ESA & SST (ETC) Board Requirements

Rev.	Date	Description of Change	Approved By
1.1		First Draft	-
1.2	3/02/04	Changed description of Distributions (sec 3.1.2) Changed order and description of telemetry (sec 4.3)	
1.3	6/21/04	Changed addresses for distribution tables (sec 4.1)	
1.4	7/23/04	Changed address and size for SST housekeeping (s 4.2)	
1.5	09/15/04	Changed commands, data description, SST data order.	
1.6	01/27/05	Spacecraft potential, moment calculation, commands	
1.7	04/01/05	Corrected wording in commands, details in distribution	

The ETC board interfaces with both the ESA and the SST collecting data, calculating moments, accumulating distributions, and transferring data to the solid-state recorder.

1. ESA Interface

The ESA requires 2 serial interfaces: 1 for commanding and 1 for data. Both interfaces are 3 wires, but the 3rd wire for both is a shared signal called CMD_GATE.

1.1 Command Interface

The interface signals consist of a gated CMD_CLK at 2^{20}Hz (1,048,576Hz) , a CMD_DATA line, and a 2-CMD_CLK cycle long CMD_GATE pulse. The interface timing is shown in Figure 1. The CMD_DATA should be clocked in on the rising edge of CMD_CLK. Data is shifted in Most Significant Bit (MSB) first. Because commands will arrive at the ETC without regard to the CMD_GATE, the ETC will hold a command until it sees a CMD_GATE signal go high and then low. It will then send the command to the ESA.

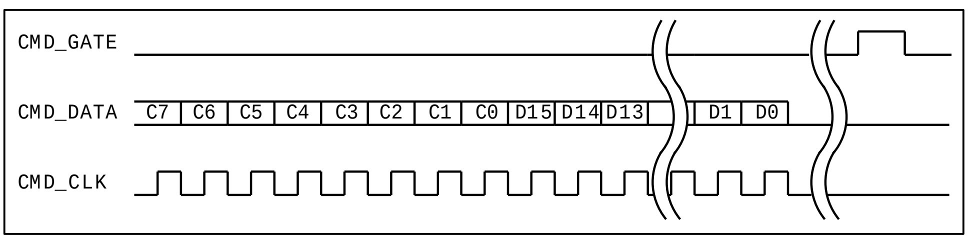

Figure 1: ESA Command Interface

Commands consist of 24 bits. The first 8 bits are considered the address of the register to be programmed (ESA commands are those with Address 0X or EX). The 16 remaining bits are the value to be programmed into the register. The CMD_GATE signal should be used to latch the data field into the selected register and to synchronize transfers.

The CMD_GATE signal shall be spin-synchronous at 16,384 pulses per spin continuously. This signal is used for the ESA to time accumulations and control sweeps. If no clock pulses occur, no command should be latched. The CMD_GATE has also been resynchronized to the 2^{20}Hz = 1,048,576Hz clock so that its edges are synchronous with TLM_CLOCK (see below). This involves less than 1μs jitter in the sector timing.

1.1.1 Spin Synchronization

The ESA collects data on a spin basis and therefore needs to know when a spin begins and ends. To provide this information, the ESA will receive a command through its command interface which tells it where a spin boundary is. The beginning of a new spin is defined as the first rising edge of TLM_CLK after CMD_GATE goes high to latch in the SPIN_SYNC (02) command. The SPIN_SYNC command will be generated by the ETC.

1.2 Telemetry Interface

Data shall be sampled synchronous to the spin using the timing provided by the Command interface. Data from the counter string shall be shifted out onto the serial telemetry interface.

The interface shall consist of 3 wires; the CMD_GATE provided by the ETC board (the same one used in the Command interface described above), used to latch counters and synchronize collection and transmission, a gated TLM_CLK signal (2^{20}Hz = 1,048,576Hz) also provided by the ETC board, and the serial TLM_DATA line provided by the instrument. The timing for the interface is shown in Figure 2. A counter readout sequence is initiated every sixteenth CMD_GATE, synchronized to include the CMD_GATE of the SPIN_SYNC command.
Following the CMD_GATE pulse starting the readout sequence, 24 counter read cycles will be performed. Counters are read out starting with 16 iESA counts followed by the 8 eESA counts. Each datum represents the count (sample) of electrons or ions at one energy for one elevation angle.

