REVISIONS

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A	36-280	INITIAL RELEASE	MB	RFG	7/20/95
B	36-412	ADD SCREENING TABLE 5			

NAME	DATE
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MICROCIRCUIT, CHARGE-COUPLED DEVICE, (CCD) MONOLITHIC, SILICON

Size	Code Identification No.	Drawing No.	Rev.
T	80230	36-02308	B

Scale: NONE

Sheet: 1 of 11

1.0 Scope

This drawing delineates the design, performance, and test requirements for charge coupled devices (CCDs) which will be used in the ACIS instrument. These are position and energy sensitive devices, which will be used to detect x-rays emanating from celestial objects, which will be observed by AXAF. These devices will be used on a satellite in Earth orbit.

1.2 Part Number The complete MIT part number shall be 36-02308

2.0 Applicable documents

2.1 The following MIT and Lincoln Laboratory documents form a part of this specification to the extent specified herein.

36-02103	CCD Description
36-01207	Contamination Control Plan
427853	CCD Array Assembly
427871	Test Handling Fixture, Test Container
427871-1	Parts List, Test Handling Fixture, Test Container
427897	Schematic, Test Handling Fixture, Test Container

2.2 Order of precedence In the event of conflict between the text of this drawing and the references cited herein, the text of this drawing shall govern.

3.0 Requirements

3.1 General The general requirements for the ACIS CCD devices are contained in MIT drawing 36-02103. Specific requirements identified in 36-02103 are repeated herein.

3.2 Architectural

3.2.1 Image array. The imaging array is 1024 columns by 1026 rows with 24-μm-square pixels.

3.2.2 Abuttablilty. The CCDs are designed so that individual devices may be abutted on three sides within 500 μm of an adjacent device.

3.2.3 Frame store array. A frame store array is required for each pixel of the imaging array. Frame store array pixel size is 24 to 21 μm wide, and 13.5 μm high.

3.2.4 Output amplifiers. Four output amplifiers are required, with each outputting a 256-pixel segment of a full 1024-pixel row.

Table 1
Device Performance Requirements

Parameter	Requirements	Ref. Par.	Remarks
System noise	< 4 electrons RMS	4.3.1.7	
Responsivity	1 electrons /ADU	4.3.1.7	(at nominal AE gain)
Parallel CTI	< 5 x 10-6 < 5 x 10-5	4.3.1.8 4.3.1.8	at 5900 eV at 525 eV
Serial CTI	< 1 x 10-5	4.3.1.8	at 5900 eV
Mean Dark Current	< 0.3 e/pix/s < 1 e/pix/s	4.3.1.9 4.3.1.9	nom. oper. temp. nom. oper. temp. +5°C
Bias/Dark Current Stability	< 2 e/pix/hr	4.3.1.10	from corner pixel dist.
Bright Pixels	<1000 total<500/ output node	4.3.1.11	
Bright Columns	<20 total<10/output node	4.3.1.11	
Edge glow	<1% area	4.3.1.11	

Table 2
X-ray Spectral Resolution Requirements: Front-Illuminated Devices

Energy (kev)	Illumination	FWHM (eV)	Measurement Details in Par.	Remarks
0.53	Full-frame 60 rows	70 65	4.2.3.1	g0234, sp15e$^-$
1.5	Full-frame 60 rows	100 90	4.2.3.1	g0234, sp15e$^-$
5.9	Full-frame 60 rows	165 150	4.2.3.1	g0234, sp15e$^-$

Table 3
X-ray Spectral Resolution Requirements: Back-Illuminated Devices

Energy (kev)	Illumination	FWHM (eV)	Measurement Details in Par.	Remarks
0.28	Full-frame 60 rows	130 110	4.2.3.1	g0234, sp15e$^-$
0.53	Full-frame 60 rows	120 100	4.2.3.1	g0234, sp15e$^-$
1.5	Full-frame 60 rows	120 110	4.2.3.1	g0234, sp15e$^-$
5.9	Full-frame 60 rows	165 150	4.2.3.1	g0234, sp15e$^-$

3.3 Electrical.

3.3.1 Output amplifier gain. The output amplifier gain is 15 μV/electron, nominal.

3.3.2 Output amplifier noise. The output amplifier read noise is <5 electrons rms at -100°C and an output register clock rate of 100 Khz.

3.4. Construction.

3.4.1 Front and Back Illumination. The devices are required in two configurations; front illuminated, and back illuminated.

3.5 Performance.

3..5.1 Front illuminated sensitivity. The front illuminated devices will be able to detect 530 eV x-ray photons with an energy resolution of 70 eV (FWHM).

