ISEE

Jeff Childs

4/25/77

A SPIN SYNCHRONOUS CLOCK

GENERAL:

For spinning spacecraft, it is necessary to have a method of relating spin rate and position to a known reference in order to execute maneuvers and process experiment data. As an outgrowth of these requirements, experimenters have found it useful to have the spin period divided into sectors. For these reasons, the Spin Sync Clock was developed for use on ISEE-A and ISEE-C.

The Spin Sync Clock (SSC) has the following operating capabilities:

1. Select, by serial command, one of two sun sensors, each of which has a pre-programmed offset, selectable at time of fabrication, in increments of 1/2048-th of a spin period.

2. Select, by serial command, a mode which ignores all sun sensor signals and causes operation at a rate specified by that command. There are 21 command bits for varying the rate.

3. Select, by serial command, a mode which ignores all sun sensor signals and causes the operation to remain at the last known rate of spin.

4. Select, by serial command, only the actual sun sensor signal or alternately, the sun sensor signal and the SSC generated signal to determine the two quantities-SUN TIME and SUN PERIOD. Both quantities are determined before the control signal changes.

5. Provide input channel for the magnetometer so that MAG TIME and MAG PERIOD can be determined.

The quantities described in 4 and 5 are read out in the telemetry. The SENSOR TIME is the time between a telemetry signal and sensor signal; and SENSOR PERIOD is the time between sensor signals. These two times are measured in cycles of 8192 Hz by individual 16 bit binary accumulators (8 seconds maximum without overflow protection).

The SSC is basically a digital phase locked loop. Its outputs are two signals, SUN PULSE, occurring once per input signal, and 1024 PULSES PER SPIN (PPS), occurring 1024 times between input signals. The rates of these two signals are determined by some previous period between inputs.

COMMAND BIT FUNCTIONS:

C23 & C22 - Mode Select

C22	C23	Function
0	0	Selects SENSOR I with pre-programmed offset when A-taps = "1" and B-taps = "0".
0	1	Selects SENSOR II with pre-programmed offset when A-taps = "0" and B-taps = "1".
1	0	Selects CAL SUN PULSE which is the differentiated MSB of the countdown as it overflows. The period of the countdown is determined by the state of CO (MSB) to C20, where the spin period is:

$$T_{spin} = T_{CL} \times (2^{14} + [(C0 \text{ to } C20)_2 \times 2^6)]$$

where $(C0 \text{ to } C20)_2 = C20 \times 2^0 + C19 \times 2^1 + \ldots + C0 \times 2^{20}$

The selected offset is that in which the A-taps = "1" and B-taps = "0". The operation is initiated when the Command Envelope falls. If this command is sent with $(C0 \text{ to } C20)_2=0$, all pulses are inhibited. 1024 PPS may be in either state. SUN PULSE is at ground.

C22	C23	Function
1	1	This mode inhibits any pulses into the system, which leaves the SSC operating in the automatic Pseudo-sun mode using whatever spin period was last accumulated or commanded.

C21 - Selects the stimulus for SUN TIME and SUN PERIOD accumulation.

C21	Function
1	Actual SUN SENSOR being selected by C23 & C22 determines the accumulation.
0	Every other accumulation is controlled by the actual Sun Sensor. The ones in between are controlled by the generated SUN PULSE of the SSC. SUN CONTROL bit in the R.O. DATA is a "1" when sensor controlled, and a "0" when SUN PULSE controlled.

This mode is useful for verifying that the SSC electronics is following the sensor signals during normal operations. However, if SUN TIME and/or SUN PERIOD telemetry data is necessary for maneuvers of the spacecraft, it is recommended that the non-alternate mode be used. This is because, during changing spin rates, the SUN PULSE may be in error or missing. The sensor only collection mode precludes this problem.

C20 to C0 (MSB) - CAL SUN mode program bits.

All except C0 to C3 are read out for verification in R.O. DATA. They are located in the 9-, 10-, and 11-th 8-bit words of R.O. DATA. C4 is the first bit out of the 9th word. C20 is the first bit of the 11th word.

OFFSET PROGRAMMING:

When the Sun Sensor signal or CAL SUN PULSE is received, the offset is loaded into an 11-bit counter. Each time the MSB changes from "1" to "0" a SUN PULSE is generated. The offset can be programmed in steps of 1/2048-th of a spin period. Either of two hard-wired offsets can be selected via C23 of the command bits.

A useful formula for determining the offset bit configuration is given below:

N = Number of (spin period/2048) sectors for delay.

$0 \leq N \leq 2047$

Then: Offset is (binary) = $\overline{(N-1)}_{mod\ 2048}$

Examples:

A) N = 1   [360/(1 X 2048)] = 0.175°

00000000001	(N)
− 00000000001	(−1)
00000000000	(N−1)

11111111111 $\overline{(N-1)}$ = Pre-set Bit Pattern

B) N = 2047   [360/(2048)] X 2047 = 359.825°

11111111111	(N)
− 00000000001	(−1)
11111111110	(N−1)

00000000001 $\overline{(N-1)}$ = Pre-set Bit Pattern

C) N = 1024   (360/2048) X 1024 = 180°

10000000000	(N)
− 00000000001	(−1)
01111111111	(N−1)

10000000000 $\overline{(N-1)}$ = Pre-set Bit Pattern

D) N = 1536   (360/2048) X 1536 = 270°

11000000000	(N)
− 00000000001	(−1)
10111111111	(N−1)

01000000000 $\overline{(N-1)}$ = Pre-set Bit Pattern

R.O. DATA BITS: The output shift registers are loaded on the rising edge of the DATA XFR signal (MSB out first where applies). For ISEE, this is the word gate of Digital Subcom Step #32.

1st 16 bits out after DATA XFR - SUN TIME
(1-16) Steps 32&33 — This contains the number of counts of 8192 Hz from DATA XFR to 1st SUN SIGNAL following, if SUN TIME and SUN PERIOD have completed an accumulation. (Accumulation is defined as the period from DATA XFR to the second SUN SIGNAL following.)

2nd 16 bits out after DATA XFR - SUN PERIOD
(17-32) Steps 34&35 — This contains the number of counts of 8192 Hz between the 1st and 2nd SUN SIGNALS following DATA XFR, if SUN TIME and SUN PERIOD have completed an accumulation as defined above.

3rd 16 bits out after DATA XFR - MAG TIME
(33-48) Steps 36&37 — Same as 1st 16 bits except using magnetic sensor.

4th 16 bits out after DATA XFR - MAG PERIOD
(49-64) Steps 38&39 — Same as 2nd 16 bits except using magnetic sensor.

65-72 bits out after DATA XFR
Step 40
65 = SSC Command bit #C4
66 = SSC Command bit #C5
. .
. .
72 = SSC Command bit #C11

73-80 bits out after DATA XFR
Step 41
73 = SSC Command bit #C12
. .
. .
80 = SSC Command bit #C19

81-88 bits out after DATA XFR
Step 42
81 = SSC Command bit #C20
82 = C21 - Sun Control Mode ("1" = Sun Sensor Only, "0" - Alternate)
83 = C22
84 = C23

C22	C23	
0	0	Prime Sensor
0	1	Secondary Sensor
1	0	CAL MODE
1	1	No Sensor

85 = O.A. COMPLETE - SUN TIME and SUN PERIOD complete = "1"
86 = MAG COMPLETE - MAG TIME and MAG PERIOD complete = "1"
87 = SUN CONTROL - "1" = SUN SENSOR. "0" = GENERATED PULSE
88 = MTOS - "1" If SUN PERIOD increases more than 2 times as long or disappears totally.