TLM_DATA is shifted out on the rising edge of TLM_CLK following the first falling edge of TLM_CLK with CMD_GATE high. The MSB of the data will be shifted in the ETC on the next rising edge of TLM_CLK synchronous with the falling edge of CMD_GATE. A word transfer constitutes 16 bits. Subsequent words are read out after 48 clock gaps until all 24 counters are read.

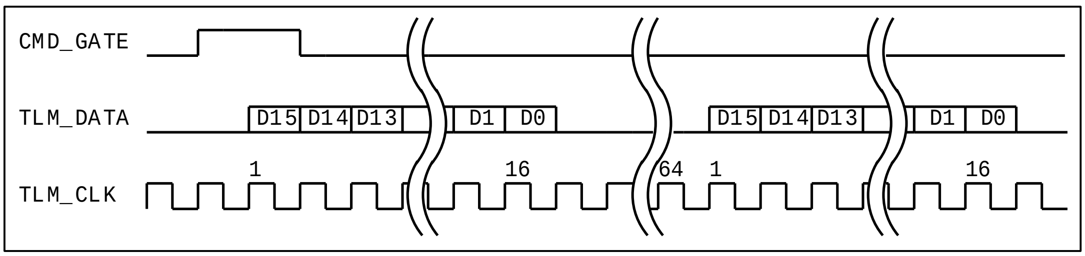

Figure 2: ESA Telemetry Interface

1.3 Analog housekeeping

The ESAs have several analog housekeeping channels that are read through one analog feedback. The ESA has a multiplexer on it that selects which channel is fed to the ADC that resides on the DCB. The mux channel is selected through CDI.

1.4 Connector to ETC

The connector between the ETC and the ESA resides on the DCB/ETC board on the ETC half. It is a male DB9 connector. The pinout is:

1: EANA_HSK – Analog housekeeping
6: EANA_GND – Analog ground from ESA
2: Digital ground
7: ETLM_CLK – Telemetry clock from ETC
3: ECMD_CLK – Command interface clock from ETC
8: ECMD_DATA – Command interface data from ETC
4: ECMD_GATE – Command interface gate signal and 16384 clock from ETC
9: ETLM_DATA – Telemetry (science) data from ESA
5: Digital ground

2.0 SST Interface

2.1 Command Interface

The SST uses the standard THEMIS command interface to be commanded by the DCB (main processor). Figure 3 shows the command interface timing. Note all signal polarities are as measured on the backplane.

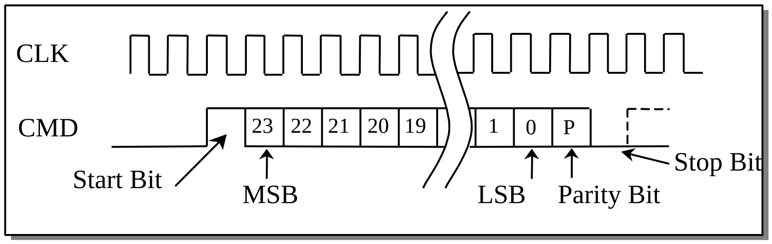

Figure 3: SST Command Interface

2.1.1 Clocking edge

The receiving circuit should clock in the data bits on the falling edge of CLK (to avoid a race between the CMD and CLK signals).

2.1.2 Command Synchronization

The system synchronizes by finding the first non-zero bit (the START bit), and verifies synchronization by the presence of a zero-value STOP bit. After a reset or loss of synchronization, the receiving system should look for 24 consecutive zero-level bits before starting to look for a start bit to avoid incorrect interpretation of a transfer in progress.

2.1.3 Data Stream Format

Commands are 24-bits long, preceded by a start bit, and followed by parity bit and a stop bit. The 24 bits are sent MSB first. The parity is odd and includes the 24 command bits but not the start bit, so that a command with all 24 bits zero would have the parity bit on. Commands can start on any rising edge of CLK, and any number of idle bit periods can occur between commands. The data is transferred Most Significant Bit (MSB) first. Messages consist of an 8-bit identifier (CMD_ID) in the 8 MSB, followed by a 16-bit data field in the LSB (CMD_DATA). The parity bit shall be set such that the sum of the number of set bits in the 24 command data bits plus the parity bit is odd. It is expected that instruments will reject commands with bad parity or framing (no stop bit), and optionally report an interface error in their telemetry stream. No commands retries will be attempted.

