Pictor™ XT/XTE-Series CCD Autoguider/Imagers

For the beginner, or for the most advanced observer, the real CCD revolution is here!

Imagine with your telescope capturing an image of Jupiter that appears to have been taken with a 36" observatory telescope. Or obtaining, in 2 minutes or less, without guiding, an image of the spiral galaxy M51 that outresolves 30-minute photographic exposures. Or imaging a supernova in an obscure 18th-magnitude galaxy. Meade CCD imagers can accomplish all of this, and much more! How such results can be obtained is explained on a step-by-step basis, from preliminary definitions to more advanced imaging techniques, in the following Question and Answer section.

Q. What is a CCD imager?

A. A CCD (“charge-coupled device”) is a detector sensitive to light. When light (consisting of discrete photons) hits the detector elements, or pixels, on the surface of the CCD sensor, electrons are liberated and stored in the detector elements, or pixels.

A CCD sensor consists typically of thousands of pixels. When a CCD imager is pointed at a brighter area of the sky, a larger number of photons come in contact with the chip. More photons generate a larger number of electrons. Thus, a brighter portion of an image has a greater number of electrons stored in each pixel.

Q. What is the basic role of CCD imaging in amateur astronomy? Why are amateur astronomers using these devices?

A. The CCD imager attaches to the telescope’s eyepiece-holder in a roughly similar manner as a 35mm camera body is attached. The imager allows a very fast “picture” (digital exposure) to be taken of even faint celestial objects. This exposure can be seen immediately on the display screen of a common personal computer and, if desired, can be stored on a disc for future reference or printed out to obtain a hard copy of the image. These points will be expanded upon in the discussion that follows.

Q. What materials are CCD chips made of and what makes one sensor "better" than another?

A. CCD sensors are made of semiconducting materials such as silicon that have been
manufactured to be sensitive to the impact of light hitting their surfaces. Factors that can give one chip an advantage over another are physical dimensions (the larger the chip, the more sky area that can be imaged at one time); their pixel sizes (smaller, more tightly-packed pixels result in higher image resolution); the pixels' well capacity (the total number of electrons that can be stored in each pixel before it becomes saturated); fill factor (the percentage of the chip's area that is sensitive to light); and quantum efficiency (the sensitivity level of the chip to light).

Q. What is dark current?
A. In any pixel some undesirable electrons will be stored that are not the result of light photons hitting the detector surface. Some of these electrons result from thermal noise, a random effect due to the interaction of heat with the CCD chip material. The electric charge of these unwanted electrons—electrons that would exist in the pixel even if there were no light coming in contact with the chip—is called dark current. The effect of dark current is to limit the practical length of a CCD time-exposure: ultimately, dark-current electrons saturate the pixels so that no additional photon-induced electrons can be generated. Thus, the lower the dark current, the longer a CCD exposure can be.

Q. But I've heard that it is possible to "subtract out" the effects of dark current.
A. Fortunately, dark current is highly predictable. By taking a CCD image with the telescope optics covered (for the same length of time as the intended image-exposure time) so that no incoming light reaches the CCD chip, it is possible to measure the dark current—electrons stored in the pixels when the chip is literally in darkness—that will occur during the actual image exposure. This dark current value can then be subtracted from the total number of electrons stored in each pixel well, to obtain the net number of stored electrons not due to dark current. While this subtraction process is valuable to eliminate most of the effects of dark current from the desired electrons, it does nothing to solve the problem mentioned above of dark current pixel-saturation. The only real solution to this problem is to use CCD chips that have very low dark current, and, as we will see below, that is one of the important advances incorporated into Meade CCD imaging systems.

Q. What is analog-to-digital (A/D) conversion?
A. The process of CCD imaging converts a smooth, continuous, analog signal (e.g. the image of a galaxy) into a series of discrete digits. Suppose, for example, that a galaxy's image is divided into a large number of squares, with each square covering a small area of the image, and that the varying brightness levels in different squares are represented by a series of digits, one through eight, where "1" is black (dark sky) and "8" is pure white (the nucleus of the galaxy); digits in between represent varying levels of gray. With this "digital" representation of the galaxy we could compose a "discretized" picture of the galaxy, replacing the smooth, continuous one that is in fact emitted by the galaxy.

