CALIBRATION REPORT

For

X-Ray Sensor System S/N 001, Rework / GOES-D (-4)

P.O. No. 08-779412-LBG

May 21, 1980

Telescope: Part No. 3540806 - 100, Serial No. 001

DPU : Part No. 3540805 - 100, Serial No. 001

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TABLE OF CONTENTS

1. Introduction

The X-Ray Sensor is primarily designed to measure the X-Ray flux from the sun in two (2) distinct spectral bands. They are: 1) .5 - 3Å and 2) 1 - 8Å. The electronics is, therefore, divided into two separate processing channels. Channel A processes the .5 - 3Å X-Ray Signal, and Channel B processes the 1 - 8Å X-Ray Signal. The composite X-Ray calibration of the Sensor - Signal voltage out vs. X-Ray flux in - consists of two individual calibrations. One is the calibration of the ion chamber with Fe^{55} sources of known intensity, the other is the X-Ray channel electronics calibration with simulated A. C ion chamber signals.

A secondary function of the X-Ray Signal Sensor is to monitor the electron environment of the spacecraft. Two outputs per channel, Wide band (WB) and Background (Bkg) are provided for this purpose. The WB output measures spin modulated, and the Bkg output the mean steady state electron induced ion chamber currents. The WB channels are calibrated with simulated preamplifier output signals; the Bkg channels are calibrated with simulated D. C ion chamber currents. Temperature analog monitors for the DPU and the Telescope electronics were calibrated during the thermal integration tests.

2. Ion Chamber Calibration

The detailed calculation of the ion chamber responses and of the calibration constants from the measured responses were described in the GOES D, E & F CALIBRATION REPORT - X-RAY SENSOR, PANA-GOESX-CR1, October 30, 1978. The flight x-ray telescope, S/N 001, uses ion chamber S/N W2338, with a beryllium light shield, S/N 002, of thickness 2.31 mg/cm^2 (0.499 mils). The calculated responses $G(\lambda)$ for chambers A and B of W2338 are given in Tables 3.2 and 3.3 of PANA-GOESX-CR1, and the calibrated normalization factors are given in Table 3.8 of the same report.

The Protoflight X-Ray Telescope with ion chamber W2338 must have the detailed responses, $G(\lambda)$ (A - m^2/W), corrected for the Be light shield attenuation, for the electron baffle shielding, and for the measured Fe-55 source calibration. The calibrated response function is

$$G_{cal}(\lambda) = G(\lambda)\, B_m\, F_{el\text{-}bf}\, Tr\,(\text{Be shield}, \lambda)$$

where Tr (Be shield, λ) is the transmission of 2.31 mg/cm^2 of beryllium, B_m is the Fe-55 Calibration Constant, and $F_{el\text{-}bf}$ is the electron baffle shielding.

Chamber (W2339)	B_m	F_{el-bf}
A	1.068	0.920
B	1.056	1.000

The detailed responses are calculated using the Be absorption coefficients of PANA-GOESX - CR1 and are given in the tables below:

Second Flight Unit, X-Ray Telescope S/N 001 Rework

Calculated Responses for the A Chamber (0.5 - 3Å)

Wavelength λ(Å)	$G_{cal}(\lambda)$* ($A - m^2/W$)
0.1	1.26 - 7
0.2	6.26 - 7
0.3	1.31 - 6
0.358- (Xe Kedge)	1.69 - 6
0.358+	7.50 - 7
0.4	1.00 - 6
0.5	1.81 - 6
0.6	2.91 - 6
0.7	4.28 - 6
0.8	5.87 - 6
0.9	7.62 - 6
1.0	9.48 - 6
1.1	1.14 - 5
1.2	1.32 - 5
1.3	1.48 - 5
1.4	1.62 - 5
1.5	1.70 - 5
1.6	1.79 - 5
1.7	1.85 - 5
1.8	1.87 - 5
1.9	1.88 - 5
2.0	1.87 - 5
2.1	1.82 - 5
2.2 (Xe LI edge)	1.79 - 5
2.3	1.69 - 5
2.4 (Xe LII edge)	1.63 - 5
2.5	1.50 - 5
2.59- (Xe LIII edge)	1.45 - 5
2.59+	1.13 - 5
2.6	1.12 - 5
2.7	1.11 - 5
2.8	1.07 - 5
2.9	1.05 - 5
3.0	1.01 - 5
3.1	9.68 - 6
3.2	9.13 - 6
3.3	8.59 - 6
3.4	7.97 - 6
3.5	7.38 - 6
3.6	6.68 - 6
3.8	5.44 - 6
4.0	4.27 - 6
4.2	3.24 - 6
4.4	2.38 - 6
4.6	1.68 - 6
4.8	1.15 - 6
5.0	7.54 - 7
5.5	2.24 - 7
6.0	5.13 - 8
7.0	1.22 - 9
8.0	7.64 - 12

