Command Block and Telemetry Block.

The Command Block shall be transferred to the instrument starting shortly after the 1Hz tick. When the transfer is complete, the DMA End-of-Process (EOP) shall cause a processor interrupt. The interrupt handler should set up the DMA receive channel for a new command block next second. The command block receive buffer should be double-buffered, so that the Command Block Handler is working on the command block received on the previous second while the serial interface is transferring into the second buffer. The buffer selection is swapped once a second.

A hardware status bit indicating a parity error in the serial receive interface shall be checked and cleared at the time of the receive DMA EOP interrupt. In case of an error, the command block shall be discarded and an error indicated in the SOH telemetry.

The Telemetry Block Handler shall start transfer of the Telemetry Block using the DMA once a second, shortly after the 1Hz interrupt. Again, double-buffering shall be used so that the Telemetry Block handler is accumulating a Telemetry Block into one buffer while the block accumulated the previous second is being transmitted. For the Transmit DMA channel, the DMA EOP interrupt can be ignored.

4.2.1. Command Block Handler

The command handler parses the command segment of the Command Block received by the IDPU from the spacecraft in the previous second over the serial interface. Each command includes a Function Code indicating which task is to receive the command (reference 8). The Command handler passes each command received to the relevant task for disposition. The Command Handler also maintains the command verification information for inclusion in the SOH data (see reference 2). Command Blocks also contain spacecraft status information, which shall be placed in global variables for use by the appropriate tasks.

4.2.2. Telemetry Block Handler

The Telemetry Block Handler shall collect and format the Telemetry Block that is passed to the spacecraft by the Spacecraft Serial Interface Handler once a second (reference 7). The Telemetry Block contains SOH data, Aspect Data from the Aspect Data Processor (ADP), and possibly diagnostic data. The Telemetry Block handler shall call each Task Telemetry entry point to get SOH data for that task. The data will be formatted by the task and returned to the handler for inclusion in the Telemetry Block SOH segment. The ADP task will also return the aspect segment data for the Telemetry Block. Any task may also return a Diagnostic Packet for inclusion in the Diagnostic segment of the Telemetry Block. Only one diagnostic packet may be returned each second, so the handler must lock out other task diagnostic packets once one has been collected.

4.3. *ADC Handler*

The ADC handler uses the housekeeping ADC to sample all the analog housekeeping values (about 150 – TBD) once a second. This data is provided as SOH data to the Telemetry Block handler and to various routines for monitoring. The sampling procedure is:

- Set the analog housekeeping multiplexer to select the desired value
- Wait for the analog value to settle (at least 1ms)
- Start the ADC conversion
- Wait for the converter to complete
- Get the value from the ADC

The delays can be implemented either as timing loops or using the timing interrupt (TBD). The sampling procedure must be repeated for each housekeeping value. The list of housekeeping multiplexer values to cycle through is TBD.

Temperature data collected by the ADC is used by other tasks to control heaters and the cryocooler. The measured values shall be converted to temperatures using a look-up table. Likewise, some voltages must be converted using programmable conversion coefficients for on-board use. SOH telemetry shall be raw measurements, not converted values.

4.4. *HV Handler*

The HV handler controls the setting of the nine detector HV voltage. Ground commands set the desired levels. A separate ground command controls the hardware HV enable switch. The handler shall ramp the voltages to the desired levels using a programmable rate (DAC steps per second or seconds per DAC step).

On reset the HV settings should be Off and disabled.

The high voltage shall be disabled whenever the cold-plate temperature is above 100K

The HV Handler also monitors the HV supply output value read back by the ADC handler. Undervoltage indicates excessive current, so the supply should be shut off. Overvoltage indicates a problem with the supply control loop, so the supply should be shut down. The supply voltage shall compared to the programmed setting using programmable calibration coefficients and a programmable tolerance. The measurements should be out of range for two (TBR) measurements in a row before the supply is shut down.

4.5. *ADP Handler*

ADP SOH Data Collection
ADP Aspect Data Collection
ADP Commanding
Power controller, safe mode

4.6. *Detector Analog Front End (AFE) Handler*

The nine detector interface cards have a number of registers that shall be set by ground command to control the AFEs (threshold DACs, etc. – see reference 6). The detailed list of registers and default values is TBD.

AFE power switches are also controlled by ground command via registers controlled by the processor. They should all default to Off on processor reset. This task shall also monitor the SAFE signal provided by the spacecraft. If the SAFE signal is activated, the AFE power switches shall be set to Off.

The AFE also includes an electronic calibration source controlled by the processor. The processor can set the rate and amplitude of calibration pulses independently for each of the nine detectors. The registers can either be set manually by TBD ground command, or automatically in a ground-commanded sequence (TBR).

4.7. *Particle Detector Handler*

Particle detector controls consist of the bias supply setting and the threshold setting. Both are set by 8-bit DACs, and are set to levels indicated by ground command. The bias supply shall default to zero on reset.

