Construction and Use of an Audine CCD Camera

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Introduction

Imaging the vast number of objects in our night skies remains a huge challenge to all serious amateur astronomers. In South Africa an added challenge is the financial implications of buying a CCD camera that is capable of recording worthwhile images. This article describes the home construction and use of such a camera.

The Audine design is extremely well documented and all the documentation is available free of charge on the Internet. The building process requires a fair amount of patience but not necessarily an electronics background. Manufacturing the aluminium hardware, assembling the camera and acquiring the first-light images are very exciting and rewarding stages of the process.

Learning to use a CCD camera is an exercise in trial-and-error but it can be very rewarding. Discovering or mastering a new trick could happen every weekend in your back garden until one day you are capturing the images that you have only dreamt about before.

1. What is a CCD?

A CCD (charge coupled device) detector basically consists of a photo-electrically sensitive area, positioned at the focal plane of an optical instrument. The basic material of the photosensitive area is silicon which is doped in order to imbue it with photoelectric properties. When this photosensitive area absorbs a photon, there is a good chance that it will produce an electric charge.

Looking at the photosensitive area of a CCD though a microscope, a network of tiny electrically independent cells can be seen. These cells are called pixels, with sizes ranging from a few microns to a few tens of microns. If they are correctly polarised, each pixel is able to gather a large number of the electrons that the incident light generates. The number of electrons is directly related to the brightness of the incident light and to the duration of exposure. For example, if the time of exposure to a given light flux is doubled, the number of electrical charges generated at the pixel will also be doubled.

After the image has been formed on the chip, it is read out by transferring the electrical charge or voltage sequentially, pixel by pixel, and row after row. This analogue signal is then converted to a digital signal before being stored and processed by the electronics and software in a camera or computer.

The use of a CCD camera allows the observer to obtain images very quickly compared to the photographic process. A CCD uses an electronic process compared to the photographic method that uses a chemical process to record an image. The fact that an image is visible a few seconds after it was taken makes it possible to adjust the setup and take more pictures until the required results are obtained, unlike the photographic process where you only see the results after the film has been developed. The sensitivity of a CCD is also a plus-point compared to visual and photographic methods. It is possible to image very dim objects quite successfully from any location, sometimes even from an urban, light-polluted area.

All these positive aspects come at the price of a number of typical problems, complications and costs. In order to use a CCD camera a PC of some sort is required and obviously a laptop-type is preferred. In addition, a stable power supply is necessary to operate the camera, making the telescope-camera setup quite complicated and cumbersome. On top of this it is not quite so easy to focus an image perfectly on the surface of the CCD. It requires that a number of new skills are learnt and patience is exercised (especially in the beginning).

The basic specifications of the Kodak KAF 0401E CCD, the chip used in this design, are:

- number of pixels: 768 x 512
- dimensions of a pixel: 9 x 9 microns
- size of the sensitive area: 6.9 x 4.6 mm
- fill factor of the pixel: 100%
- dark current: less than 10 $pA \cdot cm^{-2}$ (MPP technology)
- sensitivity of the output stage: 10 μV per electron
- 74 dB dynamic range
- average quantum efficiency: 35%
- 0.4 nm to 1.0 nm wavelength
- load capacity: 80 000 electrons
- type of clock: 2 phases
- number of clocks: 5

2. Why build a camera?

CCD cameras are available commercially, so why build one ?

Top-of-the-range cameras are available at prices starting at about US$ 8 000. These are typically used by professional astronomers and are obviously out of reach of most amateurs. The intermediate range of cameras is quite popular, with prices from $1 500 to $4 500, and a number of them use the KAF 0401E sensor. At the low end, we find products that cost between $500 and $1 500 . These products are either cameras which specialize in autoguiding, or are used in more traditional imaging systems. They typically have very small surface areas making them very difficult to use for astronomical imaging.

If it was possible to build a camera with adequate performance at a price that is reasonable, it would be viable for an amateur to participate in a field where one normally has to invest up to R20 000 beforehand.

The ability to image astronomical objects with an immediate result is extremely exciting. To point a telescope and camera at a galaxy or other object that is invisible to the naked eye and after a few minutes to view it, is an unforgettable experience.

Because there are many technical issues to take care of during the construction of a camera, it is important that the person who attempts it has some experience in small electronics projects.

3. The Audine design

The Audine CCD camera project was initiated by the French AUDE Association. Their objective is to stimulate interest and to assist amateur astronomers to participate in the field of CCD imaging. A group of thirteen French specialists designed the Audine camera in the mid- to late-1990's.

In spite of its very simple design, the Audine camera has the performance of a product in the intermediate range but with a price that is in the low-end range.