SUN PULSE TIMING and GENERATION:

The SSC is capable of producing its SUN PULSE and 1024 PPS when the spin period is between 0.36S and 43.696 minutes. Any period shorter than the minimum will inhibit all pulses from being generated. For periods greater than 43.696 minutes, the SSC operates modulo 43.696 minutes.

If for any reason one wishes to inhibit pulse generation at any time, commanding the clock to the CAL MODE with a spin period of '0' seconds will accomplish this. The SUN PULSE lines will be at ground and the 1024 PPS lines could be at either state. Repetition of the command will make 1024 PPS lines change state.

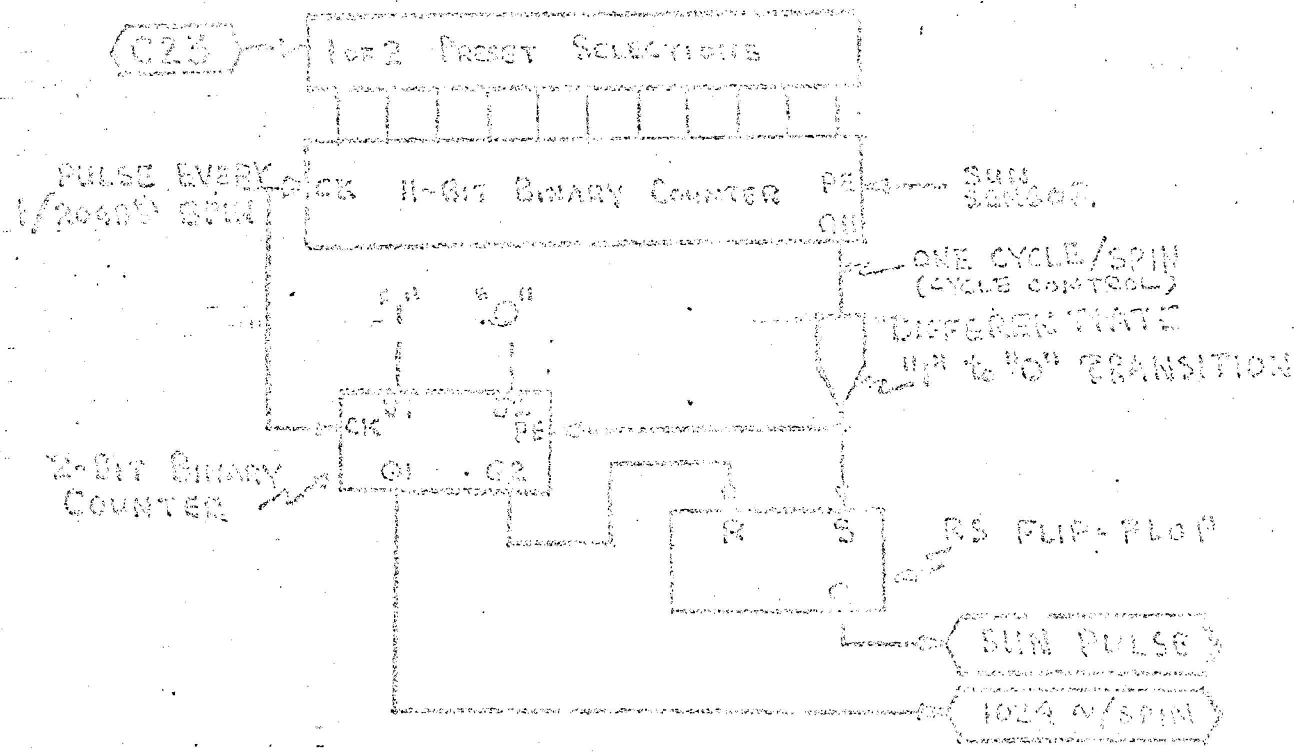
The SSC has the capability of translating the SUN SENSOR signal by increments of 1/2048 of a spin period. This implies that the user signal is electronically generated.

There are two preset selection patterns - one for each state of command bit C23. Upon receipt of the Sun Sensor signal, the selected pattern is loaded into the 11-bit binary counter. If this causes CYCLE CONTROL to transition from "1" to "0", the SUN PULSE signal is initiated and the 1024 cycle per spin signal is brought into sync with the new spin period (see Functional Diagram). This system gives rise to several different cases for the SUN PULSE.

When the spin rate is constant to within 0.0488%, all 2048 edges of 1024 PPS will be present and SUN PULSES will be produced each cycle. When the rate is changing more than this, it is possible for the SUN PULSE to be omitted. In all cases, the rate of 1024 PPS will follow the new spin rate synchronously with the new sensor signal. Phasing of 1024 PPS will only be done when a SUN PULSE is generated which means that discontinuities in the 1024 PPS can occur when the spin rate is changing faster than 0.0488%.

The following diagrams will show representative examples of SUN PULSE and 1024 PPS generation.