The particle detector count rates shall be monitored as an indicator of high particle flux, which would cause high background levels in the GeDs. Ground-programmable thresholds on each of the two particle detector rates shall be used. If either of the thresholds is crossed, the Event and Fast Rate channels shall be shut down by command to the AFE.

4.8. *Event Throttle Controller*

4.8.1. Automatic Shutter Control

The automatic shutter system shall be disabled by default, and cannot be enabled until the shutter lock-down actuator has been fired (check the actuator monitor). This system shall control the shutter based on two inputs (each with a separate enable): the front segment detector fast rate monitor and the Solid State Recorder memory capacity (provided by the spacecraft as part of the Command Block once a second). Shutter actuation is subject to the constraints indicated in the Shutter Actuator handler.

4.8.1.1 Rate Control

When the average detector front segment fast rate exceeds a programmable threshold (default 30-50khz – TBR), the system shall trigger the shutter actuator to increase attenuation. When that rate falls below a second programmable threshold (default TBD), the system shall similarly decrease attenuation (but not below the minimum level set by the Memory Capacity Control).

4.8.1.2 Memory Capacity Control

The minimum shutter attenuation level (most open), shall be a function of the memory capacity. If the memory is greater than a programmable threshold of full (default TBD), then the system shall raise the minimum shutter attenuation level, triggering the shutter actuator to increase attenuation if necessary. A set of three thresholds shall be available; one for each level of attenuation. A second set of three memory capacity level thresholds shall be available to control when the minimum attenuation level can be decreased.

4.8.2. Decimator Control

The decimators act as electronic rate attenuators. They have programmable characteristics (energy level and attenuation ratio) set by the Detector Analog Front End handler. This code shall turn on and off the decimator based on memory capacity. A set of programmable memory capacity thresholds (default TBD) shall control when the decimator is turned on/off. The decimator may be enabled simultaneously with the shutter system.

4.8.3. Event Disable

As a final contingency, detector events (and Fast Rates) may be disabled to avoid exceeding the memory capacity. At programmable memory capacity threshold (default TBD), the front segment events and Fast rates shall be shut down. A second threshold (default TBD) shall control shut-down of the rear segment events.

4.8.4. Fast Rates Mode

Fast Rates provide an alternative to events. They have much lower energy resolution, but can handle about 10 times the event rate. When the average front segment Fast monitor rate exceeds a programmable threshold (default TBD), the Fast rates mode shall be enabled. Fast rates shall be disabled when this monitor rate falls below a second programmable threshold (default TBD).

4.9. *Science Packet Data Header Handler*

The science data packets include a 6-byte data header that is provided from registers set by the processor. The header shall contain instrument status information required for analysis of the data (see reference 2). This data is time-sensitive, since the hardware may be making packets at a large rate. For this reason, other handlers may either directly write to these registers, or call a routine in this handler to write those registers, when they change or measure a change in a parameter.

4.10. *Imager Grid Tray Temperature Controller*

The imager grid trays must be kept within 3°C of each other when the instrument is in data taking mode. Heat must be applied as evenly as possible to minimize distortion cause by time-varying thermal gradients. When enabled, this task shall control the Imager Grid Tray Heaters to maintain the grid trays within the desired differential based on the measured grid tray temperatures. The grid trays have several temperature sensors;

one or more sensors (programmable) will be averaged for the control function. Proportional control shall be maintained by cycling power to the colder grid tray heater with a selectable duty cycle in one second increments on a 10 second cycle. The software shall implement a simple PID control loop (gains TBD by thermal modeling, and programmable).

A second control mode which keeps both grid trays at a desired temperature, rather than just controlling the difference, may be required (TBD).

4.11. *Cryocooler Power Converter (CPC) Temperature Controller*

The CPC must be maintained above its lower operating limit. When enabled, this driver shall implement a simple on/off control of the CPC heater based on the measured CPC temperature provided by the ADC (a software thermostat). The temperature setting shall be programmable, defaulting to -30°C.

The measured temperature shall also be compared with an upper limit (default value TBD). If the upper limit is exceeded, a message shall be sent to the Coldplate Temperature Controller task to turn down the cryocooler power level (to decrease the CPC power dissipation).

4.12. *Cryocooler Temperature Controller*

The Cryocooler must be maintained above its lower operating limit. When enabled, this driver shall implement a simple on/off control of the Cryocooler heater based on the measured Cryocooler temperature provided by the ADC (a software thermostat). The temperature setting shall be programmable, defaulting to -30°C.

The measured temperature shall also be compared with an upper limit. If the upper limit is exceeded, a message shall be sent to the Coldplate Temperature Controller task to turn down the cryocooler power level.

4.13. *Spectrometer Temperature Controller*

The spectrometer temperature controller controls the internal temperature of the spectrometer by setting the cryocooler and cold plate heater power levels.
Reset mode selection based on coldplate temperature.