Q. But isn't a smooth, continuous image better than the discontinuous, unsmooth one you just described?
A. If we use a large enough number of squares to cover the galaxy's image (i.e. if the squares are small enough) and if the quantity of digits used to represent all of the gray shades between pure black and pure white is large enough, then the digitized image becomes, for all practical purposes, smooth and continuous. In the Meade Pictor 416XT CCD Imager, for example, the squares (pixels) used to cover the incoming image are so small that the resulting image appears smooth and continuous.
image are about 0.0004" (0.01mm) on a side and shades of gray from pure black to pure white are represented by 65,536 digits. In such a case the digitized image is so smooth as to be virtually undetectable from a smooth, continuous, analog image.

Q. That still doesn't explain why it is desirable to digitize an image as you just described, instead of working with a continuous image.

A. The answer to this question goes to the basis of all CCD imaging. Once an image is digitized, an important range of operations, called image processing, become possible, using sophisticated image processing software such as Meade Epoch 2000ip. Such image processing is also possible with analog-sensitive procedures, such as traditional photographic film imaging, but the possibilities with photographic film are vastly more limited than with the digital image output by a CCD chip. Rather poor digitized images of celestial objects that are hardly recognizable as originally imaged can be processed into magnificent, beautiful images with good image processing techniques. Digital image processing enables the extraction of a weak signal from a large amount of noise.

Q. What are the other advantages of CCD imaging as compared to photographic imaging?

A. Because of a CCD chip's greatly increased light-sensitivity compared to film, exposure times are typically much shorter; as stated above, a 2-minute unguided exposure of the Whirlpool Galaxy (M51) with the Meade 216XT CCD Imager, for example, outresolves photographic exposures of 30 minutes' duration. The CCD image provides instant gratification—the image is immediately visible on your PC display as soon as it has been taken, without the normal darkroom work required of film. In addition film suffers from a phenomenon called reciprocity failure: the photographic emulsion becomes less and less sensitive as exposure time is increased; by contrast, the response curve of a CCD imager is linear: twice the exposure time yields exactly twice the results. And, post-exposure image processing provides an amazing level of image enhancement, an enhancement that is simply not possible with film. With advanced image processing techniques, CCD images through amateur telescopes have been taken of Jupiter, for example, that exceed the level of detail that can be photographed through the largest telescopes on Earth. As Mr. Jack Newton, one of the world's foremost CCD imaging specialists, has said: "When I attach the Meade Pictor 416XTE or 1616XTE to my 16" LX200 and expose and co-add a couple of ten-minute exposures at a random position in the sky, I am imaging faint background galaxies that quite likely have never been imaged before with any telescope, amateur or professional."

Q. Are you saying, then, that photography, and particularly astrophotography, is an obsolete science?

A. Absolutely not. Even the largest CCD chips are small compared to the formats of common films. The Meade Pictor 1616XT includes one of the largest CCD units (13.80mm x 9.20mm in dimensions) currently available, and yet it images an area less than 20% of the standard 35mm film format. (This problem is, however, significantly reduced in importance by the mosaic feature of the four Meade Pictor imager models, as we will see below.) And in a sense, photography with a 35mm camera is perhaps more convenient to the average user, since a PC and external power source are not required. Notwithstanding the preceding words, however, there is little question but that the future of imaging, whether for astronomy or for recording a family gathering, lies in the CCD chip: simply put, the boundaries of CCD imaging are almost endless; the boundaries of photographic imaging, for all its rich history, are not.

Q. You mentioned above that a large number of gray scales is highly desirable in a CCD system. How does this relate to the design specifications of a CCD imager?

A. The basic specifications of any CCD system state whether it has, for example, an "8-bit," "12-
bit," or "16-bit" register, or converter. An 8-bit converter (i.e. an 8-bit analog-to-digital conversion register) permits 2-to-the-8, or 256, varying levels of gray to be digitized. CCD cameras (e.g., the Meade Pictor 208XT) that include 8-bit converters yield a reasonably satisfying level of smoothness and continuity to the image, but more advanced cameras with 16-bit converters (e.g., Meade Pictor Models 216XT, 416XTE, and 1616XTE) present, by comparison, vastly enhanced images in all respects. Imagers with 16-bit A/D converters yield 2-to-the-16, or 65,536, gray scales.