$*\overline{G}_{cal}(0.5 - 3\text{Å}) = 1.73 \times 10^{-5}$ ($A - m^2/W$)

$\overline{G}_{0.5-3} = \overline{G}_{cal\,0.5-3} \div (\overline{B}_m \times F_{el \cdot bf})$

$= 1.73 \times 10^{-5} \div (1.068 \times 0.920)$

$= 1.76 \times 10^{-5}$

the equivalent $\overline{G}_{0.5-4}$ should be $\overline{G}_{0.5-3} \times \frac{(0.5-3)}{(0.5-4)} = \overline{G}_{0.5-3} \times 0.714$

$\overline{G}_{0.5-4} = 1.76 \times 10^{-5} \times 0.714 = 1.257 \times 10^{-5}$

$*1.26 - 7 = 1.26 \times 10^{-7}$, etc.

Second Flight Unit, X-Ray Telescope S/N 001 Rework

Calculated Responses for the B Chamber (1 - 8 Å)

Wavelength λ(Å)	$G_{cal}(\lambda)$* (A - m^2/W)	Wavelength λ(Å)	$G_{cal}(\lambda)$* (A - m^2/W)
0.2	2.08 - 8	6.2	3.36 - 6
0.4	1.49 - 7	6.4	3.13 - 6
0.6	4.47 - 7	6.8	2.65 - 6
0.8	9.65 - 7	7.2	2.19 - 6
1.0	1.64 - 6	7.6	1.74 - 6
1.2	2.48 - 6	8.0	1.35 - 6
1.4	3.42 - 6	8.4	1.01 - 6
1.6	4.35 - 6	8.8	7.45 - 7
1.8	5.18 - 6	9.2	5.29 - 7
2.0	5.84 - 6	9.6	3.67 - 7
2.2	6.32 - 6	10.0	2.47 - 7
2.4	6.60 - 6	10.4	1.59 - 7
2.6	6.72 - 6	10.8	9.97 - 8
2.8	6.74 - 6	11.2	6.00 - 8
3.0	6.68 - 6	11.6	3.49 - 8
3.2	6.56 - 6	12.0	1.97 - 8
3.4	6.42 - 6	13.0	3.75 - 9
3.6	6.25 - 6	14.0	5.73 - 10
3.8	6.06 - 6	15.0	7.03 - 11
3.87- (Ar K edge)	6.00 - 6	16.0	6.19 - 12
3.87+	4.13 - 6		
4.0	4.25 - 6		
4.2	4.38 - 6		
4.4	4.46 - 6		
4.6	4.50 - 6		
4.8	4.49 - 6		
5.0	4.42 - 6		
5.2	4.32 - 6		
5.4	4.18 - 6		
5.6	4.01 - 6		
5.8	3.81 - 6		
6.0	3.59 - 6		

$\overline{G}_{cal}(1 - 8 Å) = 4.56 \times 10^{-6}$ (A - m^2/W)

*2.08 - 8 = 2.08×10^{-8}, etc.

