Research Paper

Volume : 3 | Issue : 11 | November 2014 • ISSN No 2277 - 8179

Review on Charge Coupled Devices in Cameras

Electronics

KEYWORDS :

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ABSTRACT

Any camera will need a device to convert optical image into an electrical signal. Now let us consider a picture frame made of small picture element. For more sharpness or better resolution we have to increase these elements. This picture frame can now be focused on to a structure of so many CCD elements. Each CCD element will now convert the light information on it to a charge signal. All we need now is to have an arrangement to collect this charge and convert it to voltage. This is the basic principle on which CCD cameras are based

I.INTRODUCTION

Charged coupled devices are being used these days even in studio cameras of full broadcast quality. CCD Device is a kind of transducer which converts optical image into electrical signal. In order to understand the working of a CCD chip consider its construction as shown in Fig. 1. Initially with V=0, there will be an even distribution of holes (majority carriers) in the substrate doped with P type of impurities.

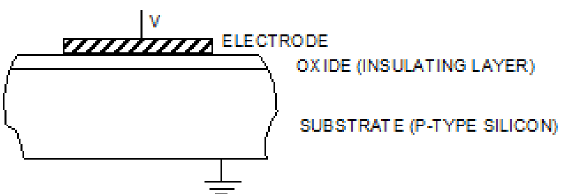

Fig. 1 A CCD Element

If V is now increased to 10 volts, free holes are repelled deeper into the substrate and a depletion layer is formed below the electrode. The potential within this depletion layer is highest at the surface, and decreases with depth.

II. GENERATION AND TRANSFER OF CHARGE

When the light falls on such device, electron hole pairs will be formed in the substrate. Amount of electrons hole pairs thus generated is proportional to the amount of light or optical image. Since the substrate is p type, holes formed by the light get mixed with the majority carriers already present and can therefore be ignored. But the Photo generated electrons will get attracted by the positive potential forming an inversion layer, dominated by electrons just below the electrode. Recombination of electrons hole pairs cannot occur as there are no free holes in the inversion and depletion layers. Also the negative charge on the electrons causes the potential at the semi-conductor surface to drop. This in turn reduces the depth of the depletion layer. You may also note that this mechanism sets a theoretical limit on the storage capacity of a CCD since the depletion layer is must to prevent recombination.

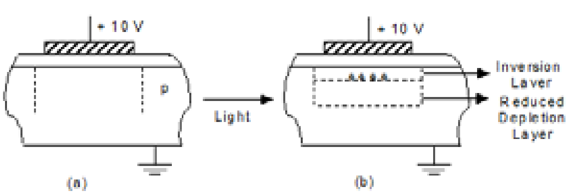

Fig. 2 Generation of Charge

CHARGE COUPLING

Now it is important to convert the charge packets into an output voltage. The process by which charge packets are moved through the device and eventually delivered to the amplifier is known as charge-coupling (sometimes charge transfer) figure 3 shows this process in three stages. When V2 goes positive a depletion layer is formed in the usual way, so that as V2 becomes more positive than V1 the charge packet will move to the new site without encountering any free holes in the process.

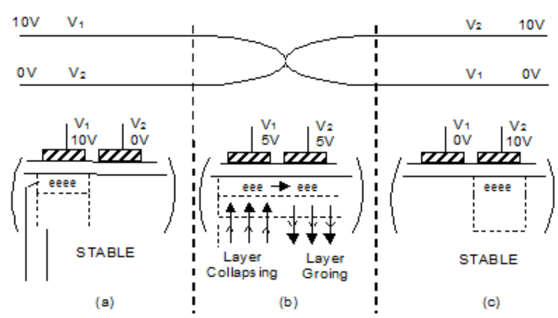

Fig. 3 Process of Charge Coupling

This process of coupling the charge between adjacent electrodes continues until the whole charge image is routed to the output stage. It would be impractical to control every electrode individually as this would require far too many connections to the device. One solution is to connect every 3rd electrode together and drive them with a 3-phase clock signal as shown in figure 4.

One of the clock phases is held high and the other two are held low during the charge collection and storage period. In this way charge image is built up under the 'on' electrodes. Switching on the three phase clocks will then shift the charge packets through the device towards the on chip amplifier. It is important to notice that with the 3-phase clock system 3 electrodes are required for every picture element.