Q. What is thermoelectric cooling?

A. As stated above, dark current, one of the chief enemies of any CCD imaging system, is the undesired random generation of electrons into the pixel well, stimulated by heat in the environment of the CCD chip. Dark current can be very significantly reduced by lowering the chip's temperature. In CCD specification tables dark current is specified at a certain temperature--e.g., dark current of the Meade Pictor 216XT is "less than 8 electrons per 5 seconds at a chip temperature of -5°C." Achieving this low chip temperature requires a cooling system. Thermoelectric cooling, the most common method of CCD chip cooling, entails the input of an electric current to two metal plates separated by a semiconducting material; the result (the so-called Peltier Effect) is to make this thermoelectric module act as a heat pump, pulling heat out of the CCD chip that rests next to the module. The efficiency of heat dissipation is augmented by radiating fins, included with all Meade Pictor CCD's. On more advanced CCD systems, such as the Meade Pictor 416XTE and 1616XTE, thermoelectric cooling is cascaded with two similar modules, resulting in 2-stage cooling which thereby reduces the chip's operating temperature, and resultant dark current, still further. The advanced cooling systems on all Meade Pictor imaging models (208XT, 216XT, 416XTE, and 1616XTE) are regulated, meaning that the cooling system automatically turns ON and OFF to keep chip temperature close to the desired temperature.

Q. What is flat-field compensation?

A. Due to manufacturing considerations in the production of any CCD sensor, not all of the chip's pixels have the same level of sensitivity to light; small variations in the thickness of the chip can affect sensitivity. In addition light does not hit the chip uniformly due to natural optical vignetting, however small, of the image by the telescope's optics. Total sensitivity variations can easily reach 5% to 10% from place-to-place on the chip, variations which become apparent in the imaging of faint objects. To minimize these vignetting effects, Pictor models facilitate combining a flat-field exposure with the actual image; this process is called flat-field compensation.

Q. I've heard that an effect called blooming can also be a problem with CCD's.

A. CCD images of bright objects, such as first-magnitude stars, sometimes show the effects of blooming. This effect, visible as a trail of light emanating from the illuminated pixel (similar in appearance to one spike of a "spider diffraction" pattern in a Newtonian reflector), is due to a spillover of electrons from a fully saturated pixel. All Meade CCD systems have built-in blooming correction, reducing the probability of streaking in an image.

Q. How is a CCD imager actually used with the telescope?

A. CCD imaging requires three basic components: the telescope, the CCD imaging system, and a personal computer (PC). In the simplest format, the CCD head, containing the CCD chip itself, is placed into the telescope's eyepiece-holder in place of an eyepiece; the object to be imaged is centered and focused on the CCD chip; the image is taken, and the image data are transferred and processed by the PC. The image is immediately displayed on the PC's monitor. (With all Meade CCD models, CCD operating and image processing software is included on a floppy disc that is loaded into the PC before starting.)
Meade Pictor Models 208XT and 216XT include all of the associated control electronics inside the same CCD head; Models 416XTE and 1616XTE, because of their larger, higher-resolution chips, and consequently more sophisticated control systems, utilize a separate control box.

Q. Is it really that simple? I've heard that CCD imaging can be something of a chore.

A. Before the advent of the Meade Pictor Series your statement was often true: CCD imaging usually required a knowledge of PC techniques and a flair for working with a rather complex piece of hardware. Using a Pictor system, CCD imaging is accessible to anyone with an interest in astronomy or photography. To illustrate the contrast between any of the four Pictor models and other CCD imagers, consider this summary of the imaging procedure required of typical competing units, even very expensive ones: after the telescope, imager, and PC are set-up, the operator must set the imager temperature; take a flat-field exposure use an eyepiece to center a medium-bright star in the field, focus the star in the eyepiece; re-check focus of the star with the imager in the telescope; center on the CCD chip the object to be imaged; if not centered, use the telescope's drive corrector to center the image; re-check focus of the object; specify image exposure time; take dark frame exposure; take actual image exposure. Keep in mind that the foregoing is a summary of what is required without a Pictor CCD and without a Meade LX200 telescope. It is not uncommon for an operator to spend one hour simply preparing to take the image exposure!

