CHIP CHARACTERISTICS
FOR
Tektronix TK2048EB4-1 1604CR17-01

Sebastian Deiries Olaf Iwert Evi Hummel

ESO Garching

Optical Detector Laboratory

January 19, 1996

1 General Description

Chip type	: Tektronix TK2048EB4-1 Grade 1, thinned, AR coated, MPP
Chip characteristics	: AR coating: Indium die attach,
Chip format	: 2048x2046, 19 pre-scan pixels in horizontal direction
Pixel size	: 24 x 24μm^2
Serial No.	: 1604CR17-01

The cryostat electronic board has special clock shaping capacitors for this CCD (C57-60: 1000pF, C61-64: open, C65-68: 150nF, C69-72: 2.2nF).

2 Flatness of the chip

The surface of the CCD can be fitted with a sphere of a radius of 2396mm $\pm$ 45mm. The definition is very good.

3 System Setup

This chip has been tested with the ESO-VME CCD camera system.

The clock-pattern tk2048eadmpp have been used for the tests.

Parameters are set to SUBPATT 3 and GAIN 2, if not otherwise mentioned.

All tests were performed between 160 K and 180 K, if not otherwise mentioned.

4 Voltage Setup

See table 1 on page 2 for all voltage values.

```
VLO1 :  -8.06 VHI1 :  1.04 VLO2 :  -8.02 VHI2 :  1.04
HLO1 :  -4.01 HHI1 :  8.01 HLO2 :  -4.02 HHI2 :  8.02
RLO1 :  0.00 RHI1 :  12.97 RLO2 :  -8.00 RHI2 :  3.52
VDD1 :  24.00 VDR1 :  13.52 VDD2 :  24.00 VDR2 :  13.52
VGS1 :  -1.99 VSS1 :  0.01 VGS2 :  -8.98 VSS2 :  0.00
```

Table 1: Telemetry values
for A, B, C and D amplifier

5 Noise and Gain

Amplifier A:

The conversion factor is (at GAIN = 2)

2.466±0.168 **e$^-$/ADU.** at subpatt 2

1.293±0.033 **e$^-$/ADU.** at subpatt 3

1.253±0.08 **e$^-$/ADU.** at subpatt 3 and 2x2 binning

0.633±0.01 **e$^-$/ADU.** at subpatt 4

The readout-noise is

5.0±0.3 **e$^-$ RMS** at subpatt 2

4.1±0.2 **e$^-$ RMS** at subpatt 3

5.4±0.5 **e$^-$ RMS** at subpatt 3 and 2x2 binning

3.4±0.2 **e$^-$ RMS** at subpatt 4

Amplifier B:

The conversion factor is (at GAIN = 2)

1.552±0.057 **e$^-$/ADU.** at subpatt 3

The readout-noise is

5.1±0.3 **e$^-$ RMS** at subpatt 3

Amplifier C:

The conversion factor is (at GAIN = 2)

2.718±0.040 **e$^-$/ADU.** at subpatt 2

1.314±0.069 **e$^-$/ADU.** at subpatt 3

1.355±0.037 **e$^-$/ADU.** at subpatt 3 and 2x2 binning

0.671±0.014 **e$^-$/ADU.** at subpat

The readout-noise is

4.7±0.3 **e$^-$ RMS** at subpatt 2

3.9±0.3 **e$^-$ RMS** at subpatt 3

5.6±0.3 **e$^-$ RMS** at subpatt 3 and 2x2 binning

3.7±0.2 **e$^-$ RMS** at subpatt 4

Amplifier D:

The conversion factor is (at GAIN = 2)

2.834±0.110 **e$^-$/ADU.** at subpatt 2

1.370±0.105 **e$^-$/ADU.** at subpatt 3

1.487±0.188 **e$^-$/ADU.** at subpatt 3 and 2x2 binning

0.713±0.009 **e$^-$/ADU.** at subpatt 4

The readout-noise is

5.0±0.2 **e$^-$ RMS** at subpatt 2

4.1±0.3 **e$^-$ RMS** at subpatt 3

5.2±0.7 **e$^-$ RMS** at subpatt 3 and 2x2 binning

3.5±0.1 **e$^-$ RMS** at subpatt 4

The noise and gain was measured using the HP-desktop procedure "MEASURE CONFACT" at different illumination levels. This procedure takes two equal dark– and two equal flat-field exposures calculating noise and gain independent from the light level with the variance of the difference of the two flat-fields.

6 Pick-up Noise

At slow-mode pick-up noise could not be seen at short dark exposures.

