

# High Speed Impactron CCD Line Sensor with Color Sensing Capability

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The Impactron technology was developed to improve the CCD sensor SNR, DR, and sensitivity by multiplying charge directly in the charge domain before readout. The multiplication is achieved by using many successive single carrier impact ionizations occurring in a suitably designed CCD register where higher clocking voltages are applied. The basic concept is shown in Fig.1. This concept can be applied in principle to any CCD architecture. This report describes the application to a color linear CCD sensor.

The main advantages of the line sensors are their high resolution and lower cost. The disadvantage is the relatively poor sensitivity in comparison to the staring area sensors due to the short integration time that is dictated by the sensor scanning requirement. This problem is now significantly reduced by including the charge domain electron multiplication on-chip. The resulting Impactron CCD line sensor device thus has significant competitive advantage over the similar devices existing on the market.

The basic device layout is shown in Fig.2. The CCD consists of two rows of photo-sites, one for the green color and the second one for the red and blue colors. The main feature of the design is the charge splitter that divides charge from the fast clocked CCD registers into two slower clocked registers that have incorporated in them the charge multiplying sections. This provides a higher readout speed as well as the color

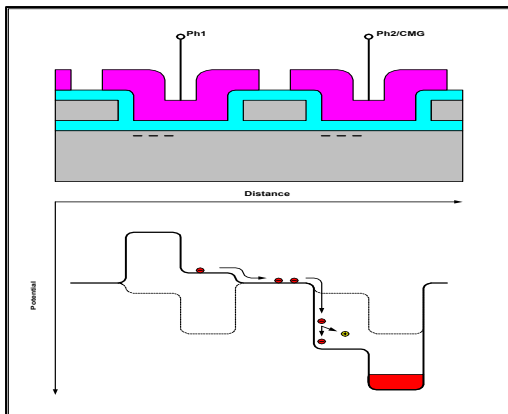


Fig. 1. Charge multiplication concept.

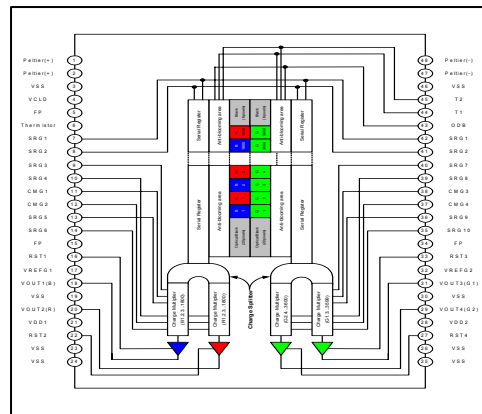


Fig. 2. CCD Sensor layout.

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separation directly on chip. The layout of the complete chip is shown in Fig.3. The charge multiplication sections occupy only a relatively small portion of the chip area.

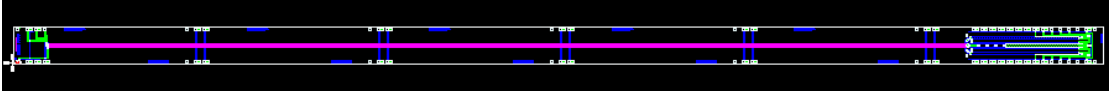


Fig.3. the complete CCD line sensor chip layout.

The sensor has been characterized in detail with the summary of the performance parameters given in table T1.

Table T1: Summary of the device performance parameters:

<u>ITEM</u>	<u>TARGET</u>	<u>ACTUAL</u>
Pixel Size	10x10um	←
Active Pixel Number	3600x2 pixel	←
OB Pixel Number	20 pixel	←
Dummy Number	6 pixel	←
Output Terminal	4-ch	←
PD Cell Well Capacity	50ke- ~ 80ke-	<b>74ke-</b>
Serial/CMG Well Capacity	50ke- ~ 80ke-	<b>74ke-</b>
FD Well Capacity	80ke- ~ 110ke-	<b>98ke-</b>
Line Rate	10kHz ~ 15kHz	<b>13kHz</b>
Serial Transfer Frequency	46MHz ~ 80MHz	<b>60MHz</b>
CMG Register Frequency	23MHz ~ 40MHz	<b>30MHz</b>
CMG Gain	500x ~ 1000x	←
Amp. Conversion gain	12uV/e ~ 14uV/e	<b>13.2uV/e</b>
Amp. Noise floor	1e	<b>&lt;1e</b>

The important parameters of the device are the charge multiplication gain as function of the gate voltage, noise as function of the multiplication gain, and dark current as function of temperature. This data is provided in graphs in Fig.4, Fig.5, and Fig.6.

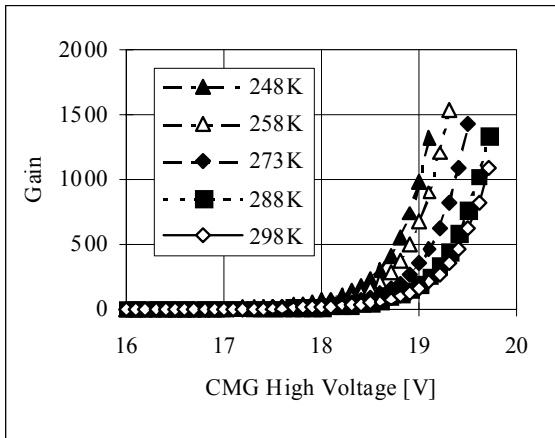


Fig.4 EM gain as function of the gate bias.