By contrast, Meade Pictor Models 208XT, 216XT, 416XTE, and 1616XTE are "point-and-shoot:" to take an image, center and focus it on the chip and click on a button on the PC display. The imager automatically determines the appropriate exposure time, takes the required dark current frame, and stores it in memory. The imager gives the user the option of taking a field-flattening image and storing it in memory, then takes the actual exposure, and stores the resulting image, again after automatically subtracting out the dark current compensation frame.

Q. I've heard that centering and focusing the image on the CCD chip can be a frustrating task.

A. Indeed it can be, but again the Pictor Series has made great improvements on both of these points. Once an object is placed anywhere on the chip, imaged, and downloaded to the PC, the Pictor's autocenter feature allows the user simply to click the PC's mouse on the PC display at the desired center of the image. The Pictor then automatically moves the telescope to center the object on the chip and retakes the image. If you're using your Pictor CCD with a Meade LX200 telescope equipped with the Meade #1206 Electric Focuser, images can be automatically focused. Trial-and-error focusing, taking test shots, and refocusing are no longer necessary. Even without an LX200, a Pictor's fast-frame mode enables viewing an-image-a-second to facilitate focusing.

Q. During the period of a CCD time-exposure, is it important to "guide," or correct, the telescope position, as in astrophotography?

A. Precise guiding of the CCD camera during a CCD time exposure is as critical to successful results as is guiding during a long-exposure astrophotograph. This guiding can be accomplished in any of the following ways: (a) by using the Shift-and-Combine mode of the imager; (b) by manual monitoring of a guide star, using a guiding device such as the Meade Off-Axis Guider and an Illuminated Reticle Eyepiece in conjunction with a drive corrector; or (c) by using an electronic autoguider, such as the Meade Pictor 201XT CCD Autoguider. In the latter case the autoguider senses the telescope's position and sends signals to the drive corrector to initiate very small changes in telescope position during the time exposure. Use of the CCD Autoguider has several advantages over the manual method; in general it is much more precise and error-free than is possible with manual guiding, and, in the case of the Meade Pictor 201XT, the autoguider can
guide on guidestars as faint as 12th-magnitude, far fainter than is possible during manual guiding. The autoguider may also be employed for long-exposure astrophotography. See for details. The Pictor 201XT is available separately or as part of the Meade CCD Accessory Package, a package that includes all of the required instrumentation and software for advanced long-exposure CCD imaging.

Q. Could you elaborate on the special advantages of using a Meade LX200 Schmidt-Cassegrain with a Meade Pictor Series CCD Imager?

A. In fact the advantages are almost overpowering, since Meade LX200's were designed with an eye toward the requirements of CCD imaging. These advantages apply to all Meade Pictor imager models and all LX200 models: (a) Autocentering: use your PC's mouse to click on to an object at the edge of the CCD chip, click on the centering tool, and the telescope microslews automatically to center the object on the chip; (b) Autofocusing: Accurate, hassle-free focusing was perhaps the biggest single headache in pre-Pictor imaging. With the Meade #1206 Electric LX200 model, by actuating Autofocus the image is automatically, and seconds. (c) Automosaicking: In the Automosaic mode the LX200 moves an arbitrarily large number of operator-specified sky areas adjacent to the originally imaged area. In this way image montages can be created to stunning effect. (d) High-Precision Pointing: With the HP-mode the telescopes can achieve much the same result, though not semi-automatically as is the case with built-in HP-mode precision pointing, simply by using the SYNC command and centering any database object located within a few degrees of the desired object. There are no other commercial telescopes and no other CCD systems currently manufactured that permit the above operations or the above-stated pointing accuracy.

Q. Can Meade ED Apochromatic Refractors, or other telescopes mounted on Meade LXD 650 and 750 equatorial mounts, achieve all of the above LX200 advantages as well?