2.2 Telemetry Interface

Figure 4 shows the telemetry interface timing. Note all signal polarities are as measured on the backplane.

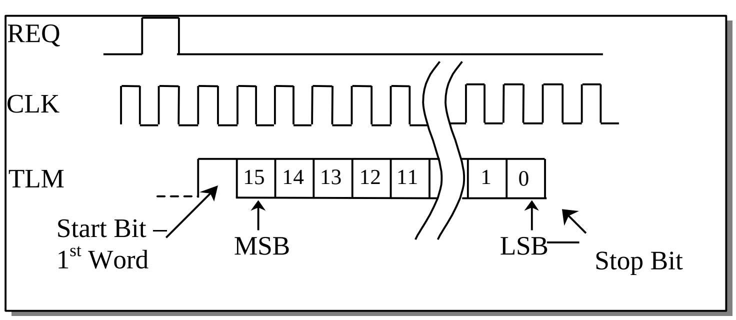

Figure 4: SST Telemetry Interface

2.2.1. Clock Edge

The instrument shall shift the next bit of the message out on the rising edge of CLK. The bit will be sampled by the ETC on the next rising edge of CLK.

2.2.2. Telemetry Synchronization

The ETC will begin requesting data when it enters a new spin sector (1/32 spin) starting with the first spin sector after a spin synchronization. The SST will synchronize to the spin sector following the 1 clock cycle long SPIN_32 signal. The SPIN_32 signal is changed on the falling edge of CLK so should be sampled on the rising edge. The ETC will issue a telemetry request and wait for the SST to respond. The ETC shall synchronize to the first non-zero data bit from the SST as the START bit of the message. The message will consist of 16 data bits followed by a zero as a STOP bit.

2.2.3 Data Stream Format

Messages shall consist of a one 16-bit word.

When a spin phase is over (1/32 spin), the ETC will begin collecting data from the SST. The rate of data collection will be variable since the ETC will also be collecting data from the ESA at the same time. Data will be collected one count (sample) at a time so that it can do all processing on the count before throwing it out. A typical period between data collection will be 65us.

The data order will be energy (starting from the lowest) followed by θ angles (lowest to highest), ions preceding electrons. After the 16 counts (16 energies) are collected for a single θ, energies for the next θ will be collected. After all data for ions are collected, electron data begins following the same ordering as ions.

2.3 Digital Housekeeping

After all science data has been passed to the ETC (64 ion words followed by 64 electron words), the SST will pass 128 digital housekeeping words to the ETC. The ETC will put these housekeeping words into memory at addresses 0x8680 through 0x86FF. Since there are 128 new housekeeping words each spin sector, these words are placed on top of the old values and collected whenever the processor wants them through the table read interface.

2.4 Analog Housekeeping

The SST will pass back through the ETC an analog output which is to be measured by an A/D converter for housekeeping. There are 5 different analog signals that need sampling – 4 thermistors and 1 bias voltage. The outputs are muxed on the SST board with the selection of the mux being done by the processor through the command interface.

3.0 Data Products

Both instruments will produce survey and burst data. Both data types are always sent to the memory where they are put into circular buffer. The processor will decide which data to keep and which to overwrite.

3.1 Survey data

The instruments will produce 2 types of survey data: 1) partial moment 2) angle distributions

3.1.1 Moment data

There are 13 moment values computed from each instrument which are calculated using raw data over an entire spin. The moment sum is

$$M_i = \sum_{Eqf} C_{Eqf} \Omega_{qfi} W_{EN} P_{EN}$$

where

C_{Eqf} is the count at a particular energy (E), angle of elevation (θ) and spin phase (ϕ)

Ω_{qfi} is the solid angle

W_{EN} is an energy weighting factor: $E^{(N-1)/2}$

P_{EN} is the spacecraft potential correction $\left(1-\frac{V}{E}\right)^{N+1/2}$ for electrons and $\left(1+\frac{V}{E}\right)^{N+1/2}$ for ions.