7 Quantum Efficiency

```
CCD SENSITIVITY CALIBRATION:                        29 Jun 1995   08:36:48
============================

Detector ID          : TK20160      Detector            : Tektronix
Calibrated against   : _SDC2_NP_2   Type                : TK2048EB4-1
Detector area (cm2)  : 5.76E-06     ESO CCD No.         :    1336
e-/[ADU]             :  1.27        Used Output(s)      :     0
System gain          :     2        Subpattern          :     3
Misc.Comments        : tk2048eadmpp_1604CR17-01

CCD System values    :          Scanned CCD area
-----------------    :          ----------------
Hor. act. Pixels     :  2086        First pixel         :    25
Tot. vert. Lines     :  2060        Last pixel          :  2063
Hor.  Binning        :     1        First line          :     5
Vert. Binning        :     1        Last line           :  2043
```

Lambda [nm]	Time [sec]	Dens [log]	Temp [K]	Counts [ADU]	RQE [%]	+/- [%]	Sensitivity [A/(W/cm2)]	Photon flux [Phot/cm2]	Irradiance [W/cm2]
320	300	0.0	162.3	1085	23.02	1.24	+3.441E-07	+3.454E+06	+2.130E-12
340	300	0.0	162.3	5261	30.77	1.40	+4.872E-07	+1.253E+07	+7.296E-12
360	300	8.6	162.3	7052	43.42	1.95	+7.268E-07	+1.190E+07	+6.555E-12
380	60	8.6	162.3	7598	57.46	2.37	+1.017E-06	+4.843E+07	+2.525E-11
400	20	0.0	162.3	5790	68.86	2.77	+1.276E-06	+9.240E+07	+4.597E-11
450	10	.4	162.3	4872	66.11	2.62	+1.379E-06	+1.620E+08	+7.158E-11
500	10	.7	162.2	4432	68.43	2.70	+1.589E-06	+1.423E+08	+5.654E-11
550	10	1.0	162.3	5708	72.31	2.79	+1.848E-06	+1.735E+08	+6.259E-11
600	10	1.0	162.3	7456	77.53	2.92	+2.157E-06	+2.113E+08	+7.005E-11
650	10	1.0	162.2	8294	76.09	2.78	+2.274E-06	+2.395E+08	+7.393E-11
700	10	1.0	162.2	11119	76.96	2.76	+2.500E-06	+3.175E+08	+9.014E-11
750	10	1.0	162.3	6964	70.10	2.60	+2.438E-06	+2.184E+08	+5.790E-11
800	10	1.0	162.2	8585	62.20	2.37	+2.309E-06	+3.033E+08	+7.537E-11
850	10	1.0	162.2	8864	48.73	2.02	+1.926E-06	+3.998E+08	+9.330E-11
900	10	.8	162.2	8655	35.36	1.58	+1.477E-06	+5.380E+08	+1.188E-10
950	10	.7	162.2	5351	22.15	1.10	+9.755E-07	+5.309E+08	+1.112E-10
1000	10	.5	162.2	5991	10.45	.62	+4.842E-07	+1.260E+09	+2.508E-10
1040	10	.5	162.1	5787	3.57	.23	+1.727E-07	+3.564E+09	+6.792E-10
1080	10	0.0	162.1	7624	1.33	.08	+6.722E-08	+1.256E+10	+2.299E-09
1100	10	.3	162.0	5463	1.46	.08	+7.444E-08	+8.234E+09	+1.487E-09

```
Calibration_error=    1.50%  Conversion_factor_error=   2.93%
_TK20160_8 stored on /users/ms/cali:HFS at 29 Jun 1995 17:59:06
```