3.5.2 Back illuminated device sensitivity. The back illuminated devices will be able to detect 280 eV x-ray photons with an energy resolution of 120 eV (FWHM).

3.5.3 Charge Transfer Inefficiency (CTI). The parallel CTI of the device is $<5x10^{-6}$, and the serial register CTI is $<1x10^{-5}$.

3.6 Environmental

3.6.1 Temperature. The nominal operating temperature of the device is -120°C.

3.7 Packaging. Devices will be packaged in custom packages with flexprint electrical connections as shown in the Lincoln Laboratory drawing 427853.

3.8 Identification Devices will be identified by a six-character alphanumeric sequence for front illuminated device assemblies, and an eight-character alphanumeric sequence for back-illuminated device assemblies. In both cases, the sequence is attached to the flexprint connector of the device assembly.

4.0 Quality Assurance Provisions

4.1. Screening Flight candidate devices will be subjected to initial screening at CSR, as detailed in tables 1, 2, and 3. The purpose of the screening measurements is to identify quickly, devices which do not warrant detailed calibration. Ordinarily, only devices which meet the performance criteria described below will be subjected to detailed calibration. Final device screening is accomplished during detailed calibration, and is itemized in Table 5.

4.1.1 Quality Conformance Inspection (QCI) All (100%) flight CCDs are tested extensively at three temperatures, including the operating temperature of -120°C. Therefore, Group A, QCI testing is not performed. Groups B and C QCI testing is detailed in Tables 6 and 7. These flight CCDs are un-packaged, therefore QCI Group D testing does not apply.

4.2. Acceptance criteria The following device performance parameters will be measured during CSR screening. The minimum acceptable performance levels for each parameter are listed in tables 1, 2 and 3. Details of the measurement methods and conditions, and data analysis techniques for each parameter are described in this section.

4.2.1 Functionality The following criteria define the functionality of the device.

4.2.1.1 Output nodes All four output nodes must meet the requirements listed in table 1.

4.2.1.2 Serial registers The noise and CTI requirements listed in table 1 must be met with the device readout in ABCD, AC and BD (two output) modes.

4.2.2 Device performance parameters All devices must meet the requirements specified in Table 1.

4.2.3 Spectral Resolution Each front-illuminated device must exhibit the X-ray spectral resolution characteristics listed in Table 2. Each back-illuminated device must exhibit the X-ray spectral resolution characteristics listed in Table 3.

4.2.3.1 Measurements conditions and analysis for spectral resolution measurements Spectral resolution measurements shall be made by fully illuminating the detector with a nominally uniform, monochromatic beam of X-rays. The mean X-ray flux for these measurements shall be 10^3 photons/cm^2/frametime. At least 75% of the detector shall be exposed to a flux within 50% of the nominal value. At least 10^5 events shall be collected for each output node for each measurement. Raw data frames from spectral resolution measurements shall be bias and overclock corrected. A mean(TBR) of at least 5(TBR) bias frames, taken immediately prior to the X-ray exposures, shall be used for bias correction. Overclock correction shall make use of horizontal overclock regions. The ASCA event detection and grading algorithms shall be used to extract events from the bias and overclock subtracted data. Histograms of graded event pulse height shall be computed. The spectral resolution specifications shall be met for the histogram of event grades 0, 2, 3, and 4, with a split threshold of 15 electrons. A model consisting of the sum of two gaussian distributions shall be fit to the appropriate region surrounding each peak of interest in the histograms. The full-width at half maximum of the best fit model shall be used to assess spectral resolution. Adequate bias stability during the measurement shall be assured by verifying that the histogram of bias-corrected corner pixels for grade 0 events has first and second moments consistent with zero bias error, given the noise measurements specified in 4.3.1.7. In addition, a time history of the frame-averaged corner pixel value shall be examined.

4.3.1 Common measurement conditions Unless otherwise specified, all screening measurements will be made under the following conditions:

4.3.1.1 Operating Temperature Focal plane temperature will be controlled to -120°C, with a stability (over time) of ±1°C. The accuracy of the temperature measurement shall be such that the actual, time-averaged device temperature shall be within 5°C of the specified setpoint.

4.3.1.2 Analog Electronics ACIS brassboard detector electronics (DEA) shall be used.

4.3.1.3 Readout Rate The nominal readout rate shall be 100 kpix/s/output node.

4.3.1.4 Readout Format Measurements requiring full frame data shall be read out in framestore mode, using the following format: i) all four output nodes read out simultaneously, ii) for each output node, 4 underclocks and 28 horizontal overclocks iii) 32 vertical overclocks This results in a data array with 1152 columns per row and 1058 rows. Measurements requiring two-output readout shall used the following format: i) either outputs A and C, or B and D, to be read out simultaneously; ii) for each output node 4 underclocks and 60 horizontal overclocks; iii) 32 vertical overclocks. This results in a data array with 1152 columns per row and 1058 rows.