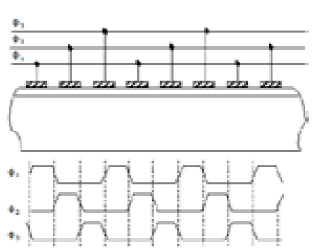

Fig. 4 Phase Clocking in a CCD

CHARGE DETECTION

In order to convert charge image to a more convenient form, the charge packets are passed on to an on chip capacitor. Using the relationship V = Q/C gives the output voltage corresponding to optical image. V here is voltage, Q the charge and C the value of capacitance. Figure 5 shows the basic principle of charge detection.

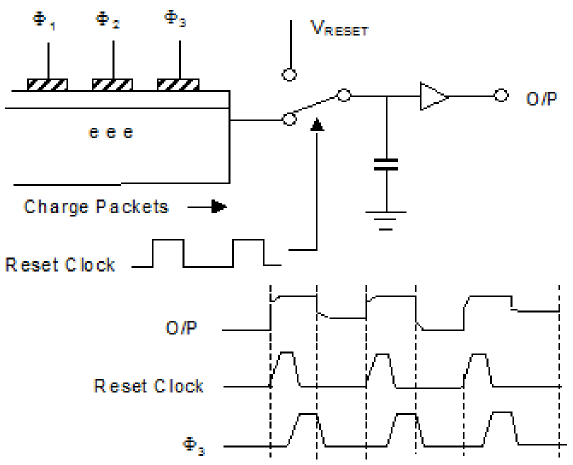

Fig. 5 Detection of charge

In order to understand its working one can note that between charge packets, capacitor C is charged to V Reset. The next charge packet is then dumped on to C partially discharging it, resulting in a signal voltage. C must be very small (approx. 0.1 pF) so that a reasonable signal voltage is developed (approx. 100 mV). The buffer stage is essential to screen C from external capacitive loading. The output voltage thus developed across the capacitor is proportional to the optical image or light falling on it.

III. TYPES OF CCD CHIPS

There are three different types of CCD chips used as a pick up device for CCD cameras, namely

- Interline transfer type
- Frame transfer type
- Frame interline transfer type

The only different about these types is the way charge is collected or transferred. CCD cameras with good resolution offers about 4,00,000 pixels or CCD element.

i) IT (Interline Transfer) Type CCD

The IT type CCD consists of a light receiving CCD a kind of photo diode, vertical transfer CCD and horizontal transfer CCD. The light receiving CCD converts light into electrical signals. Thus the photosensitive and the storage section are interleaved in this type. For the transfer of charge, during the vertical blanking period the charges are first transferred to the vertical transfer CCD (1) and during horizontal blanking they are transferred to the horizontal transfer CCD (2) for each scanning line (1H) in sequence. The charges transferred to the horizontal transfer CCD are transferred at horizontal scanning speed to the signal detector where they are converted into a voltage.

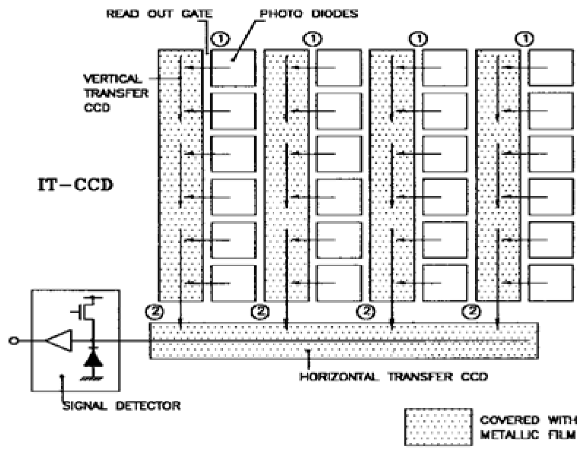

Fig. 6 Interline Transfer Type CCD

i) FT (Frame Transfer) Type CCD

These types of chips are bigger in the size, almost twice in size to accommodate additional storage area. The upper section of this chip is image section and the lower as storage section with a storage time of 20 ms or half field. The storage section is masked and is not exposed to light. FT devices are using shutter during the transfer of data from light receiving chip to this additional storage chip at fast rate to reduce smear. The shutter is synchronized with vertical blanking period. This type is not being in use in most of the present day cameras because of limitation of larger size, problem relating to the use of shutter and also because of improvement in IT cameras to reduce smear. Smear is caused when bright light enters the CCD and is seen as a comet – like effect above and below the light source.