The last entry in the preceding tables gives the calculated response to a flat x-ray spectrum, normalized to the nominal range for each ion chamber. The calibrated ion chamber responses are:

.5 - 3 A band: $I_{xA} = 1.73 \times 10^{-5} J_{xA}$ (A) Eq. 1

1 - 8 A band: $I_{xB} = 4.56 \times 10^{-6} J_{xB}$ (A) Eq. 2

where I_x is A and J_x is in W/m^2 for the designated flux interval. Note that these response constants are for a flat x-ray spectrum.

3. Electronics Calibration

3.1 X-Ray Signal

The X-Ray Channel output voltage is directly proportional to its input current according to

$$V_x = S_x I_x + C_x \quad \text{Eq. 3}$$

where S_x = constant depending on channel, range and temperature

C_x = constant depending on channel and temperature

I_x = simulated ion chamber A.C signal

The constants S_x and C_x are tabulated for channel, range and temperature at the end of this section. Both were determined from test data of the preamplifier calibration (RTP-26, Sec. 7), the thermal integration test (RTP-29, Sec. 4.3) and the thermal vacuum test (RTP-29, Sec. 5.3). C_x was obtained by direct measurement of the particular channel bias voltage for zero input current. The bias voltage is fixed by a voltage divider consisting of two (2) precision metal film resistors. Therefore, very little variation with temperature is observed, with an almost negligible difference between channels.

S_x was obtained by the measurement and calculation, representing the slope of the calibration curve in terms of output voltage (V_x) versus simulated input current (I_x). This slope is dependent on channel, range and temperature. A weighted average of S_x was used from the various measurements made during preamplifier PCBD calibration, thermal integration, and vacuum performance testing.

The current I_x was simulated by applying a negative ramp voltage of value ΔV and of ramp length ΔT to the preamplifier input via its effective input coupling capacitor.

The simulated input current is then determined by:

$$I_x = C_{eff} \frac{\Delta V}{\Delta T} \qquad \text{Eq. 4}$$

During thermal integration and vacuum testing, the input coupling capacitance is not directly available except through a protective diode in the External Calibrate line. However, the ramp voltage which is applied to the preamplifier (after the diode) is available as a test output on the S/C Simulator. The voltage drop across the diode does not affect the ramp voltage since it has a constant offset of -.7V. Thus, the simulated input for thermal integration and vacuum testing is again determined by Equation 4.

C_{eff} is determined by the preamplifier PC BD tests (Section 5.5 for both ranges and each channel). ΔT is measured with a frequency counter and ΔV with a calibrated oscilloscope having an internal graticule to avoid parallax.

Table 3.1 Values of S_x and C_x for X-Ray Channel Electronics Calibration

Temperature		$+25^\circ \pm 1^\circ C$		$-20^\circ \pm 3^\circ C$		$+35^\circ C \pm 2^\circ C$	
Channel	Range	S_x (V/A)	C_x(V)	S_x (V/A)	C_x(V)	S_x (V/A)	C_x(V)
A	1	1.78 E12	.499	1.91 E12	.511	1.76 E12	.480
	2	1.68 E11	"	1.83 E11	"	1.65 E11	"
	3	2.44 E10	"	2.58 E10	"	2.42 E10	"
	4	2.26 E9	"	2.36 E9	"	2.24 E9	"
B	1	5.85 E11	.499	6.3 E11	.514	5.78 E11	.484
	2	5.47 E10	"	5.93 E10	"	5.38 E10	"
	3	7.60 E9	"	7.90 E9	"	7.52 E9	"
	4	7.00 E8	"	7.26 E8	"	6.92 E8	"

3.2 Wide band Signal

The Wide band (WB) signal outputs are intended as a monitor of the preamplifier output signal before demodulation. The band width of this amplifier (200 Hz) allows the scanning of X-Ray signal pulses and the slower spin modulated signal from the electron induced background. Because these are A.C signals, the amplifier output is biased to about mid-scale. The only calibration provided for the WB output is given below:

$$V_w = G_w V_{In} + C_w \qquad \text{Eq. 5}$$

where V_w = Wideband output voltage

G_w = Amplifier gain from PANA RTP-12, Sec. 5.1

C_w = Amplifier bias and V_{In} = Output voltage at attenuator

The constants G_w and C_w for the two channels are tabulated below. The temperature coefficient of the two (2) constants is negligible.