4.3.1.5 Image-to-framestore transfer rate and frame time The image-to-framestore transfer shall occur at less than 20 μs per line. The nominal frame time, derived from section 4.3.1.3 and 4.3.1.4, is 3.06 seconds.

4.3.1.6 Measurement and Data Analysis Methods Unless otherwise specified herein, the approved data analysis methods will be used.

4.3.1.7 Noise and responsivity measurements RMS system noise shall be measured for each output node for imaging and overclock areas. For each such area, difference of two subsequent frames shall be computed. A gaussian model shall be fit to a histogram of these differences. The system noise, measured in engineering units (ADU) is taken to be $1/\sqrt{2}$ times the RMS deviation of the best fit gaussian model. The responsivity, in electrons/ADU, shall be determined assuming that the centroid of a histogram of g0234 events produced by Mn K-alpha characteristic X-rays represents 1620 electrons.

4.3.1.8 Charge Transfer Efficiency Measurements Charge transfer efficiency shall be measured from the spatial variation of mode of the pulse height distribution produced by the illuminating beam. A model of the form: ph(y) = ph(0) + delta*y shall be fit to the data, where ph is the mode pulse height for photons landing at location y, and y is either row number (for parallel CTI measurements) or column number (for serial CTI measurements). The CTI shall be taken to be CTI = delta y/ph(0). The function ph(y) shall be estimated with a spatial resolution no lower than delta y =64 pixels. The statistical errors in the CTI 5.9 keV CTI measurement shall be less than 1.2×10^{-6} and less than 5×10^{-6} for parallel and serial CTI, respectively. The maximum tolerable statistical errors at other energies shall be scaled from the limits at 5.9 keV, taking the limit to vary inversely with photon energy.

4.3.1.9 Dark Current Measurements Dark current shall be measured at two temperatures: the nominal operating temperature, specified in 4.3.1.1, and at a temperature 5°C higher than the nominal temperature. Exposure times for dark current measurement Dark Current shall be measured by operating the CCD in timed exposure mode with various exposure times, ranging from the nominal frame time (as specified in 4.3.1.5) to 10 times the frame time, with no X-ray or optical excitation present. Nominally, 5 (TBR) frames shall be acquired at each exposure time, and an average frame for each exposure time shall be computed. The average frame at the nominal exposure time, (called the mean bias) shall be subtracted from each longer average exposure, and each longer exposure shall be corrected to zero overclock level.

Dark current data analysis; The mode dark level for each bias and overclock corrected average dark frame shall be determined from a histogram of the pixels in the imaging area. The data from each output node shall be analyzed separately. The mode will be determined by fitting an appropriate functional form to the histogram. A linear relationship between the inferred modes m(t) and times exposure t, $m(t) = a + b(t-t_{frame})$, will be fit to the data. The mean dark current b (adu/pixel/sec) will be expressed, converted to elec/pixel/sec using the responsivity measurements specified in 4.3.1.7. For reference purposes, a dark current estimate shall be obtained for each pixel, so that a dark current map may be constructed. The dark current map shall be obtained from the median value, in at least 100 (TBR) dark exposures, each approximately 10 times the nominal ACIS exposure time, for each pixel. The data shall be appropriately bias and overclock corrected.

4.3.1.10 Dark current stability The temporal stability of the dark current shall be determined by analysis of event corner pixel values extracted from data obtain for spectral resolution. Mean corner pixel values for grade 0 events (split threshold of 15 electrons) will be computed for all the events in each frame in a data set. The mean corner pixel value for each frame shall meet the specification listed in table 1. The histogram of corner pixel values for all grade 0 events (split threshold of 15 electrons) in each data set shall have mode within the tolerance for dark current stability listed in table 1 The RMS deviation of the corner pixel histogram shall be statistically consistent, at the 90% confidence level, with the noise measurements described in paragraph 4.3.1.7.