i is the 13 moments and N varies over the 13 moments as follows

Moment	N	Moment number(i)
Density	0	0
Flux	1	1-3
P	2	4-9
Q	3	10-12

The 13 moments need to be computed for each of the particles instruments – ESA electrons, ESA ions, SST electrons (foil) and SST ions (open). All instruments will have different tables of values used in the calculation. For more information on tables, see section **4.2.**

The product WP will be computed by the ETC board before all moment calculations begin. The computation is begun when the spacecraft potential value is commanded by the processor. The moment calculation will then take the form.

$$M_i = \sum_{Eqf} C_{Eqf} \Omega_{qfi} WP_{EN}$$

The order of evaluation should be WP * Ω, then that result times C. Multiplications are done with 16 bit values, but the sums will be accumulated using a shifted version of the multiplier's 32 bit output. How many bits are shifted is commandable from 1 to 8.

3.1.1.1 Moment Calculation Algorithm

Each of the 13 moments is updated with each new data value. When an instrument sends a count to the ETC, the ETC calculates all 13 moments for that value. The algorithm used for the moment calculation is:

Lookup M_i
Lookup Ω
Lookup WP_{EN}
Multiply Ω * WP_{EN} (temp = omega*weight)
Shift product right 14 bits (temp = temp >> 14)
Add 1 if the value is negative (if (temp <0) temp = temp + 1
Shift result right 1 bit (temp = temp >> 1)
Multiply result by C (temp = temp * C)
Shift result right 1-8 bits (temp = temp >> mom_shift+1)
Add result to M_i (moment += temp)

3.1.1.2 Spacecraft potential correction calculation

P is calculated using several lookup tables loaded by the processor. These tables are:

$$1/E,\ 1/\sqrt{E},1,\sqrt{E},E$$

where E takes on 32 instrument specific values and *i* takes on 4. P cannot go negative so that if a negative value is computed, it is set to 0.

We will also need tables of values for $0 \le x \le 1$ of $x^{1/2}$, x , $x^{3/2}$, x^2 .

The P correction calculator will then compute $WP_{Ei} \rightarrow E^{(N-1)/2}\left(1-\frac{V}{E}\right)^{N+1/2}$ and put it into a table. For the SST, P is 1.

3.1.2 Survey accumulated data

The ETC board will reduce the number of raw fields of view (a.k.a. angles) seen by the instruments by combining neighboring angles in such a way as to reduce oversampling of any field of view. Data will be binned to produce this reduced field of view. There will be both a high data rate accumulation and a low data rate accumulation operating at all times, both covering the entire field of view. These differ in that one is a full distribution with finer angle bins and energies while the other is a reduced distribution with coarser angle bins and energy. For each count received, ϕ and θ will be combined and used as the index into a lookup table. The lookup table value will be the index into the memory that holds the accumulation for the reduced angle bin. The data at the location will be read, incremented, and written again. Before transmission, all data will be converted from 16 bits to 8 bits using pseudo-square root compression (see section 3.3).

Because sometimes the accumulation needs to be aligned with the magnetic field, ϕ will be offset before the lookup takes place:

$f = f - f_B$ where ϕ_B is the sector offset from the magnetic field.

3.1.2.1 Full data distribution

The full data distribution will reduce the number of ESA angles from 512 (32ϕ* 16θ) down to a smaller number of solid angle bins. Ion and electron data will use separate angle definitions. For the ESA, there will generally be 88 angles bins.

Since ESA counters are 14 bits, the accumulations may overflow. When any addition overflows, the value will be set to all 1s but left at 16 bits. The lookup table will be 1024 or 512 values long by 2 bytes wide and will be loaded by the processor.

The SST will also reduce it's number of viewable angles from 128 (32ϕ* 4θ) down to 64(16ϕ* 4θ). It will also use a separate lookup table for its ion and electron data, both tables being 128 16-bit values.

For each instrument there will be a commanded value called xYZspins that tells the ETC how many spins to process before transmitting data to memory. There will also be a commanded value called "Overwrite" that tells the ETC to sum distribution data over those spins or to simply produce a single spin (the last one).

3.1.2.2 Reduced data distribution

The reduced data distribution differs from the full data distribution in the number of angles and energy bins. Typically, instead of having 88 or 64 fields of view, the reduced data distribution will have 6 or 8 fields of view, again, set up by lookup tables. Also, instead of binning into 32 (ESA) or 16 (SST) energies, the ETC will bin into 16 (ESA) and 8 (SST) energies.