Table 3.2 Values of G_w and C_w for WB Channel Electronics Calibration

Channel	G_w	C_w
A	10.23	2.34V
B	10.30	2.36V

Since the attenuator divides the preamplifier output by a factor of exactly 10 in ranges 2 and 4, V_w can be related to preamplifier voltage as follows:

$$V_{PA} = \frac{V_w - C_w}{G_w} \qquad \text{for ranges 1 and 3,} \qquad \text{Eq. 6}$$

$$V_{PA} = 10\,\frac{V_w - C_w}{G_w} \qquad \text{for ranges 2 and 4,} \qquad \text{Eq. 7}$$

where V_{PA} = Preamplifier output voltage

V_w = WB amplifier output voltage

V_{PA} is linked to the preamplifier input current through a complex conjugate bandpass transfer function, too cumbersome for purposes of analysis.

3.3 Background Signal

The Background signal channels are calibrated in terms of output voltage (V_B) versus simulated ion chamber D.C current. The relationship can be expressed as follows:

$$I_x = \frac{V_B - C_B}{S_B} \qquad \text{Eq. 8}$$

where S_B = constant, depending on channel and temperature

C_B = constant, depending on channel and temperature

I_x = simulated ion chamber D. C current

C_B was obtained by direct measurement of the particular channel bias voltage at zero input current and over the temperature range. S_B was calculated as the slope of the calibration curve from data obtained during preamplifier PCB calibration (PANA RTP-26, Sec. 7. 2). The average slope of 5 data points is used. Note that S_B is independent of range.

I_x is the D. C current applied to the input of the preamplifier. A precision current source (Keithley 261) was used to inject the current, and the output voltage (V_B) was measured at the x 1 gain buffer output of the integrating Null amplifier.

This measurement requires that the ion chamber be disconnected from the preamplifier input. Thus, the calibration was performed at room temperature only, using the temperature measurements of the effective R_{Null} resistance to calculate S_B for -20° and +35°C. This is valid since it was shown by the Design Review Summary Report (PANA GOESX-DR) that the main components contributing to temperature dependence are the Hi-Meg resistors. In this case, it is R_{Null}. The constants S_B and C_B are tabulated below:

Table 3. 3 Values of S_B and C_B for Background Channel Electronics Calibration

Temperature / Channel	25° ± 2°C		-20° ± 3°C		+35° ± 3°C	
	S_B (V/A)	C_B (V)	S_B (V/A)1)	C_B (V)	S_B (V/A)1)	C_B (V)
A	3. 23 E11	. 991	3. 46 E11	. 994	3. 16 E11	. 990
B	9. 12 E10	. 997	9. 81 E10	. 995	8. 91 E10	. 996

Note: 1) Tabulated values are calculated from R_{Null} Tempco.

3.4 Temperature Sensors

Two temperature sensors are provided, one located in the Telescope measures the preamplifier temperature, the other, located in the DPU on the Auto-Range PC BD, measures the DPU electronics temperature.

Calibration was performed at the end of the thermal vacuum test by applying a regulated D. C current to the HAC provided temperature sensor. The measurements taken have to be corrected for the specified current of 1 ± .005 ma. The corrected temperature data is tabulated below and shown on Figure 3.1.

Table 3.4 Corrected Temperature Monitor Output Voltage vs. Temperature

Monitor	+25° ± 2°C	-20° ± 2°C	+35° ± 2°C
DPU	2.309 V	1.573 V	2.526 V
Telescope	2.176 V	1.493 V	2.391 V

3.5 Reference Voltage

The reference voltage monitor (Ref V) measures the +8V DC/DC converter supply voltage of the X-Ray Sensor. The monitor output voltage is the buffered output from a 2:1 resistive divider network. Precision metal film resistors are used in the divider.