Complete documentation of the design and detailed assembly instructions are available at [http://www.astrosurf.com/audine/

English/index0.htm]. The design consist of the layout of the printed circuit boards, the mechanical drawings, and two software packages. Figure 1 shows the high-level design of the Audine camera system. A number of new design options recently became available, including a USB-camera interface and an Ethernet link to enable remote operation of the camera.

The software packages include PISCO, a camera image acquisition program and IRIS, an image processing package. Regular updates are available on the website. An important point to note is that the Audine camera is controlled by the PISCO software and by the electronic hardware onboard the camera itself. This makes it possible for modifications to be made to the camera's functionality by changing the software only. Because the available software is open-source, it is an attractive option for those with software experience.

4. Building the camera

The first and most important step in the construction process is to study the design in detail. It helps to understand, and be aware of, the options and alternatives available in the design.

Most of the electronic components are available locally [in Gauteng] except for three items:

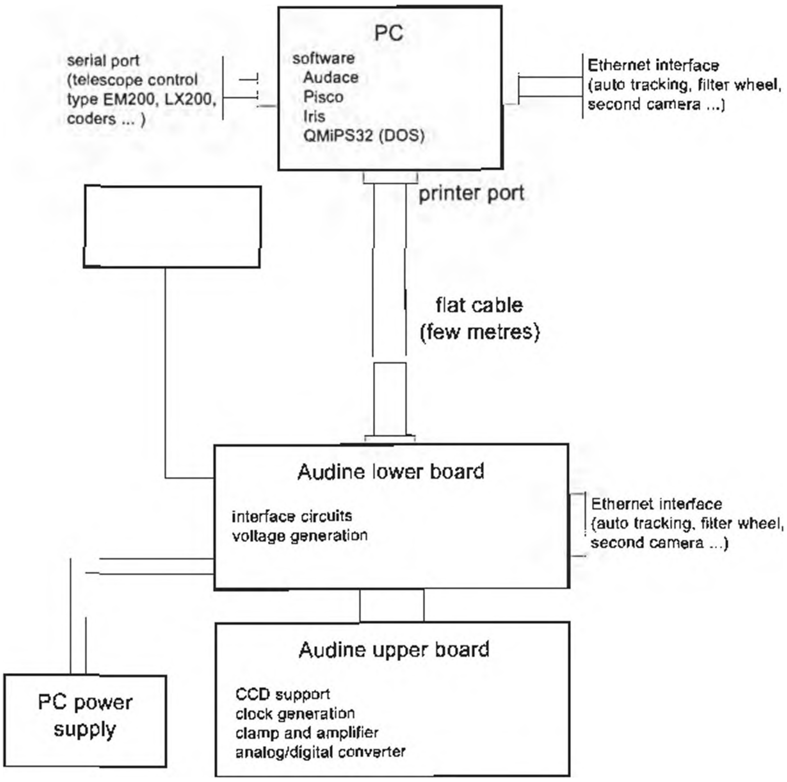

Figure 1. High-level design of the Audine camera system.

- The Kodak KAF 0401E has to be ordered directly from Kodak in the USA. The delivery time from ordering is about a week. This is also the most expensive component, at about $290 for a class 2 chip.
- The peltier device can be ordered directly from a number of suppliers worldwide but here the challenge is to be able to purchase only one unit and not a larger quantity. Prices are fairly low at $12–20 a unit.
- The two printed circuits boards are available from one of the original designers in France at about $30 a set.

The aluminium camera body consist of a number of separate units that can be machined locally by any competent machine shop or handyman with the suitable tools.

The process of soldering the components to the printed circuit boards are covered in great detail on the website and should be no problem to anybody except the complete novice.

When the boards are fully populated the circuits can be tested to assess functionality and calibrate the various voltage levels required by the CCD chip. As soon as all the tests are passed the first live test can be done with the CCD chip in place. This test is quite nerve-racking and serves as an important milestone in the completion of the camera. When all is well with the electronics the two boards can be assembled onto the aluminium hardware to complete the camera unit.

A separate power supply is required to drive the camera electronics, peltier device and fan.

5. Starting to use the camera

The first time the camera is deployed outside on a telescope or lens is both exciting and frustrating. A number of challenges face the operator at that time. Hopefully by the end of the observing session the functionality of the camera has been verified and at least a few recognizable images are saved on the computer's hard disk to be processed at a later stage.