The reduced data distribution will also have a commanded xYZspins value that tells how many spins to capture data over. Data also will either be summed over this period or the last spin will transmitted.

3.1.2.3 Distribution Algorithm

Because distributions combine bins and because the binning may be irregular, lookup tables will be used to translate the angle and energy to a bin. There will be two separate lookup tables for each distribution, one for angular binning and one for energy binning. These two table values will be added together to produce a memory location for a particular bin. One of the tables must define a full 16 bit memory address (the 17th MS bit will be assumed to be 1) so that when they are added, the number can be used to access memory with no further computation. The 16th bit must also be zero as it will be toggled for double buffering the data.

angle_bin = table_base | phi < 4 | theta
energy_bin = table_base | ion < 5 | energy
count_bin = {angle_bin} + {energy_bin}
bin_value = {count_bin} + count

3.2 Burst Data

Burst data is simply a full data distribution that gets transmitted to the solid-state recorder every spin. There will be one accumulation for each instrument.

3.3 Data compression

All distribution data will be compressed from 16 bits to 8 bits via a pseudo square-root compression scheme.

3.4 Solar wind mode

In solar wind mode, iESA data is collected with finer angular resolution when the instrument is pointed toward the wind. To do this, ϕ will be increased to 64 angles, but energy bins will be reduced from 32 to 16 bins. Distributions can be calculated the same as when we are not in solar wind mode (extra phi angles will be put into separate energy bins), but moments will need to keep track of all 64 angles.

4.0 Processor interface

4.1 Commanding

The processor controls the ETC setup through the command interface. The standard THEMIS command interface described in section 2.1 is used.

Table 2: ETC Commands

Command	Name	Description
20	iEF_addr	Address of iESA Full Distribution (FD) data
21	iER_addr	Address of iESA Reduced Distribution (RD) data
22	eEF_addr	Address of eESA FD data
23	eER_addr	Address of eESA RD data
24	iSF_addr	Address of iSST FD data
25	iSR_addr	Address of iSST RD data
26	eSF_addr	Address of eSST FD data
27	eSR_addr	Address of eSST RD data
28	iEF_spins	Collect over iEF_spins +1 for iESA full distribution
29	iER_spins	Collect over iER_spins +1 for iESA reduced dist
2A	eEF_spins	Collect over eEF_spins +1 for eESA full dist
2B	eER_spins	Collect over eEF_spins +1 for eESA reduced dist
2C	iSF_spins	Collect over eEF_spins +1 for iSST full dist
2D	iSR_spins	Collect over eEF_spins +1 for iSST reduced dist
2E	eSF_spins	Collect over eEF_spins +1 for eSST full dist
2F	eSR_spins	Collect over eEF_spins +1 for reduced dist
30	Average	Sum (1) distributions or overwrite (0) iEF|iER|eEF|eER|iSF|iSR|eSF|eSR
31	Mag_offset	Magnetic field offset from sun in ϕ
32	V	Spacecraft potential
33	Control	bit 0: Start processing ESA data (ON/OFF) bit 1: Start processing SST data (ON/OFF) bit 3: Disable spacecraft potential correction
34	Transmit	Transmit data from iEF|iER|iEB|eEF|eER|eEB|iSF|iSR|iSB|eSF|eSR|eSB
35	Table address	The address used for reading and writing tables
36	Table value	The value to write for the next address
37	Table read	Read a value from the table pointed to by address
39	iEB_addr	Address of iESA Burst Distribution data
3A	eEB_addr	Address of eESA Burst Distribution data
3B	iSB_addr	Address of iSST Burst Distribution data
3C	eSB_addr	Address of eSST Burst Distribution data
3D	iEF_length	Length in words of iESA Full Distribution
3E	iER_length	Length in words of iESA Reduced Distribution
3F	iEB_length	Length in words of iESA Burst Distribution
B0	eEF_length	Length in words of eESA Full Distribution
B1	eER_length	Length in words of eESA Reduced Distribution
B2	eEB_length	Length in words of eESA Burst Distribution
B3	iSF_length	Length in words of iSST Full Distribution
B4	iSR_length	Length in words of iSST Reduced Distribution
B5	iSB_length	Length in words of iSST Burst Distribution
B6	eSF_length	Length in words of eSST Full Distribution
B7	eSR_length	Length in words of eSST Reduced Distribution
B8	eSB_length	Length in words of eSST Burst Distribution
B9	iESA_config	Configuration of iESA tables
BA	eESA_config	Configuration of eESA tables
BB	iSST_config	Configuration of iSST tables
BC	eSST_config	Configuration of eSST tables
BD	mom_shift	3 bit value determines shift before sum for moments bits 2-0: Shift eSST product 1-8 bits bits 6-4: Shift iSST product 1-8 bits bits 10-8: Shift eESA product 1-8 bits bits 14-12: Shift iESA product 1-8 bits