Thus,

$$+8V \text{ Supply Voltage} = 2(\text{Ref V}) \pm .05V$$

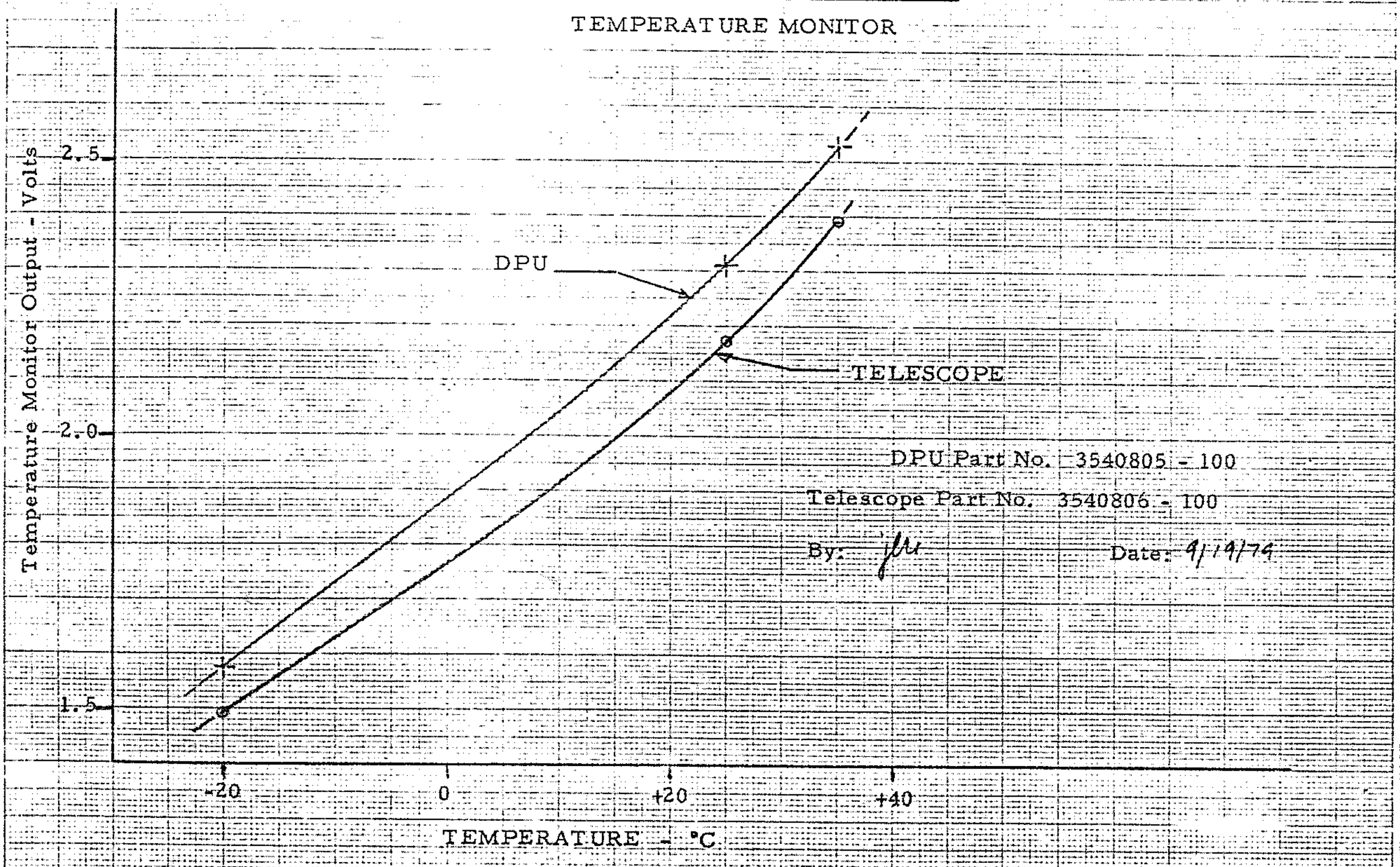
4. X-Ray Signal Composite Calibration

The main objective of the X-Ray Sensor is to measure the X-Ray flux emanating from the sun in two spectral bands. To help in evaluating this data, two (2) additional quantities are measured in each band, the spin modulated background, including the X-Ray pulse, and the steady state electron induced background. Calibration of these channels are described in Sec. 3.2 and 3.3.