When the camera is mounted on a telescope at prime focus, focussing is extremely critical. It will take a long time to centre a specific object on the CCD chip and have it in focus at the same time. When the object is not visible with the naked eye it becomes even more difficult. At this time help is normally sought from other amateur astronomers who have done this before. The Internet is a great help in this regard. The Audine

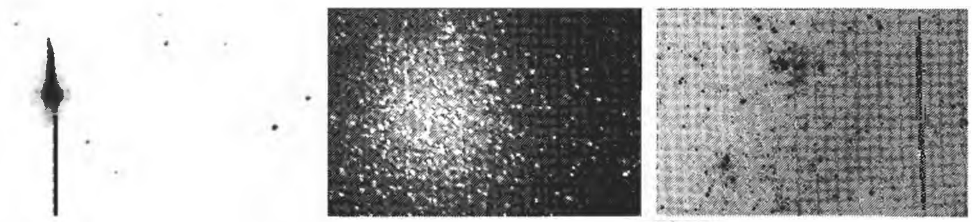

Fig.2a Fig.2b Fig.2c

Figure 2a. First image acquired by the author with a home-built Audine camera. This 5 s exposure was made on 2002 March 19 through an 8-inch SCT. **Figure 2b.** Omega Centauri, taken the same night, 5 s exposure. **Figure 2c.** Eta Carinae, a 16 s exposure made with a 50-mm lens.

design team are available for answering questions and also to diagnose problems.

Figures 2a and 2b show two images captured soon after the author's Audine camera was completed. The vertical line in Figure 2a is typical of an image taken of a bright star without a shutter on the camera.

In order to learn how to use the camera, as well as to take wide-field images, it can be mounted on a normal photographic tripod along with a good-quality 50mm camera lens. There is a limitation on the exposure time that can be tolerated by this setup: normally about fourteen seconds at most. This is not really a problem as a large number of separate exposures can be taken and combined at a later time. Figure 2c shows a sample image captured by the author with such a setup.

6. Some difficulties encountered

A working CCD camera does not necessarily result in good images. There are a large number of skills that must be developed and also some technical fine-tuning on the equipment to ensure that good images can be recorded. Some of the tricky issues are:

- The basic camera does not include a shutter but it is possible to start off without one by closing the telescope or lens with a piece of black material after each exposure. This is cumbersome but works. The author has recently implemented an internal camera shutter with an iris from a CCTV lens.
- Regulation of the CCD temperature is not a simple matter and requires a lot of experimentation. A built-in temperature controller could also be used. If steps are not taken, formation of frost on the CCD surface will be a recurring problem.
- The focussing problem was mentioned above; fortunately there is plenty of help available to overcome this.
- The polar alignment of the telescope is critical for any exposure longer than a few seconds. Even when polar alignment is accurate, exposures of more than a few minutes might require tracking to ensure that the image does not move on the CCD surface during the exposure.
- Finding dim objects normally requires that the object first be placed in view visually with an eyepiece. When the eyepiece is then replaced by the CCD camera it is normally not focussed or the object is no longer in view. To get both of these correct is quite a challenge.
- In order to make the most of a CCD image it is necessary to use dark frames and flat fields to optimise the image during the image processing phase. In the great excitement it is easy to forget to take a suitable dark frame for each exposure time and chip temperature.

7. Learning

Some important lessons have been learnt from an excellent e-book, 'The New CCD Astronomy' by Ron Wadalski, available from the author's website [http://www.newastro.com]. The book covers basic topics, such as focussing and practical imaging, as well as more complex issues like guided exposures, colour imaging and image processing.

One of the lessons learnt was to start with the basics and prepare well. This includes thorough research of the objects that will be imaged. It also includes polar alignment of the telescope, which is very important for longer exposures. This is time well-spent, even if it takes 60 minutes or more to set up the telescope properly.

It is important to concentrate while recording images. It is very easy to become distracted and forget to save an image or to take a dark frame. One should rather focus on one worthwhile object and take multiple exposures of it than to try and do a Messier marathon in one night. Later, when the image processing is done, it will be possible to select the best raw images and combine them, rather than having a number of mediocre images of various objects.

8. The way forward

One of the risks that one takes when building a camera of this nature is the time that the project consumes. Even when the basic camera has been completed, smaller related projects are required to improve the basic camera design and to automate and enhance the process. The following are examples of smaller associated projects:

- automated shutter
- temperature measurement and control
- telescope's dual axis encoders and stepper motors
- guider solutions
- video camera with monitor
- web cam
- small CCD camera
- closed-loop solution for automated guiding

9. Conclusion

It has been said that the road one travels is sometime more interesting or exciting than the destination. Similarly, the construction of the Audine camera can keep you very busy for a year while you are researching technology, negotiating for the purchase of a single peltier device or finding a company that will black anodize the aluminium hardware for a reasonable price. This project is bound to present you with many challenges and it will lead you to the discovery of many ideas and future projects.

When the camera is finally ready and usable you will be the proud owner of a instrument that you made yourself, understand intimately and that will give you many years of service. You will be limited only by your patience to learn and by your dedication to observe.