A. Yes. All of the above-listed, unique LX200/Pictor advantages apply equally as well to telescopes mounted on Meade LXD 650 or 750 equatorial mounts, provided the mounts are equipped with the Meade #1697 Computer Drive System.

Q. Meade Pictor Models 208XT and 216XT use the Texas Instruments TC-255 CCD chip. I notice that this same chip is used on competing CCD models that sell for much higher prices. How is this possible?

A. The Texas Instruments TC-255 is the most advanced CCD chip available for imagers in the mid-price range, and, without qualification, Meade Models 208XT and 216XT permit the highest levels of performance of any imagers available in this range. All four Meade CCD imagers are generally less expensive, and yet with far more features and performance, than competing units for several reasons. Meade Instruments budgeted large sums of money for more than one year to develop the Pictor Series; one result of this large capital outlay is that we can, probably without exception, manufacture higher quality CCD's at much lower unit costs than our competitors. Our design philosophy in developing the Pictor Series was not to offer "just another series of CCD imagers," but to make Meade imagers the finest such units on the market. And yet, because our operating overhead is spread out over such a wide range of astronomical products—including over 40 telescope models and 250 accessory products—our unit costs put us in an extremely competitive position.
Q. What is the value of the SCSI interface included with the Pictor 416XTE and 1616XTE?

A. The SCSI (pronounced "scuzzy") interface permits data from the large Kodak CCD chips used in the Pictor 416XTE and 1616XTE to be downloaded to the PC in a fraction of the time required by serial downloading, the type of downloading included with other brands of CCD systems. For example, on one competing (and rather expensive) CCD imager, after each attempt at focusing the image, the user must wait for a period of 5 to 20 seconds before the image appears on the PC display, and then, through repeated trial and error, ultimately try to reach correct focus. The fast SCSI downloading of the Pictor 416XTE permits focusing virtually in real time: focus and see the result immediately. The Pictor 1616XTE, with its extremely large, high-resolution CCD chip requires a maximum of 4 seconds for full-frame downloading.

Q. I understand that some competing CCD models can not practically be used for imaging the Moon and planets, or are badly compromised in doing so. Is this also true of the Meade Pictor Series?

A. No. Some CCD chips are downloaded (i.e. data is read out from the pixels to the PC) without any shutter mechanism to block light from hitting the CCD during the readout. As a result, images of bright objects, such as the Moon and planets, can be badly smeared. Meade Pictor CCD’s solve this problem in one of two ways: on Models 208XT and 216XT, the TC-255 chip uses a frame-transfer system that rapidly moves the image from the chip's active area to an inactive area not affected by incoming light, thus creating an electronic shutter that can image in exposure times as short as 4 milliseconds. Pictor Models 208XT and 216XT are as a result excellent lunar and planetary imagers, in fact the best available short of the Pictor 416XTE. On Meade Pictor Models 416XTE and 1616XTE a sophisticated electromechanical shutter is provided that can image exposures as short as 1/100-second. Combined with small (9.0µm square) pixels, low readout noise, and 2-stage thermoelectric cooling, Pictor Models 416XTE and 1616XTE are truly awesome in their imaging capabilities, whether for lunar, planetary, or deep-space.

Q. You have mentioned dark current as a potential problem in CCD imaging. Are there other sources of unwanted electrons that can affect imager performance?

A. The answer to this question is a bit technical, but it is vital to an understanding of why Meade Pictor CCD’s are such an improvement over other CCD systems currently available. In fact there are numerous sources of random noise in and about each pixel: noise caused by the A/D conversion discussed above, as well as, among others, readout noise, the noise caused simply by reading out a pixel's electron value and sending this value on to the PC for processing. Readout noise is independent of exposure time and complicates the taking of very faint images. The TC-255, KAF-0401E, and KAF-1602E CCD sensors used in Pictor Series CCD systems all have very low readout noise. Most other noise sources increase as the square root of time. Stored electrons which are the result of incoming photons (i.e. desirable electrons generated by the incoming image signal) increase directly proportional to time. The effect of the preceding statements is that the longer the CCD exposure time, the less the relative effect of noise on the desired incoming image signal. Equivalently, CCD engineers say that signal-to-noise ratio increases with exposure time. Thus longer CCD exposures have an added value beyond the fact that they result in more incoming signal value: they also result in relatively less noise than do shorter exposures. And, because all Meade Pictor CCD chips have such low dark current, long exposures (often impossible on other CCD systems because of dark currents that are 5 to 20 times higher) are not only practical, but highly desirable.