In order to present the X-Ray data in a convenient form, the two (2) calibrations (ion chamber and electronics) described in Sec. 2 and 3.1 must be combined. The general expression for the X-Ray signal can be shown to be:

X-RAY SENSOR SUBSYSTEM, S/N 001

TEMPERATURE MONITOR



$$J_x = \frac{V_x - C_c}{S_x K} \qquad \text{Eq. 9}$$

where

J_x = X-Ray flux in designated spectral band

V_x = Measured X-Ray analog output voltage

S_x and C_x are the constants tabulated in Sec. 3.1.

$K = 1.73 \times 10^{-5} \frac{A}{W/m^2}$ for channel A (.5 - 3 Å)

$K = 4.56 \times 10^{-6} \frac{A}{W/m^2}$ for channel B (1 - 8 Å)

5. In-Flight Calibrator

The on board In-Flight Calibrator (IFC) provides a complete check of the long-term stability of the electronics. Two calibration points are measured in each range, one at zero input current and one at 60 ± 15% of full scale. At the same time the IFC performs a functional test of the X-Ray Sensor.

Baseline values of the calibration points for all 4 ranges and over the temperature range $-20^\circ \pm 3^\circ$C to $+35^\circ \pm 3^\circ$C were recorded during the thermal vacuum tests and the final buy-off performance test. A shift of the baseline values with time would indicate a similar shift of the calibration constants, S_x or C_x or both for the X-Ray signal. Thus, the IFC can be used to apply corrections to the baseline X-Ray signal calibration.

For completeness, copies of the IFC data taken during thermal vacuum and during the buy-off performance test are attached.

Thermal Vacuum, +25°C

Temperature
DPU 2.426 V @ I = 1.040 ma. (26°C)
TEL 2.230 V @ I = 1.021 ma. (25.5°C)

7.1.2 Channel A IFC

TP Section	CAL Step	Range	NOMINAL 2^1 A [1)]	NOMINAL 2^0 A [1)]	NOMINAL X-Ray A [2)]	MEASURED 2^1 A [1)]	MEASURED 2^0 A [1)]	MEASURED X-Ray A
7.1.2.4	1	4	1	1	3.000±.75V	1	1	3.220
7.1.2.5	2	4	1	1	.495±.020V	1	1	~~3~~.497 (A)
7.1.2.6	3	3	1	0	3.000±.75V	1	0	3.040
7.1.2.7	4	3	1	0	.495±.020V	1	0	.496
7.1.2.8	5	1	0	0	3.000±.75V	0	0	2.330
7.1.2.9	6	2	0	1	3.000±.75V	0	1	2.532
7.1.2.10	7	2	0	1	.495±.020V	0	1	.495
7.1.2.11	8	1	0	0	.495±.020V	0	0	.494

Notes: 1) 1 = LED ON; 0 = LED OFF
2) At room temperature. The measured value at other temperatures is used to obtain calibration data and thus may be outside the nominal limits.

7.1.3 Channel B IFC

TP Section	CAL Step	Range	NOMINAL 2^1 B	NOMINAL 2^0 B	NOMINAL X-Ray B [2)]	MEASURED 2^1 B	MEASURED 2^0 B	MEASURED X-Ray B
7.1.3.4	1	4	1	1	3.000±.75V	1	1	3.653
7.1.3.5	2	4	1	1	.495±.020V	1	1	.497
7.1.3.6	3	3	1	0	3.000±.75V	1	0	3.432
7.1.3.7	4	3	1	0	.495±.020V	1	0	.496
7.1.3.8	5	1	0	0	3.000±.75V	0	0	2.703
7.1.3.9	6	2	0	1	3.000±.75V	0	1	2.882
7.1.3.10	7	2	0	1	.495±.020V	0	1	.498
7.1.3.11	8	1	0	0	.495±.020V	0	0	.492