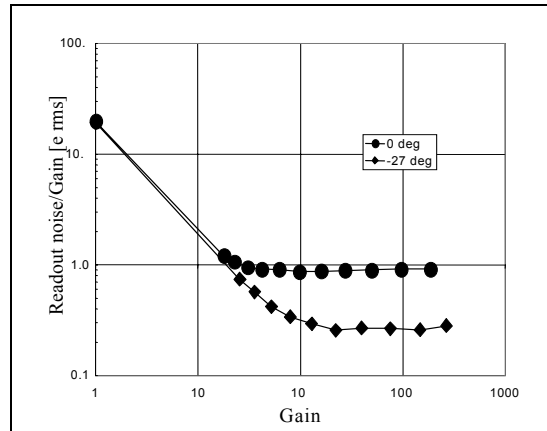


Fig.5. Readout noise as function of Gain

Since this is a color sensor and the green signal has been divided in to two channels it is important to make sure that both channels have the same performance. In many CMOS sensors using the Bayer color filter geometry the green channels exhibit a difference that causes problems in subsequent image processing. This is known as Gr-Gb difference. This performance was also characterized in this sensor with the result shown in Fig.7. As can be seen from the graphs the difference is very small.

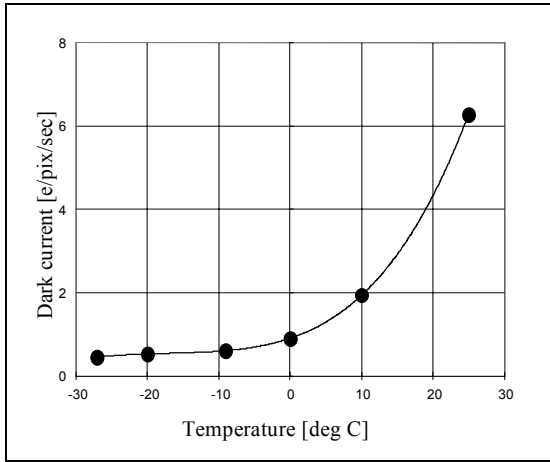


Fig.6. Dark current as function of temperature.

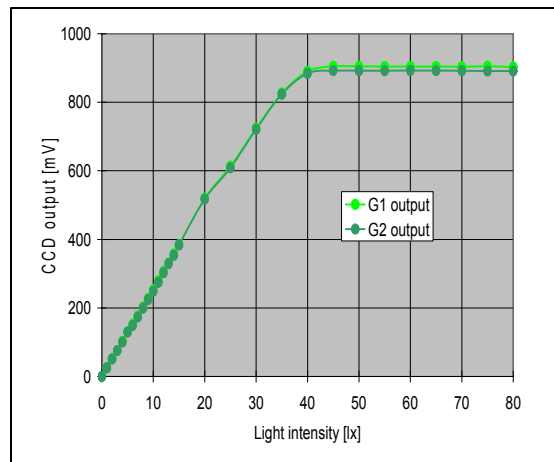


Fig.7. Gr-Gb difference as function of Lux.

The developed sensor has been incorporated into the high performance camera by the PLUSMIC Corporation that provides the race track services. To demonstrate the camera performance and to compare it with the performance of the previous model using a conventional linear CCD, several race track pictures are included below.

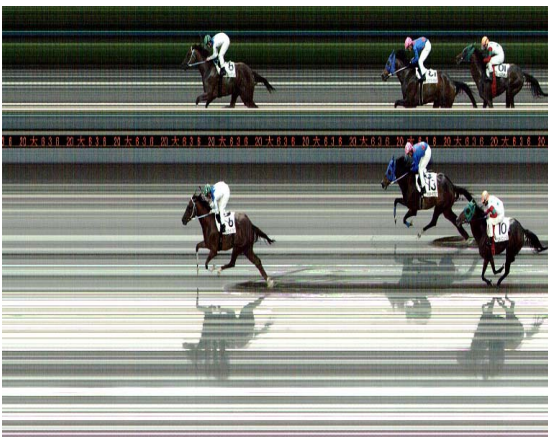


Fig.8. Race track camera image with Impactron CCD.



Fig.9. Race track camera image with conventional CCD.



Fig.10. Speed boat race image using the CCD Impactron camera.



Fig.11. Speed boat race image using the conventional CCD camera.



Fig.12. Side-by-side camera comparison test of railroad track images.

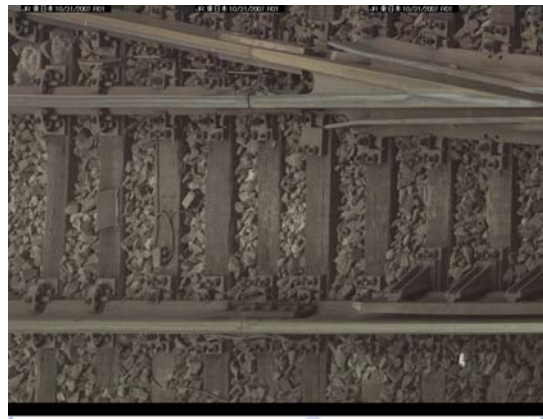


Fig.13. Railroad track image using the Impactron CCD camera.

**To summarize the report:** the color sensing CCD Impactron line sensor has been developed and characterized. The incorporation of the charge multiplication into the sensor has dramatically improved the sensor sensitivity, dynamic range, and noise performance, which are very important competitive parameters for the low cost line sensors. The high clocking speed, as well as the separation of colors directly on-chip has been achieved by developing the high speed charge splitter. The incorporation of the sensor into the race track camera has resulted in the camera superior performance.

**Acknowledgement:** Authors would like to thank the management of the PLUSMIC Corporation for the dedicated commitment to this project and for partial funding, which made this work possible. Many thanks are also extended to Mr. Yoshishige Yamaguchi who built the camera and kindly supplied the evaluation photographs shown during this presentation.