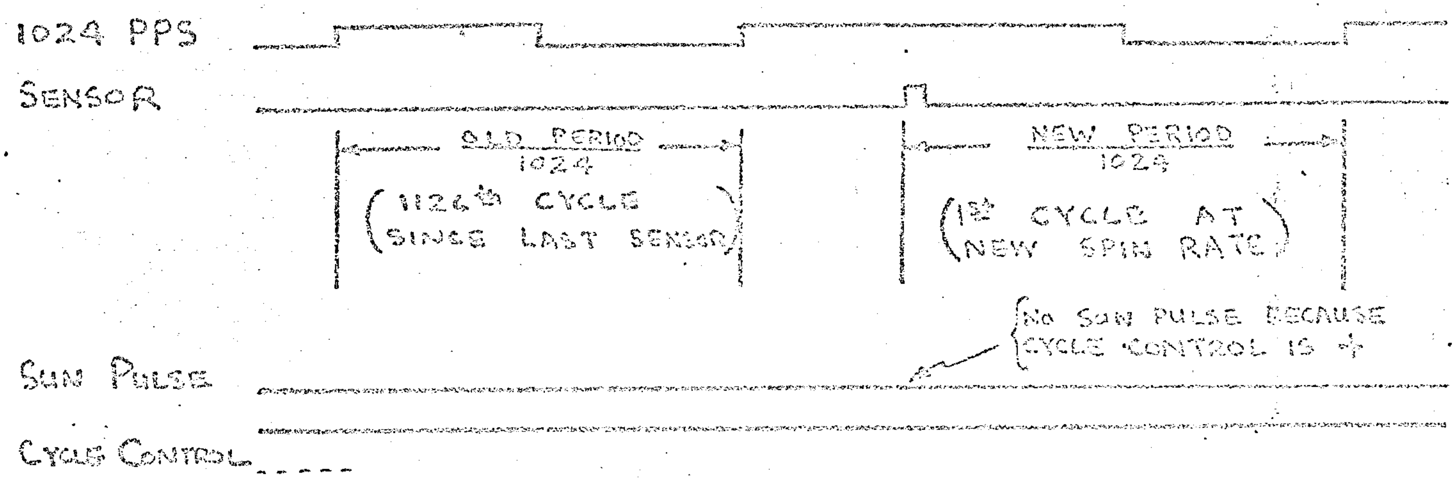
FUNCTIONAL DIAGRAM



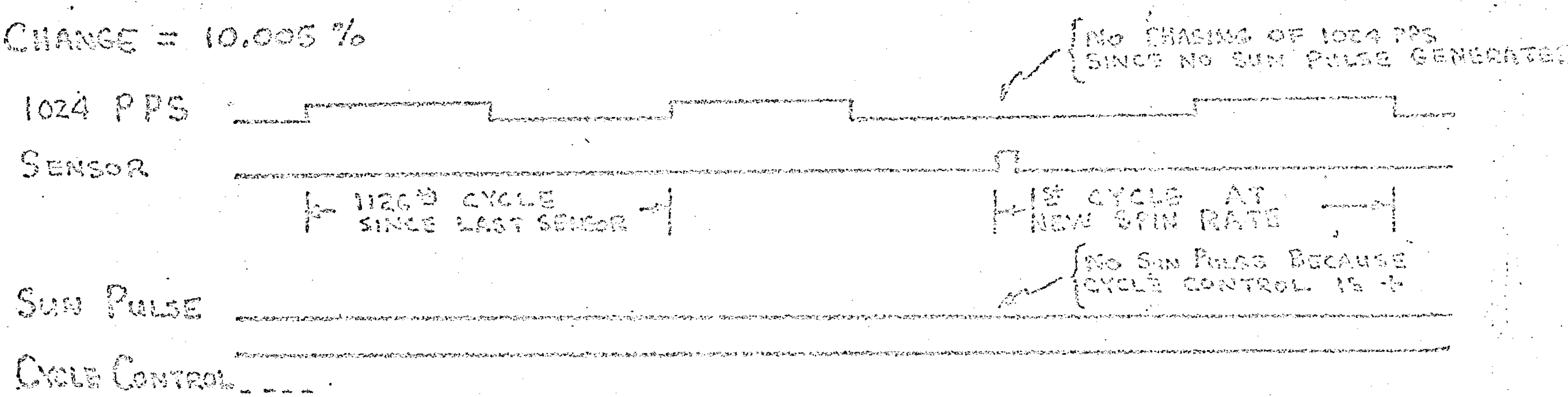
EXAMPLE 1.

1024 PPS WHEN SPIN RATE IS DECREASING > 0.0488 %. (0° OFFSET)

A. CHANGE = 10%

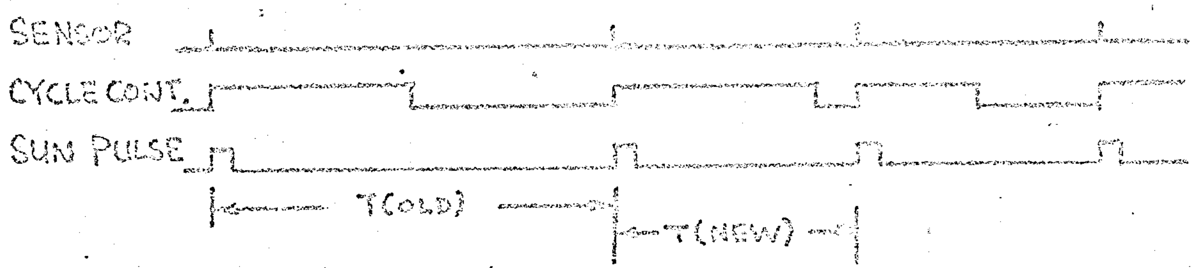


B. CHANGE = 10.005 %

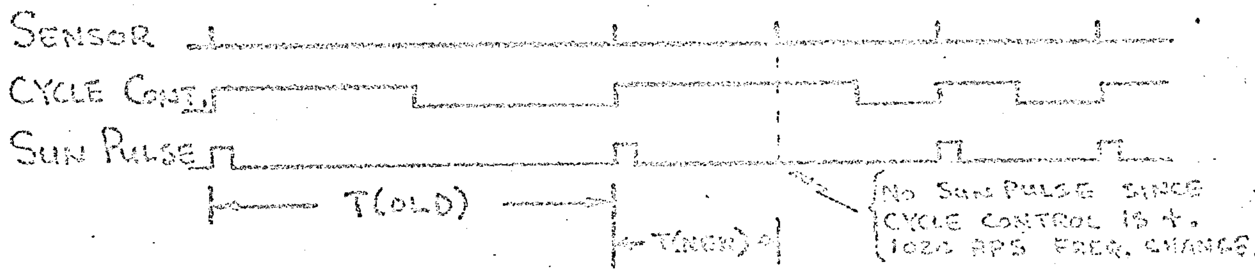


EXAMPLE 2.

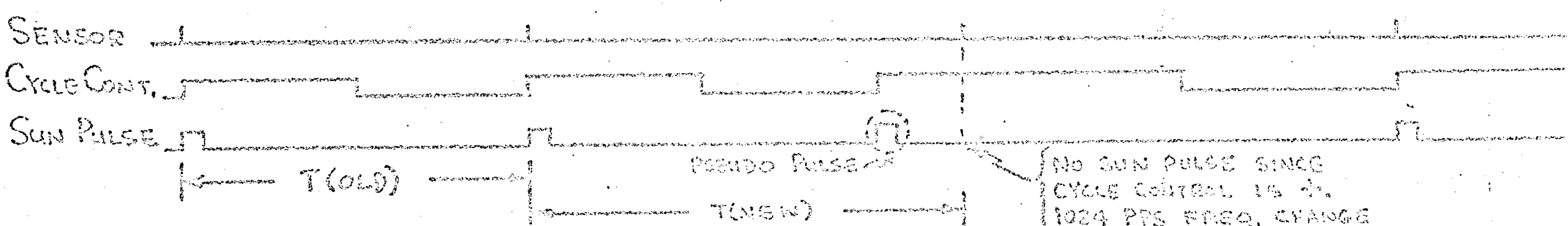
A. 0° OFFSET WITH $T(NEW) > \frac{T(OLD)}{2}$



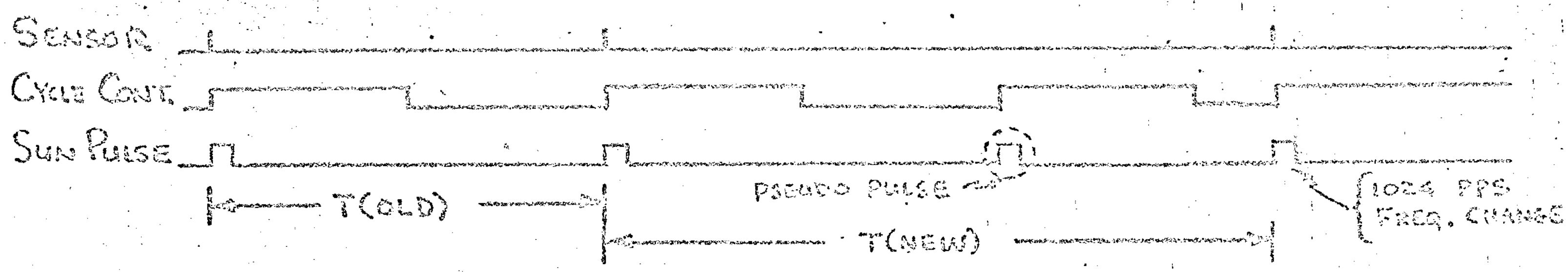
B. 0° OFFSET WITH $T(NEW) < \frac{T(OLD)}{2}$