The spacecraft potential command (V) must be sent every spin, preferable near the beginning of a spin.

4.2 Table load interface
Tables will be loaded through the command interface All tables have a set location in memory as described in table 3. There are 31 tables, all 16 bits wide. To load a table, the processor will send the "Table address" command with the address necessary for the desired table. Since the ETC will auto-increment the address used , the processor only needs to send successive "Table value" commands to fill in the table.

Table 3 describes the tables the ETC will use.

Table 3: Table Definitions

Table function	Address bits arrangement	Address Range
iESA $\Omega_{\theta\phi i}$	11 & i(4) & ϕ(6) & θ(4)	C000-F3FF
eESA $\Omega_{\theta\phi i}$	0010 & i(4) & ϕ(5) & θ(3)	2000-2CFF
iSST $\Omega_{\theta\phi i}$	0011 0 & i(4) & ϕ(5) & θ(2)	3000-367F
eSST $\Omega_{\theta\phi i}$	0011 1 & i(4) & ϕ(5) & θ(2)	3800-3E7F
iESA FD ∠ lookup table	0100 000 & ϕ(5) & θ(4)	4000-41FF
eESA FD ∠ lookup table	0100 0100 & ϕ(5) & θ(3)	4400-44FF
iSST FD ∠ lookup table	0100 1000 0 & ϕ(5) & θ(2)	4800-487F
eSST FD ∠ lookup table	0100 1000 1 & ϕ(5) & θ(2)	4880-48FF
iESA RD ∠ lookup table	0100 001 & ϕ(5) & θ(4)	4200-43FF
eESA RD ∠ lookup table	0100 0101 & ϕ(5) & θ(3)	4500-45FF
iSST RD ∠ lookup table	0100 1001 0 & ϕ(5) & θ(2)	4900-497F
eSST RD ∠ lookup table	0100 1001 1 & ϕ(5) & θ(2)	4980-49FF
ESA W_{En}	0101 0000 & ion(1) & N(2) & E(5)	5000-50FF
SST W_{Ei}	0101 0001 0 & ion(1) & N(2) & E(4)	5100-517F
ESA corrected W_{En}	0101 001 & db(1) & ion(1) & N(2) & E(5)	5200-53FF
ESA $1/E$	0101 0100 & ion(1) & E(5)	5400-543F
$x^{N+1/2}$	011 & N(2) & X(11)	6000-7FFF
iESA Burst ∠ lookup table	1000 000 & ϕ(5) & θ(4)	8000-81FF
eESA Burst ∠ lookup table	1000 0010 & ϕ(5) & θ(3)	8200-82FF
iSST Burst ∠ lookup table	1000 0100 0 & ϕ(5) & θ(2)	8400-847F
eSST Burst ∠ lookup table	1000 0100 1 & ϕ(5) & θ(2)	8480-84FF
ESA FD E lookup table	1000 0101 00 & ion(1) & E(5)	8500-853F
ESA RD E lookup table	1000 0101 01 & ion(1) & E(5)	8540-857F
ESA Burst E lookup table	1000 0101 10 & ion(1) & E(5)	8580-85BF
SST FD E lookup table	1000 0101 110 & ion(1) & E(4)	85C0-85DF
SST RD E lookup table	1000 0101 111 & ion(1) & E(4)	85E0-85FF
SST Burst E lookup table	1000 0110 000 & ion(1) & E(4)	8600-861F
SST Housekeeping	1000 0110 010 & value(7)	8680-86FF

Note: FD stands for Full Distribution, RD for Reduced Distribution, ∠ for angle, E for Energy, DB for double buffer