Table: RQE measurement protocols for the CCD chip

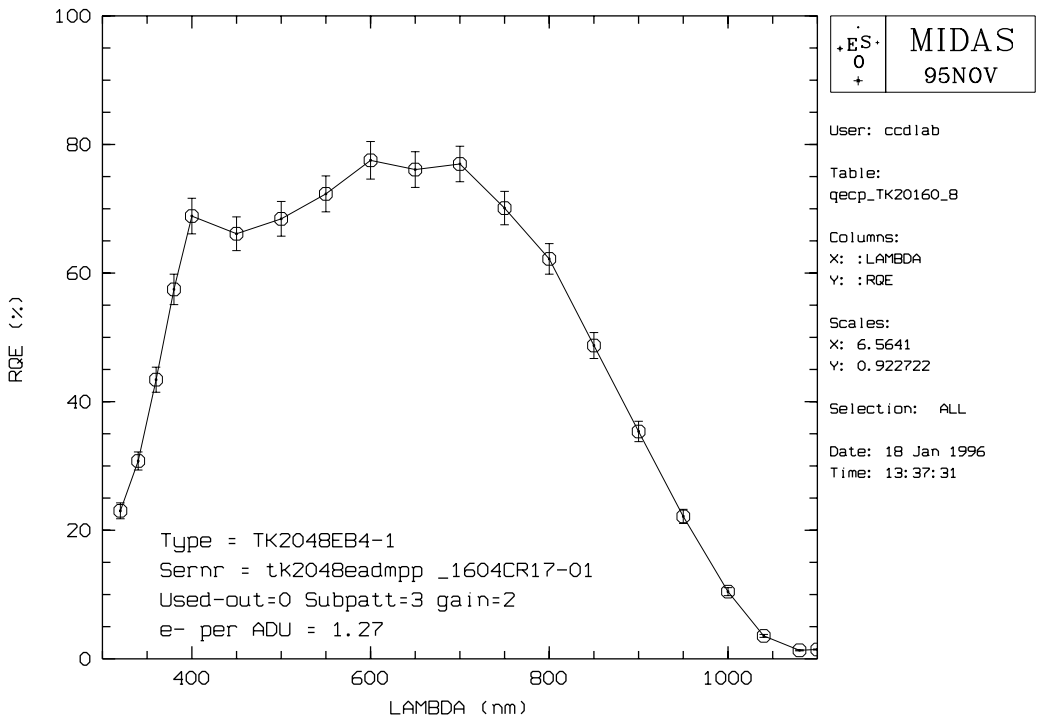


Figure 1: Plot of RQE values of the CCD (complete surface) at 161 K

The RQE was measured in an automatic mode using the test-bench computer. The quantum-efficiency values and their errors are listed below. The given error is the geometrical sum of the error of test-bench calibration (approximate 1.5%), the error of the CCD conversion factor measurement (approximate 2.9%) and of the variation of the quantum-efficiency over the whole chip surface (dependent from the light wavelength). The variation of quantum efficiency over the chip can be seen in detail in the homogeneity measurement in section 14 on page 11.
The peak value for RQE of CCD was approx. 77 % at 700nm.

Figure 1 on page 6 shows the plot of QE for the CCD.

8 Charge Transfer Efficiency

The CTE was measured using Flat Field exposures and its over-scan regions and gives:

Amplifier A:

Serial CTE = 0.9999986 and Parallel CTE = 0.9998363

Amplifier D:

Serial CTE = 0.999998 and Parallel CTE = 0.9994974

9 Dark Current

The dark current was measured with a 20 minutes dark exposures after more than 5 hours in the dark wiping the CCD every minute.

The mean dark current rate is approx. $\leq 5\ e^-/pixel/hour$ at 161 K.

10 Linearity

The CCD was not optimized for linearity. Linearity was measured taking exposures of the same exposure-time at different light levels and at a wavelength of 700 nm.

Amplifier A:

There is a maximum deviation of less than ±0.8% from the average value within 3.6 decades from 78 to 280 240 e^- per pixel.

Amplifier B:

There is a maximum deviation of less than ±0.6% from the average value within 3.2 decades from 60 to 100480 e^- per pixel.

Amplifier C:

There is a maximum deviation of less than ±0.6% from the average value within 3.8 decades from 32 to 221480 e^- per pixel.

Amplifier D:

There is a maximum deviation of less than ±0.7% from the average value within 4.1 decades from 20 to 233200 e^- per pixel.

See figure 2 on page 8 for details.

In view of the other problems with this CCD, the linearity was not optimized with the voltage setup.

11 Full well capacity

The full well capacity was measured with flat-field exposures of high intensities in MPP–mode. The limit of linearity is reached, if at higher intensities the deviation from linearity starts to get larger than the given maximum deviation in the section 10 on page 7.

Amplifier A:

Upper limit of linearity: 252 000 e^-/pixel
Saturation-value: 354 000 e^-/pixel

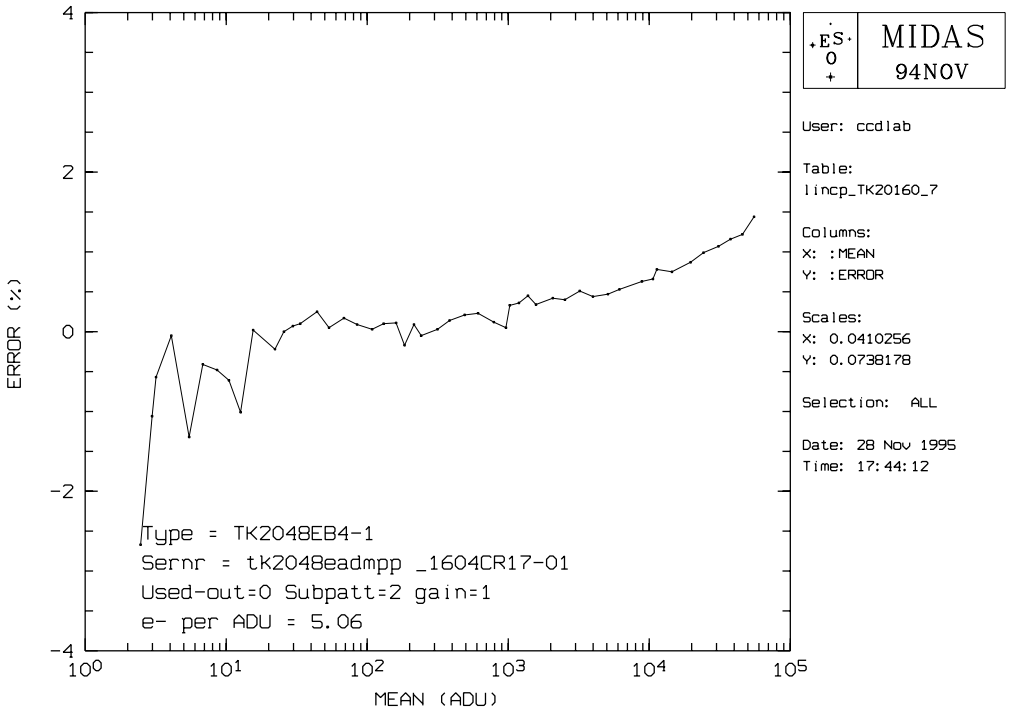


Figure 2: Linearity Measurement with amplifier A

Amplifier B:

Upper limit of linearity: 330 000 e^-/pixel
Saturation-value: 412 000 e^-/pixel

Amplifier C:

Upper limit of linearity: 133 000 e^-/pixel
Saturation-value: 356 000 e^-/pixel

Amplifier D:

Upper limit of linearity: 182 000 e^-/pixel
Saturation-value: 376 000 e^-/pixel

Horizontal voltage has to be adjusted to prevent charge smearing at high illumination values.

12 Cosmic Ray Events

The Cosmic Ray Event rate was measured using our standard method (MIDAS Batch: COSMIC) to count *events* independently of their actual size.