C. 0° OFFSET WITH $T(OLD) < T(NEW) < \frac{3}{2} T(OLD)$

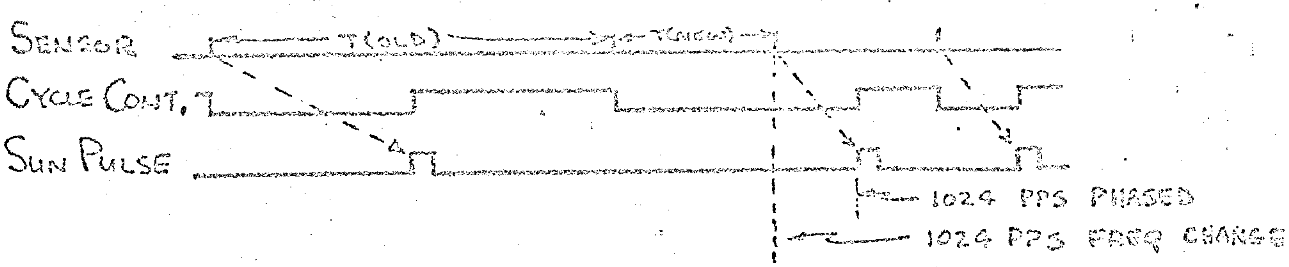


D. 0° OFFSET WITH $\frac{3}{2}$ T(OLD) < T(NEW) < 2 T(OLD)

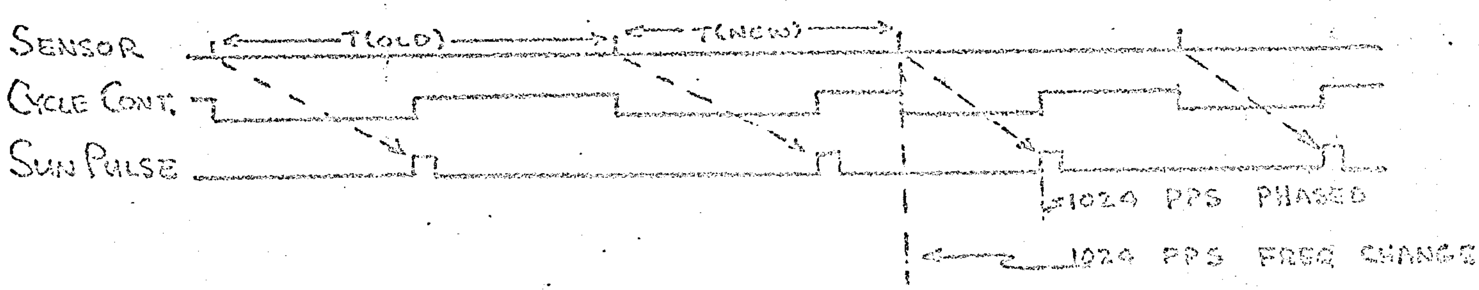


EXAMPLE 3.

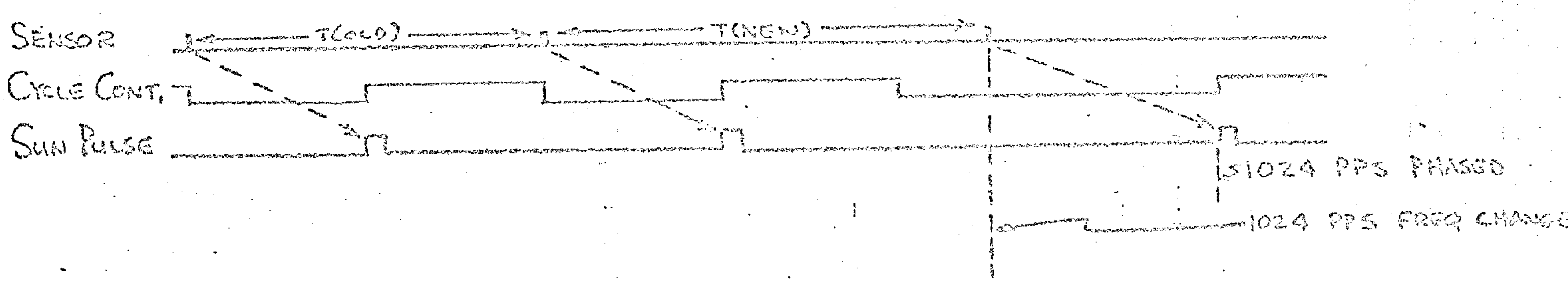
A. 180° OFFSET WITH $T(NEW) < \frac{T(OLD)}{2}$



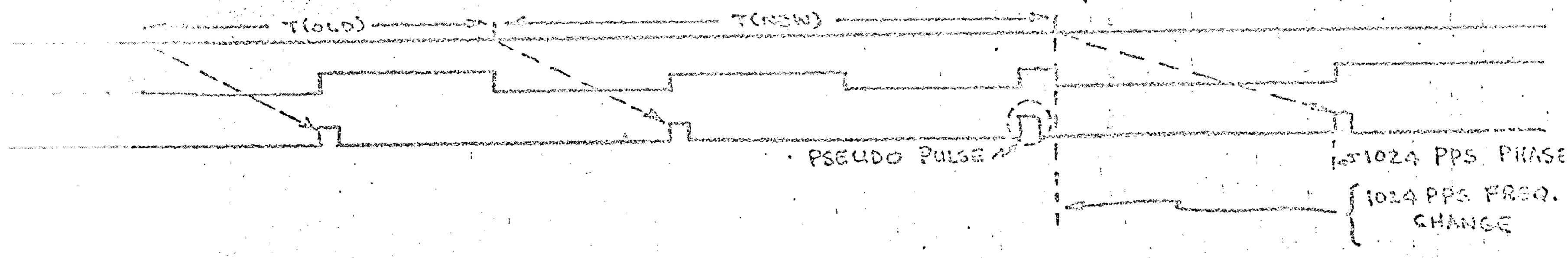
B. 180° OFFSET WITH $T(NEW) > \frac{T(OLD)}{2}$



C. 180° OFFSET WITH $T(OLD) < T(NEW) < \frac{3}{2} T(OLD)$



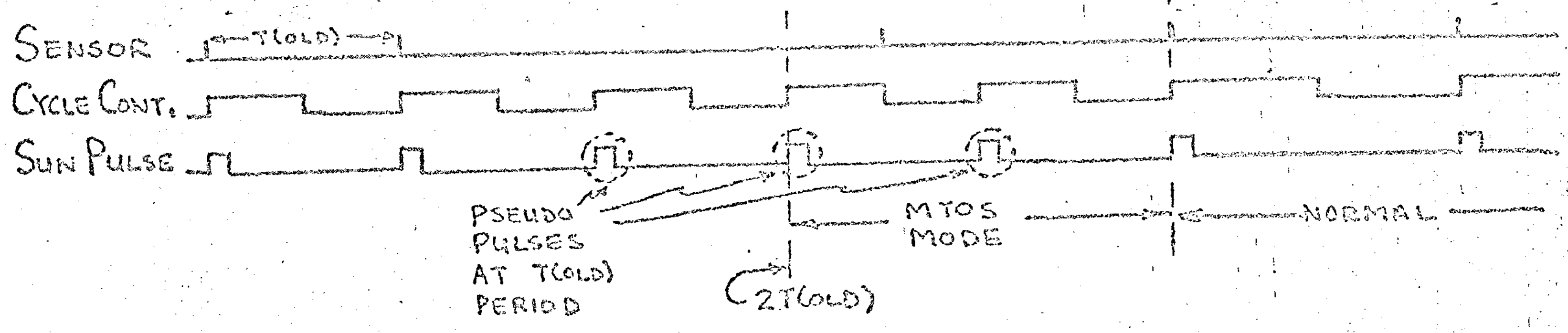
OFFSET WITH $\frac{3}{2}T(OLD) < T(NEW) < 2T(OLD)$



If the spin period increases more than twice its old value, the SSC enters a special mode called MTOS. This mode produces pulses at the last known "good" spin rate. The SSC returns to normal after two sensor signals are received as shown in the following diagram.

EXAMPLE 4.

0° OFFSET WITH T(NEW) > 2 T(OLD) OR ECLIPSE



SUN TIME and SUN PERIOD:

ISEE-A

Science Format (see following diagrams)

WORD REFERENCE TIME - Step 32 of Digital Subcom Word Time. This occurs in word 59 of minor frame 32 modulo 64 minor frames.