4.2.1 Table needs

Efficient tables, solar wind		bytes
header	200	512
iesa_omega (i=0)	800	2048
iesa_omega (i=4-9)	3000	12288
iesa_angle_fd	400	1024
eesa_angle_fd	200	512
	4000	16384

iesa_omega (i=1,2,3)	1800	6144
eesa_omega (i=0)	200	512
eesa_omega (i=1,2,3)	600	1536
eesa_omega (i=4-9)	C00	3072
isst_omega (i=0)	100	256
isst_omega (i=1,2,3)	300	768
isst_omega (i=4-9)	600	1536
esst_omega (i=0)	100	256
esst_omega (i=1,2,3)	300	768
esst_omega (i=4-9)	600	1536
	4000	16384

exponent	4000	16384

		bytes
iesa_angle_rd	400	1024
iesa_angle_bd	400	1024
eesa_angle_rd	200	512
eesa_angle_bd	200	512
isst_angle_fd	100	256
isst_angle_rd	100	256
isst_angle_bd	100	256
esst_angle_fd	100	256
esst_angle_rd	100	256
esst_angle_bd	100	256
esa_weight	200	512
sst_weight	100	256
esa_energy_fd	80	128
esa_energy_rd	80	128
esa_energy_bd	80	128
ESA 1/E	80	128
sst_energy_fd	40	64
sst_energy_rd	40	64
sst_energy_bd	40	64
	17C0	6080

4.3 DMA channels to the solid-state recorder

There will be 13 data streams (DMA channels) of instrument data to the solid-state recorder plus an additional engineering data stream. All data is sent through one standard interface that consists of 8 identification bits followed by 16 data bits. The interface clock used is the 8 MHz master clock and all channels share one data line. Although much of the data is only 8 bits long, data is packed two values to one transmission. Also, some data words (moments) are 32 bits long. All data except memory readbacks are arranged so that when it comes out of the SSR, the most significant byte is first. So a 32 bit word 0x12345678 will be transmitted as 12 34 56 78. For table reads though, the bytes are reversed.

The protocol for sending telemetry is shown in Figure 5.

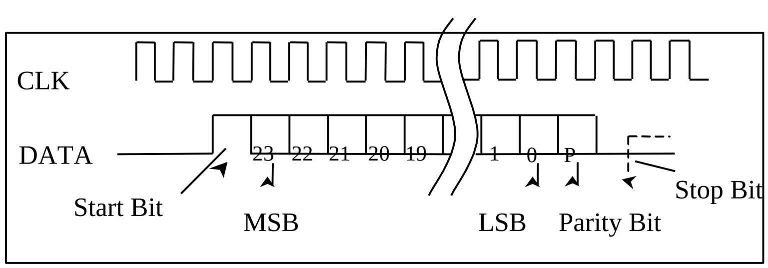

Figure 5 : ETC Telemetry Interface

The following table describes the 14 DMA channels.

Data ID	Data type	Data order	Data Length
0	Moments from all instruments	Status: MSB: 4 SST attenuator bits LSB: Valid bits: SST ESA Spacecraft potential (2 bytes) iESA moments 1-13 eESA moments 1-13 iSST moments 1-13 eSST moments 1-13	208 bytes/spin
1	iESA full distribution	Configuration (2 bytes) 4 SST attenuator bits (1 byte) #spins in data set (1 byte) Data (order programmable)	2816 bytes/iEFspins Typ 4736 bytes/iEFspins Max?
2	iESA reduced distribution	Configuration (2 bytes) 4 SST attenuator bits (1 byte) #spins in data set (1 byte) Data (order programmable)	96 bytes/iERspins Typ
3	iESA burst distribution	Configuration (2 bytes) 4 SST attenuator bits (1 byte) #spins in data set (1 byte) Data (order programmable)	2816 bytes/spin Typ 4736 bytes/spin Max?
4	eESA full distribution	Configuration (2 bytes) 4 SST attenuator bits (1 byte) #spins in data set (1 byte) Data (order programmable)	2816 bytes/eEFspins Typ
5	eESA reduced distribution	Configuration (2 bytes) 4 SST attenuator bits (1 byte) #spins in data set (1 byte) Data (order programmable)	96 bytes/eERspins Typ
6	eESA burst distribution	Configuration (2 bytes) 4 SST attenuator bits (1 byte) #spins in data set (1 byte) Data (order programmable)	2816 bytes/spin Typ
7	iSST full distribution	Configuration (2 bytes) 4 SST attenuator bits (1 byte) #spins in data set (1 byte) Data (order programmable)	1024 bytes/iSFspins Typ
8	iSST reduced distribution	Configuration (2 bytes) 4 SST attenuator bits (1 byte) #spins in data set (1 byte) Data (order programmable)	48 bytes/iSRspins Typ
9	iSST burst distribution	Configuration (2 bytes) 4 SST attenuator bits (1 byte) #spins in data set (1 byte) Data (order programmable)	1024 bytes/spin Typ
A	eSST full distribution	Configuration (2 bytes) 4 SST attenuator bits (1 byte) #spins in data set (1 byte) Data (order programmable)	1024 bytes/eSFspins Typ
B	eSST reduced distribution	Configuration (2 bytes) 4 SST attenuator bits (1 byte) #spins in data set (1 byte) Data (order programmable)	48 bytes/eSRspins Typ
C	eSST burst distribution	Configuration (2 bytes) 4 SST attenuator bits (1 byte) #spins in data set (1 byte) Data (order programmable)	1024 bytes/spin Typ
D	Table readout	Table value	2 bytes