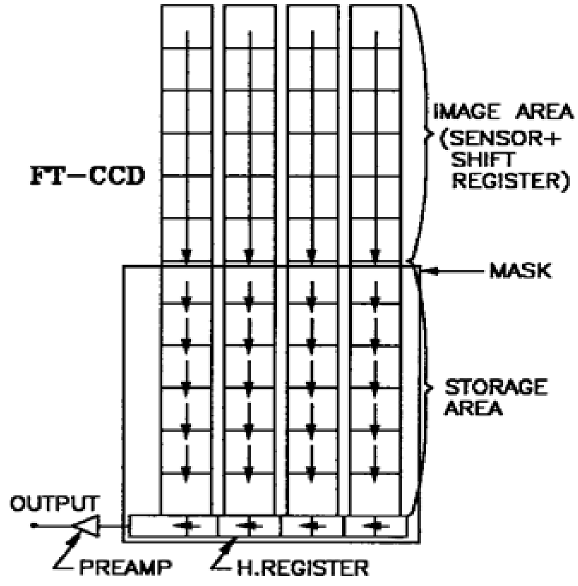

Fig. 7 Frame Transfer Type CCD

iii) FIT (Frame Interline Transfer) Type CCD

Although both the IT and FT type CCDs have excellent performance in their way, they cannot suppress the smear completely which is inherent in the CCD. The FIT type CCD consists of a light receiving CCD, vertical transfer CCD, storage CCD and horizontal transfer CCD. For the transfer of charge, during vertical blanking the charge, the result of light image converted to charge image by the photo diode (CCD pixel) is transferred to

Volume : 3 | Issue : 11 | November 2014 • ISSN No 2277 - 8179

the vertical transfer CCD(2). This takes place after the residual charge in this CCD – the cause of smear – has been swept out (1) via drain. Then the charges are transferred to the storage CCD at high speed (3). It is the high speed of the charge transfer that is the major factor in reducing smear due to light.

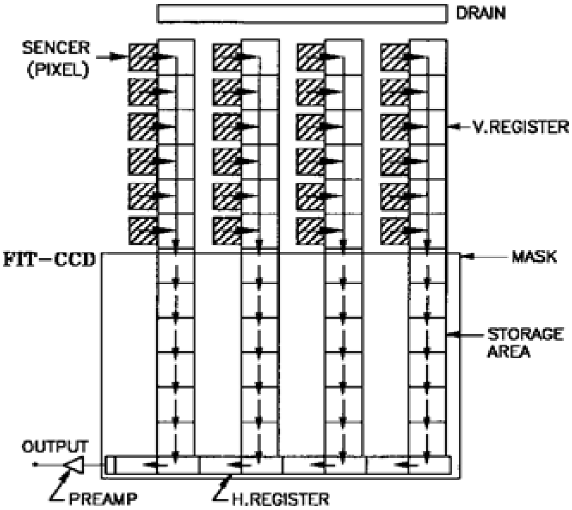

Fig. 8 Frame Interline Transfer Type CCD

IV. CCD VS TUBES

The merits and demerits of the CCD and the pickup tube are listed below :

	CCD	Pickup tube
Merits	• Compact and light weight • No head amplifier, since o/p of the device is about 400 mV • High sensitivity • No sticking caused when exposed strong light source. • Reduced image lag • Low power consumption • Maintenance free • No microphonic noise • No geometric distortion • No warm up time	• No Smear • Wide dynamic range • No moire • No fixed pattern noise
Demerits	• Smear and blooming occur • Moire • Poor blue sensitivity • High IR sensitivity	• Sticking easily occurs. • Registration error • Periodic replacement of tube required • Difficult to handle. • Needs head amp. on target itself.

Most of the demerits of CCDs have already been removed and these devices have started replacing studio cameras. Smear has been removed by having better FIT chips and fast transfer. Resolution have been improved by having more number of pixels.

V. Latest CCD Cameras

CCD were launched in 1983 for broadcasting with pixel count from a mere 2,50,000 which increased to 20,00,000 in 1994 for HDTV application. Noise and aliasing has been reduced to negligible level. CCD cameras now offer fully modulated video output at light level as low as 6.0 lumens. A typical specification for a studio camera now available in market are something like 2/3 inch, FIT, lens on chip CCD with 6,00,000 pixel, 850 lines H resolution, S/N more than 60 dB, sensitivity F-8 (2000 lux) etc.

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