SUN TIME - Time in counts of 8192 Hz from rising edge of the word gate of Digital Subcom Step 32 until the next SUN SIGNAL. (Modulo 2^{16} - No overflow flag.)

SUN PERIOD - Time in counts of 8192 Hz from rising edge of the SUN SIGNAL which terminates SUN TIME to rising edge of next SUN SIGNAL. (Modulo 2^{16} - No overflow flag.)

XFR - TRANSFER PULSE to readout data shift registers which is generated at the rising edge of Step 32 word gate if and only if SUN TIME and SUN PERIOD have completed an accumulation sequence when Step 32 occurs. This implies that more than one Step 32 could occur before a transfer is generated. The SUN DATA VALID BIT (Step 42, Bit #3) is a "1" when XFR occurs and data in SUN TIME and SUN PERIOD is valid. Ignore SUN TIME and SUN PERIOD data when the SUN DATA VALID BIT is "0".

Engineering Format (see following diagrams)

WORD REFERENCE TIME - Step 32 of Digital Subcom Word Time. This occurs in Word 0 of minor frame 2 modulo 4 minor frames.

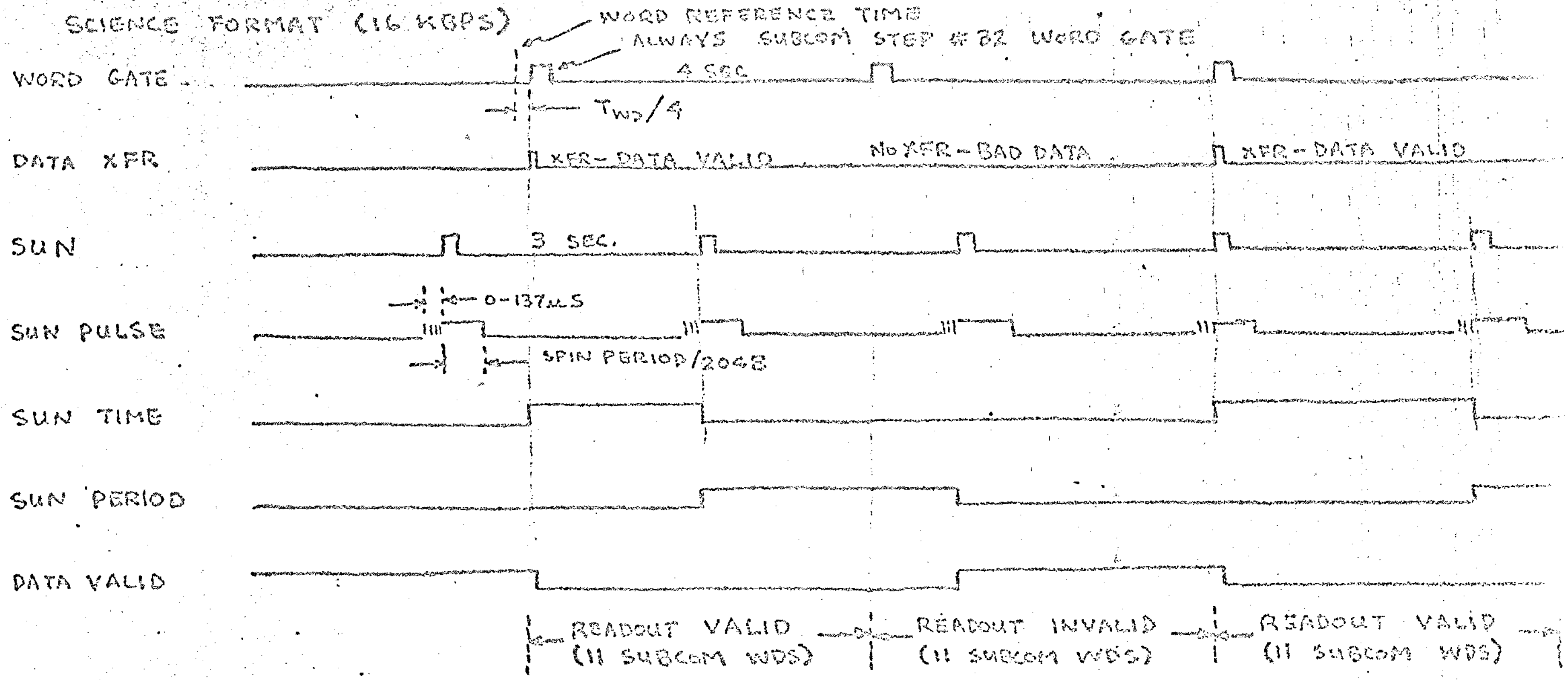
SUN TIME - Same as Science Format.

SUN PERIOD - Same as Science Format.

XFR - Same as Science Format.

ISEE A

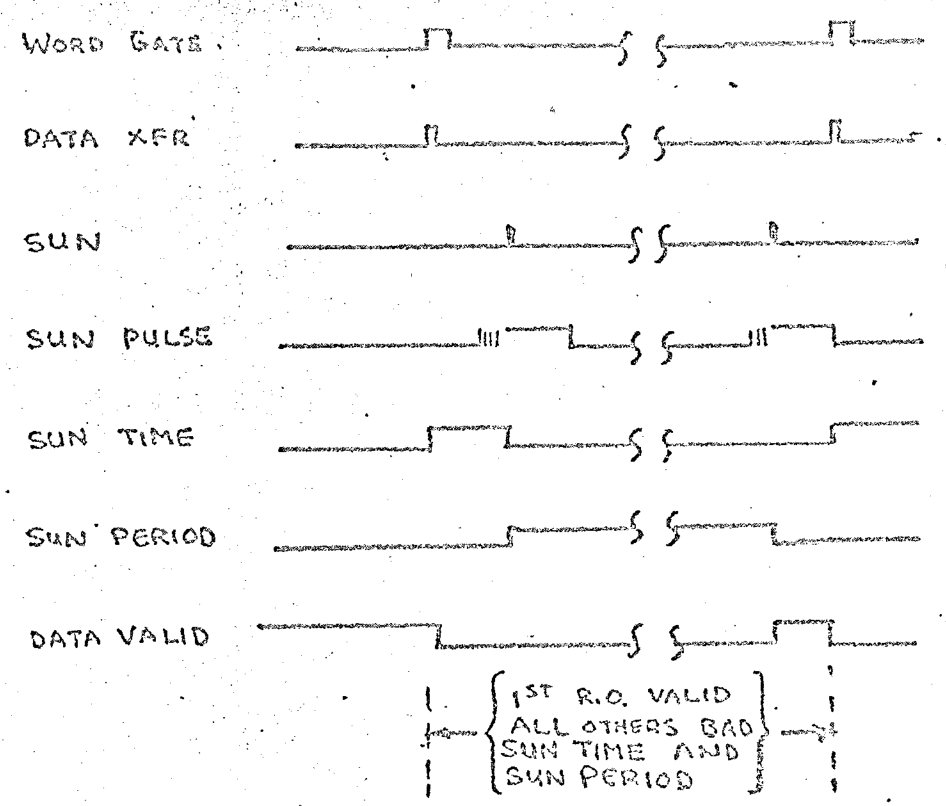
SCIENCE FORMAT (16 KBPS)



NOTE: READOUT VALID OR INVALID REFERS ONLY TO SUN TIME AND SUN PERIOD DATA. ALL OTHER DATA EXCEPT MAG TIME AND MAG PERIOD ARE GOOD EVERY READOUT. MAG TIME AND MAG PERIOD READOUTS ARE SIMILAR TO SUN TIME AND SUN PERIOD AND HAVE TELEMETRY FLAGS TO IDENTIFY VALID READOUTS.