4.13.1. Cool-Down Mode

4.13.2. Warm-Up Mode

4.13.3. Detector Anneal Mode

4.13.4. Data Taking Mode

4.13.5. Safe Mode

4.14. *Cryocooler Controller*

The desired cryocooler power level is set by the Spectrometer temperature controller. The cryocooler controller sets the controls (cryocooler waveform amplitude, balancer amplitude and phase) to achieve that power level. The cryocooler controller also enforces the following rules on the power level as a function of time and cryostat temperature:

- Power level must start at no more that TBR% at cooler power-on, and ramp up at no more than TBR%/minute
- Power level shall not be less than TBR (except when it is off).

The cryocooler power service is shorted by a relay at launch. This relay must be opened first power application

4.15. *Actuator Controller*

There are a number of one-time actuators, plus the shutter multi-use actuators, controlled by the IDPU processor. These actuators are Shape Memory Alloy (SMA) systems, which provide a force when heated by passing current through them. This current is provided by an actuator power supply run off the Switched Power Service from the spacecraft. Processor-controlled switches connect the supply to the actuators. In addition, a processor-controlled ‘Actuator Enable’ switch on the primary input to the actuator supply allows the supply power overhead to be removed when it is not being used, and provides a level of safety.

Only one actuator may be activated at a time. Requests for actuator activation must be queued if a second activation request comes while an activation sequence is in progress.

4.15.1. Actuator Enable

The software shall maintain an Actuator Enable flag. This flag will default to disabled on processor reset, and can be enabled or disabled by ground command. When disabled, the Actuator Enable switch shall remain off, and all requests to the software to activate and actuator shall be rejected.

4.15.2. RAS Shutter, Vacuum Valve, and Shutter Latch-Down Actuators

These are one-time actuators. When a command is received to actuate one of these, and the Actuator Enable flag is set, then the following sequence shall be started:

- Turn on the Actuator Enable switch
- Wait 1 second for power converter to stabilize
- Turn on the selected actuator

- Wait 2 seconds
- Turn off the selected actuator
- Turn off the Actuator Enable switch

4.15.3. Shutter Actuators

The shutter multi-use actuators may be activated either by ground command or automatically (see Event throttle Controller section). Any attempt to actuate the shutters shall be rejected if the Actuator Enable flag is not set. A separate ground-programmable enable flag must be set to allow automatic control the actuators by the Event Throttle Controller task. In addition, the software must check the status of the shutter latch-down (using the actuator monitor). If the shutters are latched-down, then any shutter actuation should be rejected.

There are two separate shutter systems, each of which have two positions. A separate actuator pulls a shutter in each direction (a total of four actuators). Two position switches for each shutter indicate when the shutter is at one of the two stops. These switches automatically turn off an actuator when the desired position has been reached. The software also can monitor the position switches. If a request comes to change the shutter position and it is already in the requested position, the request shall be rejected. Also, a given shutter cannot be activated again sooner that 2 minutes (TBR) after the previous activation. A request to move a shutter sooner than that interval shall be rejected.

Assuming all these requirements are met, the shutter actuation sequence is:

1. Turn on the Actuator Enable switch
2. Wait 1 second for power converter to stabilize
3. Turn on the selected actuator
4. Time how long it takes for the shutter to leave its starting position (polling the shutter position monitor at at least 16Hz - TBR). If it takes more than 1 second (TBR) to do so, discontinue the activation (jump to step 7).
5. Once the starting position has been left, reduce power to the shutter actuator to 40% (TBR, programmable). Do this by duty-cycling the actuator power switch on a 5-step cycle at TBD Hz.
6. Continue to power the actuator until the desired position is reached, or a time-out of 2 seconds (TBR) from the time it left the starting position.
7. Turn off the actuator
8. Turn off the Actuator Enable switch

The Timing interrupt will be needed for this sequence.

4.15.4. Actuator Monitors

There are a number of digital actuator status monitors. These shall be sampled and included in the SOH data once a second. In addition, the shutter position monitors need to be sampled more often (at least 16 Hz -TBR, sampled by the timing interrupt), and included in the science packet data headers at the sample time (see Science Packet Data Header Handler section).

4.16. *Watchdog Handler*

The watchdog handler shall reset the watchdog circuit each time it is called (once a second).

Misc:
  Data path (formatter) monitoring
  Overcurrent trip ?

5. Memory Usage

The processor has 8Kbytes of PROM and 32Kbytes of RAM. The default software will be contained in the PROM. On reset, the PROM is copied into the RAM and then turned off. Table 4-1 lists the RAM usage. Total usage is 15.1Kbytes out of 32Kbytes.

Table 4-1 RAM usage

Contents	Size
Default Code	8K
Upload code patch space	1K
ADP Diagnostic Packet Buffer	1K
Telemetry Block Transmit Buffer, 2x	2.8K
Command Block Receive Buffer, 2x	1K
ADC Sample Block	0.3K
Control Parameters, stack, etc.	1K