4.3.1.11 Bright pixels, bright columns and edge glow Pixels with bias level (at nominal temperature and nominal frame time) more than 50 electrons (TBR) above the median bias are defined to be bright pixels. The number of bright pixels shall be determined from the mean bias frame (at nominal temperature) described in 4.3.1.9. The median of all pixels from each output node shall be computed to identify bright pixels. Columns with median bias level (at nominal temperature and nominal frame time) exceeding the median bias level by more than 50 electrons are defined to be bright columns. The median bias level of all pixels in each column in the mean bias frame shall be computed and compared with the requirement in table 1. "Edge glow" areas are contiguous areas of the detector with bias level (at nominal temperature and nominal frame time) which exceed the median bias by more 50 electrons (TBR), and which are neither isolated bright pixels nor in bad columns. Edge glow area will be determined from the bright pixel search described above. For front-illuminated devices, edge glow shall be measured at both high and low back diode voltages. The two applied back-diode voltages shall be equivalent to the two values produced by the ACIS flight detector electronics assembly back diode voltage supply (nominally 12 V and 70 V). An "edge glow map" shall be acquired from

a median of approximately 100 (TBR) frames (bias and overclock corrected) acquired with the high back diode voltage and the nominal full-frame exposure time.

Table 4
Summary of Test Data for Each Device Tested

Measurement	Data	Remarks
Noise/Responsivity	Noise histograms Table of RMS Noise Estimates	Differences of overclock and image areas for each output node, 1 ADU resolution ± 100 ADU range Units of ADU and electrons
Charge Transfer Efficiency	Histograms List of Histogram Modes Fitted CTI values	For each spatial cell and energy, per 4.3.1.8 For each histogram For each energy, output node, readout direct
Dark Current	Full frame DC. map Dark Current Histograms Pixel-averaged mode DC. Corner pixel histograms Corner pixel light curve	median dark current, elec/pixel/sec For each output, long exposure For each output node Slope and offset per 4.3.1.9 for stability test for stability
Cosmetics	Bright Pixel Map Bright/bad column Map Edge Glow Map Tabular defect summary	 number of bright pixels, columns, edge glow area
Spectral Resolution	Histograms: Table of fit results Photon Image Files Corner Pixel Histogram Corner Pixel Light Curve	Each energy, grade, output node (pcf file) and combined g2034 g0, g0234: gaussian model parameters g0234 including fit parameters including deviation from mean

Table 5
Device Screening
(Method 5004.9, Table I, of MIL-STD-883)

Test inspection	MIL-STD-883 Method/Condition	Comment
Wafer Lot Acceptance	5007	100%
Non-destructive bond pull tests	2011	100%
Internal visual	2017	3 independent inspections
Temperature Cycling	+25°C to -125°C	5 cycles
Constant Acceleration	2001	Not Applicable
Visual Inspection		Not Applicable
Particle Impact Noise Detection	2020	Not Applicable
Serialization		100%
Pre Burn-in Electrical Parameters	per table 4 herein	100%
Burn-in	operation @ +25°C and -120°C	250 hours
Post Burn-in Electrical Parameters	per table 4 herein	100%
Die shear strength	epoxy coverage and measure thickness	100%
Percent Defective Allowable (PDA) calculation	5 %	
Seal	1014	Not Applicable
Radiographic	2012	Not Applicable
Qualification or Quality Conformance Inspection		See Tables 6 and 7
External Visual	2009	Not Applicable
Radiation Latch-up	1020	Immune

Table 6
Group B QCI
(Method 5005.12, Table IIb, of MIL-STD-883)

Test inspection	MIL-STD-883 Method/Condition	Comment
Resistance to solvents		Not Applicable
Solderability		Not Applicable
Non-destructive bond pull tests	2011	100%

Table 7
Group C QCI
(Method 5005.12, Table III, of MIL-STD-883)

Test inspection	MIL-STD-883 Method/Condition	Comment
Steady State Life Test	1000 hours at +25°C (Dynamic)	Quantity 5
Final Electrical Tests	per table 4 herein	100%

4.3.1.12 Bad columns Bad columns are those that do not report X-ray events with expected efficiency. Bad columns will be determined from a map of all X-ray events detected in the spectral resolution measurements. For each spectral resolution data set, the mean number of events per column will be computed. Columns with numbers of reported events below 50% of the local mean will be regarded as bad columns.

4.4 Screening and Test Data Data produced for each device in the screening process are detailed in Table 4.

5.0 Preparation for Delivery

5.1 Packaging and Packing Packaging and packing shall be sufficient to protect the device during routine handling and transportation by common carriers. An approved device storage and transportation container is shown in Lincoln Laboratory drawing 427871. Cleanliness shall be in accordance with paragraph 4.3.1.2 and 4.3.1.3 of the MIT Contamination Control Plan, 36-01207.

5.2 Marking The test container shall be marked with the six- or eight-character identification sequence (3.8 above) of the one or two device(s) contained therein.

6.0 Notes

6.1 Approved source of supply. The manufacturer listed below is the only approved source for the device listed herein.

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