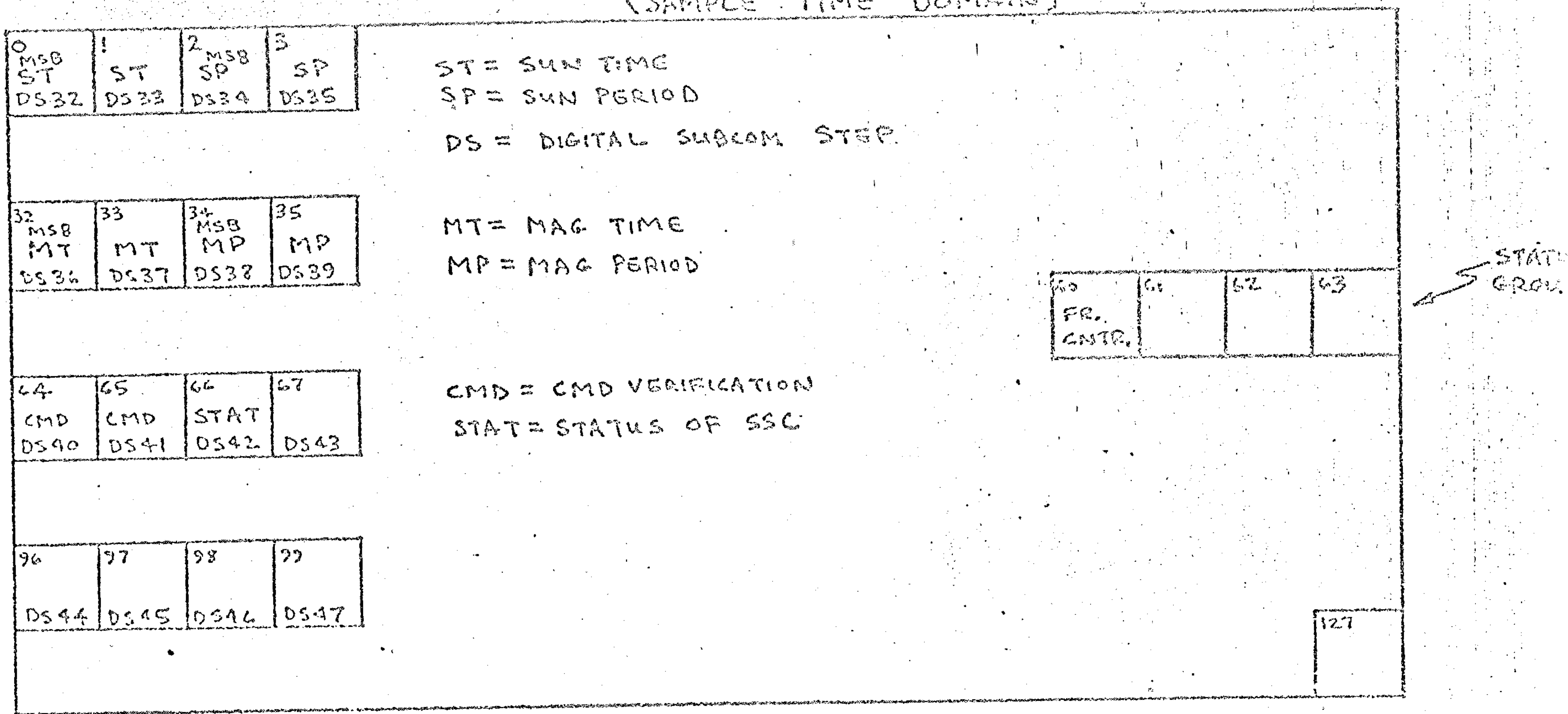
ISEE A

ENGINEERING FORMAT (16 KBPS)



NOTE: IF THE SPIN PERIOD IS 3 SECONDS THE TIME BETWEEN VALID READOUT SEQUENCES CAN VARY FROM 3 TO 6 SECONDS OR FROM 48 TO 96 MINOR FRAMES OR 12 TO 24 OCCURENCES OF STEP 32.

ISEE A ENGINEERING FORMAT FRAME # 2 (MOD 4)
(SAMPLE TIME DOMAIN)



MINOR SPIKE (S/C CLK UPDATE)

WORD #

FRAME # (MOD 4)	60	61	62	63
0	FR CTR	S/C CLK MSB	S/C CLK 9-16	S/C CLK LSB
1	FR CTR	VAM R.O.	IND. ADDR. REG.	XEQ. ADDR R.O.
2	FR CTR	STAT REG 1-8	STAT REG 9-16	STAT REG 17-24
3	FR CTR	VAM R.O.	CMD REG 1-8	CMD REG 9-16

STATUS GROUP

WORD 66 DSUBCOM STEP # 42

BIT #

7 (MSB)	6	5	4	3	2	1	0
CMD BIT C20	C21 ALT = "0"	C22 MSB MODE SELECT	C23 LSB	SUN DATA COMP. = "1"	MAG DATA COMP. = "1"	SUN CONT- SENSOR = "1"	MTOS MODE = "1"

STAT

ISEE-C

Science Format (see following diagrams)

WORD REFERENCE TIME - Step 32 of Digital Subcom Word Time. This occurs in word 59 of minor frame 32 modulo 64 minor frames.

SUN TIME - Time in counts of 8192 Hz from rising edge of the word gate of Digital Subcom Step 32 until the next SUN SIGNAL. (Modulo 2^{16} - No overflow flag.)

SUN PERIOD - Time in counts of 8192 Hz from rising edge of the SUN SIGNAL which terminates SUN TIME to rising edge of next SUN SIGNAL. (Modulo 2^{16} - No overflow flag.)

XFR - TRANSFER PULSE to readout data shift registers which is generated at the rising edge of Step 32 word gate if and only if SUN TIME and SUN PERIOD have completed an accumulation sequence when Step 32 occurs. This implies that more than one Step 32 could occur before a transfer is generated. The SUN DATA VALID BIT (Step 42, Bit #3) is a "1" when XFR occurs and data in SUN TIME and SUN PERIOD is valid. Ignore SUN TIME and SUN PERIOD data when the SUN DATA VALID BIT is "0".

Engineering Format (see following diagrams)

WORD REFERENCE TIME - Step 32 of Digital Subcom Word Time. (This occurs in Word 20 of minor frame 2 modulo 4 minor frames.)

CAUTION: ROM ERROR EXISTS CAUSING NON-BINARY STEPPING OF SUBCOM.