By jlm | Date 6/17/80 | QA (A) | Date 6/17/80

6/20

Thermal Vacuum, +35°C #2

TEMPERATURE
DPU 2.399 @ 1.047
TEL 2.222 @ 1.028

7.1.2 Channel A IFC

			NOMINAL			MEASURED		
TP Section	CAL Step	Range	2^1 A 1)	2^0 A 1)	X-Ray A 2)	2^1 A 1)	2^0 A 1)	X-Ray A
7.1.2.4	1	4	1	1	3.000±.75V	1	1	3.207
7.1.2.5	2	4	1	1	.495±.020V	1	1	.498
7.1.2.6	3	3	1	0	3.000±.75V	1	0	3.026
7.1.2.7	4	3	1	0	.495±.020V	1	0	.498
7.1.2.8	5	1	0	0	3.000±.75V	0	0	2.346
7.1.2.9	6	2	0	1	3.000±.75V	0	1	2.539
7.1.2.10	7	2	0	1	.495±.020V	0	1	.498
7.1.2.11	8	1	0	0	.495±.020V	0	0	.500

Notes: 1) 1 = LED ON; 0 = LED OFF
2) At room temperature. The measured value at other temperatures is used to obtain calibration data and thus may be outside the nominal limits.

7.1.3 Channel B IFC

TP Section	CAL Step	Range	2^1 B	2^0 B	X-Ray B 2)	2^1 B	2^0 B	X-Ray B
7.1.3.4	1	4	1	1	3.000±.75V	1	1	3.660
7.1.3.5	2	4	1	1	.495±.020V	1	1	.500
7.1.3.6	3	3	1	0	3.000±.75V	1	0	3.438
7.1.3.7	4	3	1	0	.495±.020V	1	0	.500
7.1.3.8	5	1	0	0	3.000±.75V	0	0	2.705
7.1.3.9	6	2	0	1	3.000±.75V	0	1	2.898
7.1.3.10	7	2	0	1	.495±.020V	0	1	.500
7.1.3.11	8	1	0	0	.495±.020V	0	0	.500

By JM | Date 6/23/80 | QA (A) | Date 6/23/80

Thermal Vacuum, -20°C #2

TEMPERATURE
DPU 1.690V @ 1.045 ma.
TEL 1.502V @ 1.026 ma.

7.1.2 Channel A IFC			NOMINAL			MEASURED		
TP Section	CAL Step	Range	2^1 A 1)	2^0 A 1)	X-Ray A 2)	2^1 A 1)	2^0 A 1)	X-Ray A
7.1.2.4	1	4	1	1	3.000±.75V	1	1	3.319
7.1.2.5	2	4	1	1	.495±.020V	1	1	.512
7.1.2.6	3	3	1	0	3.000±.75V	1	0	3.139
7.1.2.7	4	3	1	0	.495±.020V	1	0	.513
7.1.2.8	5	1	0	0	3.000±.75V	0	0	2.510
7.1.2.9	6	2	0	1	3.000±.75V	0	1	2.736
7.1.2.10	7	2	0	1	.495±.020V	0	1	.511
7.1.2.11	8	1	0	0	.495±.020V	0	0	.510

Notes: 1) 1 = LED ON; 0 = LED OFF
2) At room temperature. The measured value at other temperatures is used to obtain calibration data and thus may be outside the nominal limits.

7.1.3 Channel B IFC								
TP Section	CAL Step	Range	2^1 B	2^0 B	X-Ray B 2)	2^1 B	2^0 B	X-Ray B
7.1.3.4	1	4	1	1	3.000±.75V	1	1	3.797 ← Note 2
7.1.3.5	2	4	1	1	.495±.020V	1	1	.515
7.1.3.6	3	3	1	0	3.000±.75V	1	0	3.574
7.1.3.7	4	3	1	0	.495±.020V	1	0	.514
7.1.3.8	5	1	0	0	3.000±.75V	0	0	2.920
7.1.3.9	6	2	0	1	3.000±.75V	0	1	3.130
7.1.3.10	7	2	0	1	.495±.020V	0	1	.514
7.1.3.11	8	1	0	0	.495±.020V	0	0	.515

By [signature] Date 6/19/80 QA (A) Date 6/19/80