The cosmic ray event rate is $3.04 + 0.2 - 0.2$ $events/min/cm^2$**.**

13 Blemishes

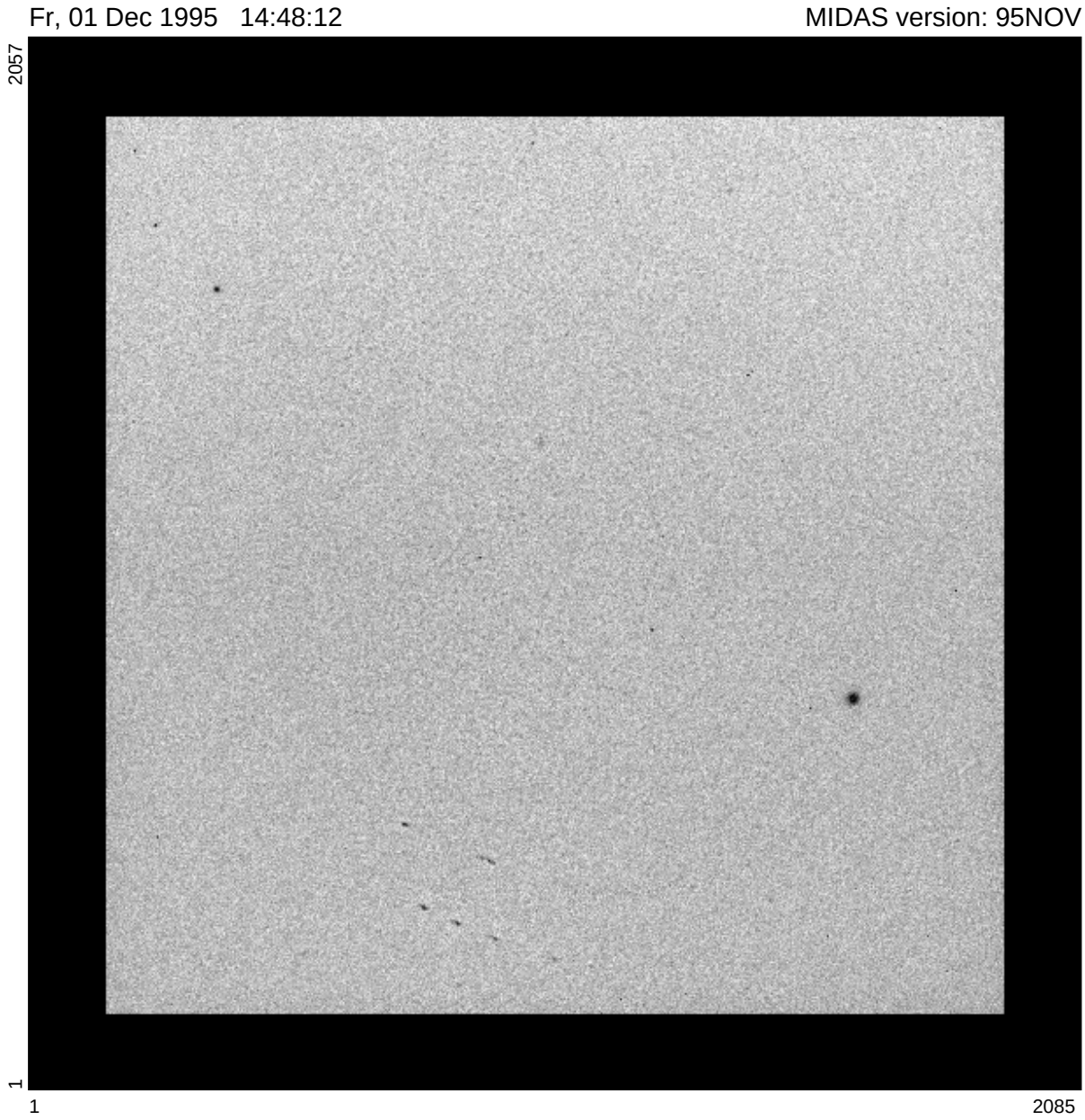
With the Amplifier A we found 98 defective pixels. This was measured using three weak light images with a level of approximate 300 e^- per pixel (see page 10) and an automatic MIDAS-procedure to identify and catalogue the defects.

This test is very sensitive: A column defect is any defect which is longer than 10 pixels and a defect is any pixel which is lower than 50 % or higher than 200 % of the mean level of a weak light flat field exposure.

```
Number of hot defects:
Hot spots: 1; Hot cluster: 0; Hot columns: 0

Number of dark defects:
Dark pixel: 0; Dark cluster: 16; Dark columns: 0; Traps: 5

Number of all defects: 22
```



Frame	: weakmean
Identifier	: average frame
ITT-table	: ramp.itt
Coordinates	: 1, 1 : 2085, 2057
Pixels	: 1, 1 : 600, 600
Cut values	: 440.98, 561.23
User	: ehummel

Figure 3: Weak Flat field (700nm,2.5): approx. 300 e^- per pixel with amplifier A.

14 Uniformity

The homogeneity was measured using a standard method of sampling the whole sensitive area and using the RMS value of it. Values of deviations from homogeneity are given in table 2 on page 11.

Flat-field exposure at a wavelength in [nm]	Maximal RMS Deviation from mean value in [%]
320	4.27
340	3.13
360	3.06
380	2.48
400	2.32
450	2.21
500	2.18
550	2.02
600	1.84
650	1.60
700	1.44
750	1.70
800	1.91
850	2.51
900	3.03
950	3.74
1000	4.93
1040	5.50
1080	5.11
1100	4.29

Table 2: Uniformity of the CCD

15 Remanence

Exposure Type	Exposure Time in [sec]	Illumination in [photons/pixel]	CCD Saturation	Remanence in [e^- per pixel]
FF white	1(Dens=1)	210000	0.39	—–
DK	600	—	—	1
FF white	1	1852000	3.39	—–
DK	600	—	—	1
DK	600	—	—	1
DK	600	—	—	1
FF white	10	18520000	33.9	—–
DK	600	—	—	2
DK	600	—	—	1
DK	600	—	—	1

Table 3: Remanence of the CCD at 161 K

The Remanence test was made after 10 hours in the dark and periodical wiping at at temperature of 161 K. After a high level flat field with white light which give oversaturation on the CCD, several ten minutes dark exposures have been taken. The mean level in the centre of these dark exposures was compared with the mean level of a ten minute dark before these saturations and the remanence in e^- per pixel has been calculated. The results can be seen in table 3 on page 12.

References

[1] S. Deiries, M. Cullum: ESO Maintenance Manual No.5 July 89, CCD Cryostat for new VME-based Control Camera.

[2] J. Janesick, JPL: Private communication