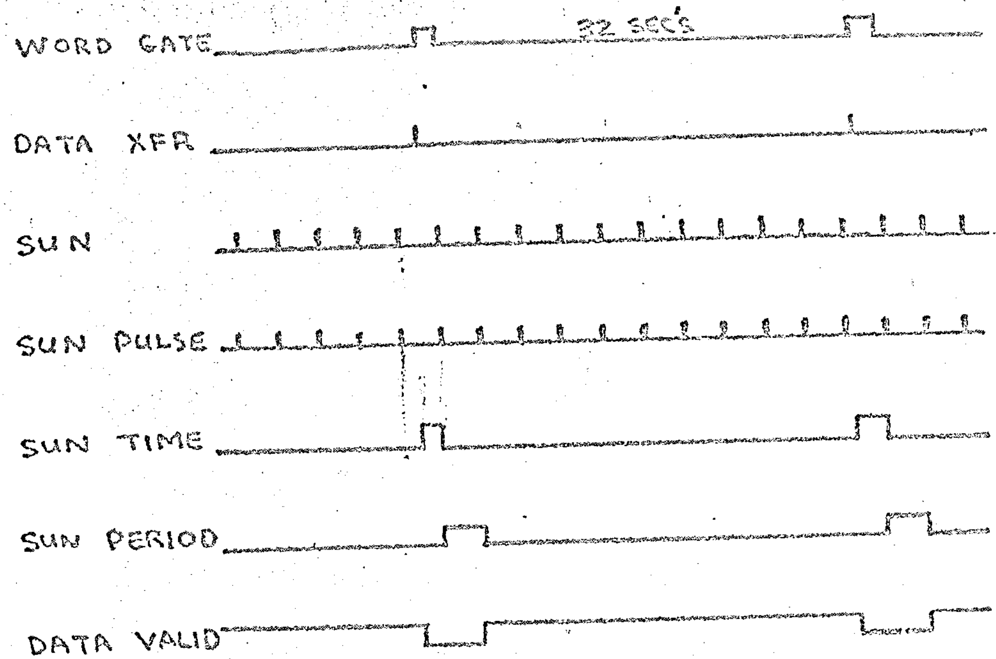
SUN TIME - Same as Science Format.

SUN PERIOD - Same as Science Format.

XFR - Same as Science Format.

ISEE C

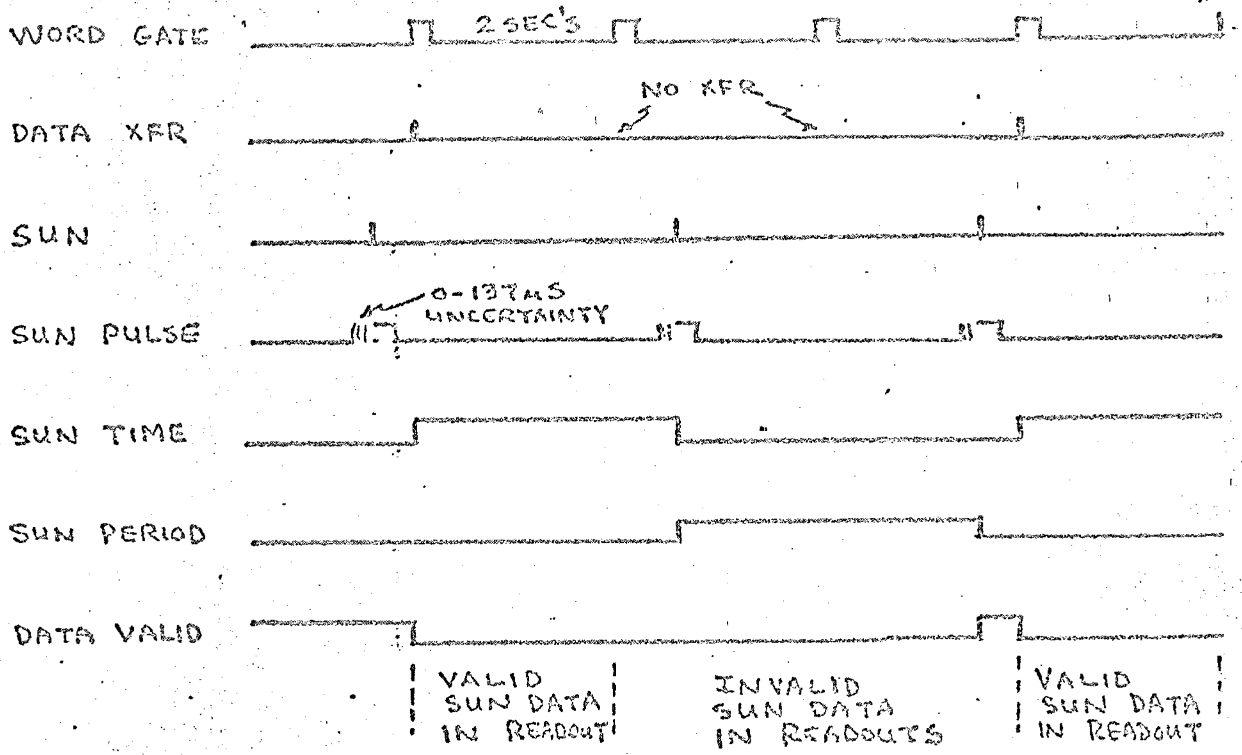
SCIENCE FORMAT (2 KBPS)



NOTE: AT NORMAL 3 SECOND SPIN RATES, EVERY READOUT WILL HAVE VALID SUN TIME AND SUN PERIOD DATA. SUN PULSES START WITH AN UNCERTAINTY OF 0 to 137 μS BEFORE THE SUN OCCURS IF THE SPIN PERIOD IS CONSTANT DUE TO THE METHOD OF PULSE GENERATION.

ISEE C CAUTION SEE P. 19

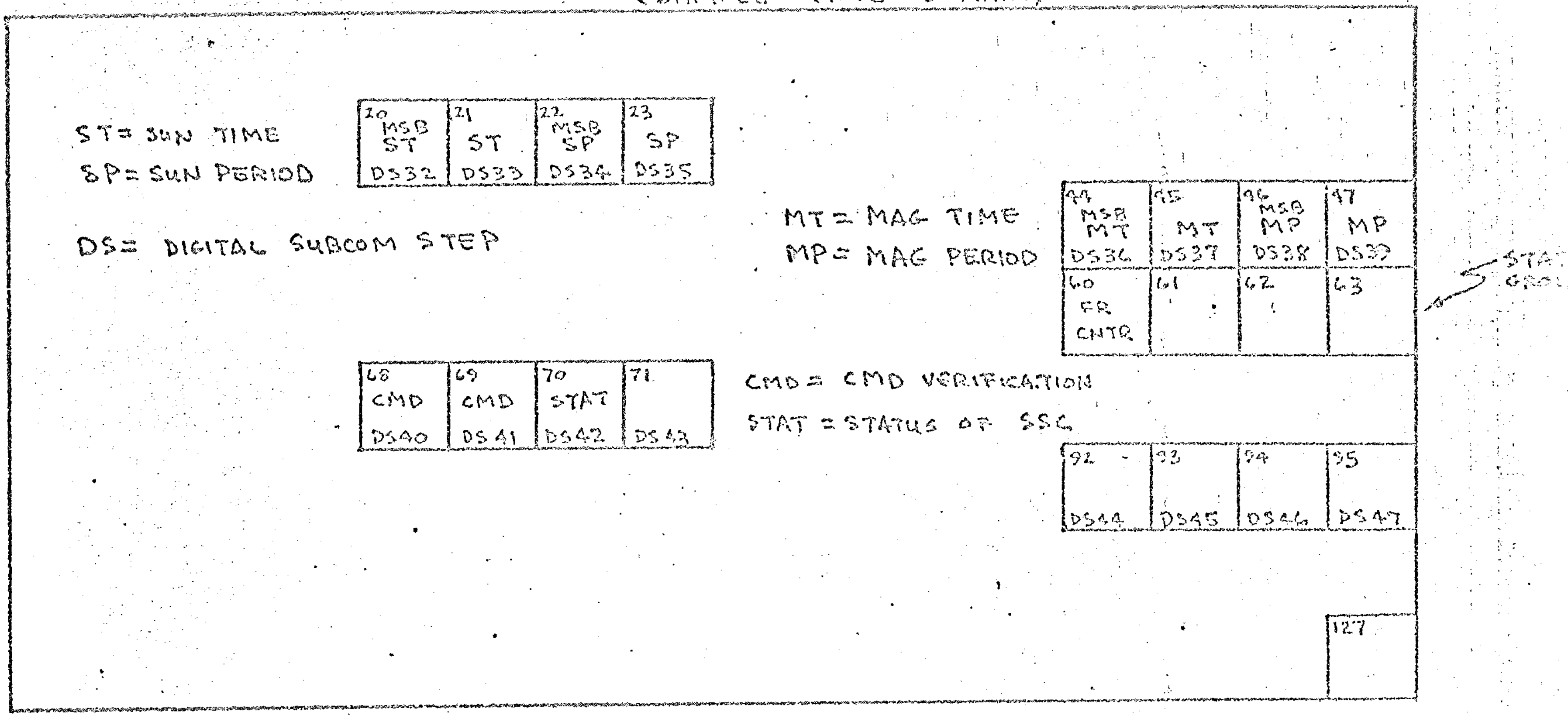
ENGINEERING FORMAT (2 KBPS)



