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Charge-Coupled Devices in Astronomy Research

Dr. D. V. Raje
Dept. of Physics & Electronics,
Rajarshi Shahu Mahavidyalaya
(Auqtonomous), Latur, Dist. Latur

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ABSTRACT

A charge-coupled device (CCD) is a device for the movement of electrical charge, usually from within the device to an area where the charge can be manipulated, for example conversion into a digital value. This device was invented in October 19, 1969 in the United States at AT&T Bell Labs by Willard Boyle and George E. Smith. CCDs work by converting light into a pattern of electronic charge in a silicon chip. This pattern of charge is converted into a video waveform, digitized and stored as an image file on a computer In recent years CCD has become a major technology for digital imaging. In a CCD image sensor, pixels are represented by p-doped metal-oxide-semiconductors (MOS) capacitors. These capacitors are biased above the threshold for inversion when image acquisition begins, allowing the conversion of incoming photons into electron charges at the semiconductor-oxide interface; the CCD is then used to read out these charges. Although CCDs are not the only technology to allow for light detection, CCD image sensors are widely used in professional, medical, and scientific applications where high-quality image data are required. In applications with less exacting quality demands, such as consumer and professional digital cameras, active pixel sensors, also known as complementary metal-oxide-semiconductors (CMOS) are generally used;

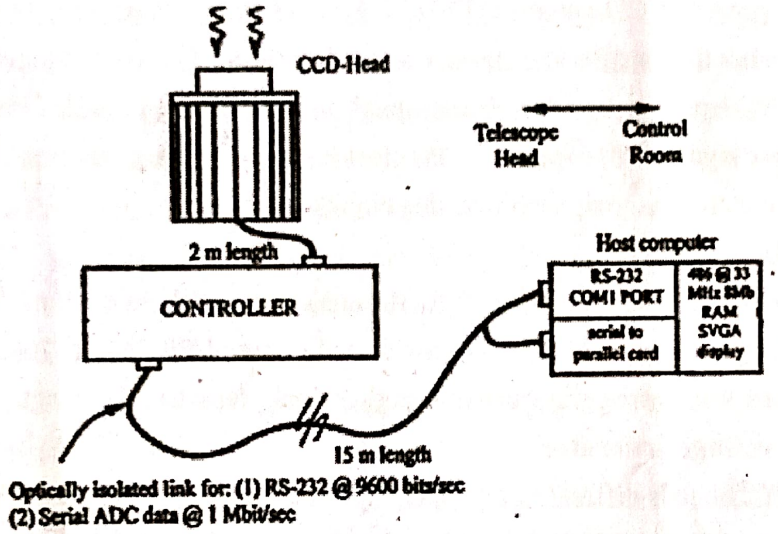
Introduction

CCD is electronic detector forming the heart of an astronomical instrument. The CCD was designed to store and transfer analog information in the form of packets of electric charges within a semi-conductor structure. The charges are storage sites in MOS capacitors. There are several hundred to thousand MOS capacitors on single chip. Electrical charges are created through photo electric effect in photo sensitive detectors with CCD registers. A CCD is an array of photosites (pixels) on a substrate arranged in rows and columns. After a certain period of being exposed to light called as integration time, the photo charges are transferred, one behind the other to an output stage. The electrical signal delivered at the output stage is proportional to incident illumination falling on the read site. Hence, one can observe the variation of electric signal at the output, synchronized with read out rhythm of CCD and corresponding to the number of charges contained in the packet. The injection of charges, their storage, transfer and read out are the basic functions of CCD. For proper operation of CCD, bias voltage and clocks should be given to different pin of CCD. CCD manufacturers provide a 'datasheet' which gives the electrical pin connection diagram for the device, the names and symbols for each pin, the voltage or range of voltages to be applied to each pin and timing diagram, i.e. a diagram showing the time sequence of CCD drive signals and relationship between them. Voltage applied to the CCD are of two type, fixed voltage referred to as DC bias levels, which remains unchanged after switch on and pulse or clock voltage which can be switched back and forth between two voltage levels.