The data size and ordering are dependent on the programming of ETC. Data order is determined by the combination of values in the Energy lookup table and the Angle lookup table (see section **3.1.2.3)**. Values can be grouped either by energy bin or by angle bin which will be determined by the compression scheme. Data size is dependent on the number of bins the distributions are programmed to accumulate into.

4.4 Data Headers

Time and spin number will be inserted into the solid-state recorder by the processor after data has been collected. The processor will also insert the attenuating shutter position.

5.0 Design analysis

5.1 Memory requirements

5.1.1 Memory size

The iESA memory usage for accumulations is (worst case 256 angles):
148*32*2 (2 bytes)*2 (double buffered)*2 (Survey+Burst) = 37,888 bytes
+ 4096 bytes for lookup tables (64*16*2bytes*2distributions)

For eESA accumulations: 88*32*2*2*2 = 22,528 bytes
+ 2048 bytes for lookup tables

SST accumulations:
64*16(E)*2*2*2*2(iSST and eSST) = 16,384 bytes
+ 512 bytes

Moment tables: 44,928

Total memory allocated: ~155 Kbytes.

Two 128k memory devices will be necessary. They should be set up as one 16 bit memory device.

5.1.1 Memory access speed

When an instrument delivers a sample to the ETC board, the ETC board will do all calculations and accumulations with it that are necessary, then it will throw the value away. This relieves the ETC from having to store large amounts of raw data. From this, it will be fairly accurate to calculate memory access speed.

For an entire spin, the ESA will deliver 32(E)*32(ϕ)*24(θ)=24,576 samples.
For an entire spin, the SST will deliver 16(E)*32(ϕ)*8(θ)=4,096 samples.
Therefore, the ETC will get 28,672 samples/spin or ~10,000 samples/s.
Each value is available for >100us for use.

In these 100us, the ETC will execute the following memory accesses:

Usage	Accesses	Notes
read lookup table (for accumulations)	3	2 survey and 1 burst
read accumulations	3	2 survey and 1 burst
write accumulations	3	2 survey and 1 burst
read Ω	13	Moment calculation
read *WP*	13	Moment calculation
write table value	2	(from processor)
read outgoing telemetry value	10	Estimate
Total	47	

5.2 Moment calculation speed

The fastest computation will be computing the moments for iESA since it has the most counts.

Multiplications/spin = 32(E) * 32(ϕ)* 16(θ) * 2 (WP*Ω*C) * 13(moments)
= 425,984

Multiplication rate = 425,984 mult/spin * 1 spin/3 sec
= 141,995 mult/sec
Multiplication time ≈ 7.0 us

If all instruments use the same multiplier:
141,995 + 70,998 + 35,499 = 248,492 or
4.02 us per multiplication

5.3 Memory Allocation

Memory is split into 2 halves: the lower half is dedicated to tables and the upper half is dedicated to data products. Where data products will go in memory will be defined in the lookup tables (for distributions of all types). Because we will need double buffers, the upper bit of the address (bit 15) will be toggled to toggle buffers.