CAUTION SGE P.19

ISEE C ENGINEERING FORMAT FRAME #2 (MOD 4)

(SAMPLE TIME DOMAIN)



Word #

Frame # (MOD 4)	60	61	62	63
0	FR CTR	S/C CLK MSB	S/C CLK 9-16	S/C CLK LSB
1	FR CTR	VAM R.O.	IND. ADDR. REG.	XEQ ADDR R.O.
2	FR CTR	STAT REG 1-8	STAT REG 9-16	STAT REG 17-24
3	FR CTR	VAM R.O.	CMD REG 1-8	CMD REG 9-16

STATUS GROUP

WORD 70 DSUBCOM STEP # 42 — ⊓ MINOR SPIKE (S/C CLK UPDATE)

BIT #

7(MSB)	6	5	4	3	2	1	0
CMD BIT C20	C21 ALT ="0"	C22 MSB MODE SELECT	C23 LSB	SUN DATA COMP ="1"	MAG DATA COMP ="1"	SUN CONT-SENSOR ="1"	MTOS MODE ="1"

STAT

NOTES:

1. Step numbers range from 0 to 63.

2. Minor frame numbers range from 0 to 255.

3. Word numbers range from 0 to 127.

4. Word bit identification numbers are 0 to 7 with MSB = 7 and LSB = 0. MSB is first bit out in telemetry.

5. Minor frame spike occurs at the beginning of word 127 with respect to sample times (word gates, etc. to experiments).

6. Spacecraft clock is updated at minor frame spike times with 0.5 second resolution in the LSB. All word gates and telemetry signals are coherent with the spacecraft clock.

EXAMPLE OF CALCULATION OF SUN PULSE LOCATION WITH RESPECT TO TELEMETRY

Refer to the previous diagrams for this discussion. This example is for the Science Format in ISEE-A at 16 KBPS.

1. WORD REFERENCE TIME is 60 word periods after preceding minor frame spike (frames 32, 96, 160, 224).

2. The XFR which initiated the accumulations of SUN TIME and SUN PERIOD is that one which occurred at a time greater than (SUN TIME and SUN PERIOD) seconds before a valid sun data subcom readout sequence.

3. Further checking should be done to determine which sensor was selected to excite the SSC and if in "Alternate" Mode, what signal (sensor or generated SUN PULSE) was responsible for the accumulations. The reason for this is because phase correction for placement (180°) of the secondary sensor is done for the generated pulse, causing a difference in SUN TIME when Sensor Signal or generated pulse is used.

4. Once the WORD REFERENCE TIME which initiated the accumulations has been determined (see 2 above), formulas a) or b) below may be used to calculate where the prime sensor slit is with respect to the telemetry.

   a) PRIME SENSOR or SECONDARY SENSOR GENERATED PULSE

$$t_{(\text{AFTER WORD REFERENCE TIME})} \equiv t_{\text{SUN}}$$

$$= (\text{SUN TIME COUNTS}/8192) + (T_{\text{WORD}}/4)$$

   b) SECONDARY SENSOR

$$t_{\text{SUN}} = (\text{SUN TIME COUNTS}/8192) + (T_{\text{WORD}}/4)$$

$$+ [(\text{SUN PERIOD COUNTS}/8192)/2]$$

USE OF S/C CLOCK AS A TELEMETRY REFERENCE POINT

The purpose is to obtain an interpolated value of the S/C Clock at the WORD REFERENCE TIME (WRT) described previously. Once this reference time is known, the sum of the S/C Clock reading and the time period from MINOR SPIKE to WRT will locate the WRT of interest. The S/C Clock reading used should be in the same minor frame as WRT in the Science Format or 2 minor frames prior to the WRT in the Engineering Format. This sum gives the time in seconds of the WRT since the data system was powered on. The following diagram will show timing relationships for ISEE-A Science Format at high bit rate (16 KBPS). The calculations for the diagram are shown below:

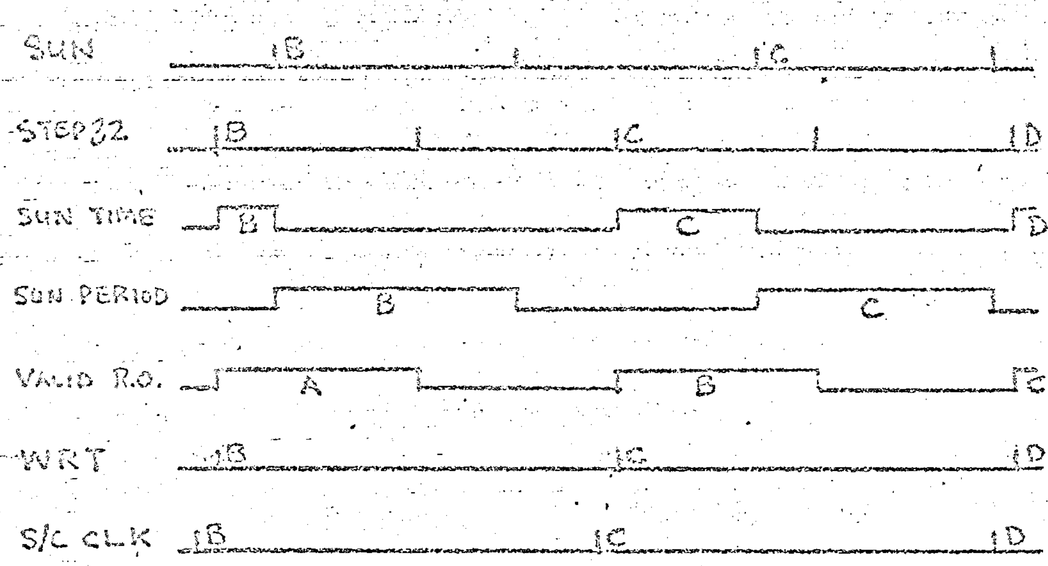
$$t_{WRT} = (S/C\ CLK) \times 0.5 + T_{WORD} \times (\text{STEP 32 Word No.} + 1)$$

and

$$t_{(SUN)} = t_{WRT} + (0.25 \times T_{WORD}) + (\text{SUN TIME COUNTS})/8192$$

$$= (S/C\ CLK \times 0.5) + [0.000488 \times (59+1)] + [(\text{SUN TIME COUNTS})/8192]$$
$$+ (0.000488 \times 0.25)$$

$$t_{(SUN)} = (S/C\ CLK \times 0.5) + [(\text{SUN TIME COUNTS})/8192] + 0.029419 \text{ seconds}$$



NOTE THAT THE LETTERS FOR QUANTIES USED IN A CALCULATION ARE ALIKE, AND THAT THE S/C CLK IS IN THE SAME MINOR FRAME AS WRT.

ISEE-A SCIENCE FORMAT