These days CCDs are widely being used by astronomers. The production of electronic image is carried out in two steps. Firstly, the optical image is integrated in such a way that a significant number of charges are placed in photosites. Secondly, at the end of integration the photo charge packets are transferred on behind the other, towards the output stage where the contents can be measured. The measurement can be analog and the image is reconstituted on a video or computer screen. The image visualized on computer screen is much better than photograph and is just pleasant as visual observation.

Block Diagram of CCD Camera

CCD Camera consists of CCD head, CCD controller, CCD power supply and personal computer. Software is used to grab the image from CCD controller and display it on computer screen. The image is stored in ST6 file format.



Block Diagram of CCD Camera

1. CCD Head

The CCD head contains the CCD chip, cooling element and heat sink. The cooling element is glued on a mounting plate with the thin layer of epox and cooling system is connected by a thermal link, consisting of aluminum, which is also glued on the cool side of the cooling element with epoxy. In between CCD and thermal link at thin layer of oil is spread to improve heat conduction. Inside the thermal link usual Si-diode is put as temperature sensor. The voltage over the diode depends on the temperature. A decrease of 1°C in the temperature makes rise of 2mV in the diode voltage. The measured value is processed in the controller, where the temperature is controlled by an on/off control circuit. A Peltier element is a cooling device. When voltage is applied to the element, one side gets cool and other hot. The heat on hot side is carried off by a heat sink.

2. CCD Controller

The controller has several functions, which are separated, in following parts on

the controller board. They are: (a) Microprocessor, (b) Clocking logic,(c) Bias voltage generator, (d) Clock drivers (e) Temperature controller (f) Analog processing unit and (g) Analog-Digital convertor.

(a) Microprocessor:

In the present CCD camera ATEMEL 89 (5) Micro controller is used. The microprocessor has the function to communicate with the host and to control the clocking logic of the CCD by applying appropriate signals to the clocking circuits for various functions. These signals are processed by the clocking logic, which gives the clocks for the CCD chip and the image signal processing circuits.

(b) The clocking logic

: It generates the clocks required for the analogue signal circuit, the ADC and CCD clock driver. The clock sequences are stored on two EPROMS (27664). One generates clocks, which are going out and the other clocks for internal settings.

(c) The bias voltage generator:

The CCD needs different voltage levels. The biases are +I2V and the clock toggle between +2V and -9V. These voltage levels are produced by the bias voltage generator.

(d) The temperature controller:

The temperature is controlled by an on/off control circuit. We compare two voltages, the measured voltage from temperature sensor diode and reference voltage (723 mv) for -20°C. The temperature coefficient of a Si-diode is -2mv for 1°C temperature rise. If the voltage of the sensor is smaller than the reference voltage the cooling element is activated, otherwise the cooling element is switched off.

(e) Analogue signal processing:

Out of three outputs of CCD, only pin out 3 is connected to preamplifier with gain ten. Since we have a DC offset in the CCD output we put a capacitor in series, to process only the voltage changes. It is followed by double sample integrator in two stages, in which there set voltage of CCD is integrated for the same duration as the CCD signal, but with the polarity of the amplifier gain reversed.

(f) ADC converter:

To convert the signal generated by the analogue processor to digital form, a 16-bit serial ADC (AD 1876) is used. It needs an external reference voltage and a clock. The +12V supplies for the ADC are generated by voltage reference elements. EPROM 8bit is connected to a NAND gate, which gives D-SAM pulse that is given to ADC to start conversion. When D-SAM is high D-CLK is low. D-CLK is also given to ADC as a clock. The serial clock and the digitized data (I6-bit series) are sent through opto-isolated links to host machine

Software Program for Image Acquisition

The software is used in CCD camera for image acquisition program. It is divided into two parts, 1) Image Acquisition Routine 2) Display Routine

Applications of CCD Camera

- CCD camera is used for Astronomical photography of a variety of faint and bright objects.
- CCD is used in many military projects where there is a need of low noise and imaging at low light.
- CCD has various uses as memories, delay lines, correlators and optical detectors.
- CCDs are also used in the UV and EUV (300-3000 ?) spectral range.
- CCD may also be used as detector in the X-ray region of the spectrum, as the absorption depth within silicon rises short ward of about 1000 ?

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