Q. How should Meade CCD systems be used in the field, where there is generally no source of alternating current?

A. All Pictor Series CCD units operate from 12 volts DC. A cord for powering each CCD from an
automobile cigarette lighter plug is included with each model; optional Meade adapters are available for operating from standard 115v.AC outlets. For safety reasons only a laptop PC should be used in the field, since this type of PC can also be powered from the 12vDC auto cigarette lighter plug. (AC-powered PC's are not designed, and are not safe, to use outdoors.) Alternately, the telescope-with-CCD head may be set up outdoors and the (AC- or DC-powered) PC remotely operated indoors by a cable link between the CCD and PC. Such cable links up to 100 ft. are possible with any Pictor model.

Q. Meade Pictor models, as noted throughout this discussion, have all recently been changed from "201, 208, 216, 416XT, and 1616XT," to have XT and XTE suffixed to each respective model number--such as 201XT, 208XT, 216XT, 416XTE, and 1616XTE. What are the major differences between the previous models and the XT/XTE-series?

A. All five Meade Pictor CCD models underwent extensive updating in hardware and/or software, as part of a continuing program at Meade Instruments to maintain Pictor imagers as the finest, most advanced imagers available to the amateur astronomer. The XT (Extended Performance) Series 201XT, 208XT and 216XT include more than 40 substantive improvements and additions in software alone. The new 416XTE and 1616XTE imagers are equipped with the latest blue-enhanced Kodak E-series CCD sensors.

Q. I notice that Pictor 208XT and 216XT CCD imagers are very moderately priced. Do these price levels come at the expense of important imaging capabilities?

A. Meade Pictor 208XT and 216XT CCD imagers were designed with one overriding thought in mind: to make high-performance CCD imaging and autoguiding available to the thousands of amateur astronomers throughout the world who were discouraged from entering the field because of the relatively high prices of previous CCD imaging cameras. Frankly speaking, Pictor 208XT and 216XT are absolutely revolutionary in both their performance and pricing: there are no other CCD imagers available from any source with the combination of capabilities and pricing offered by the 208XT and 216XT. As the images shown throughout the Meade Website indicate, the 208XT and 216XT are imagers fully qualified to yield amazing results, results that were undreamed of except from the most expensive CCD cameras only a few years ago.

Q. What are the primary differences between the Pictor 208XT and 216XT?

A. The 208XT provides for 8-bit A-to-D conversion; that is, the number of gray scales, as discussed above, is limited to 2-to-the-8 or 256, digitized levels of gray. Notwithstanding this somewhat limited number of gray scales, the 208XT is without question an excellent imager for the beginning to intermediate user, and spectacular results can be achieved with telescopes in the 6" to 12" aperture range. The Pictor 216XT permits 12- or 16-bit imaging, yielding, respectively, 4096 or 65,356 levels of gray, with a consequent significant improvement in image resolution. In addition the 216XT includes software, not available for the 208XT, that allows for color imaging, using the Pictor 616 Color Filter System. For the great majority of amateur astronomers the Pictor 216XT is all the CCD imager ever required; the 216XT, in experienced hands, is an advanced imaging tool that yields professional-quality images of the Moon, planets, and deep-space.

Q. You call all of the Pictor Models 208XT, 216XT, 416XTE, and 1616XTE "Autoguider/Imagers." Can all of these systems independently autoguide and image?

A. Yes. All four models, including the least-expensive Pictor 208XT, can be used to (a) autoguide a photographic exposure, and (b) autoguide the imager itself in a shift-and-combine mode—the imager takes a series of, say, 2-minute exposures and after each exposure the image is stored (combined) on "top" of the previous images; between image exposures the Pictor briefly autoguides, making any necessary position corrections. The shift-and-combine mode of all models is automatic: just input from the PC keyboard the number of exposures desired and the exposure time, and Pictor software does the rest, even calculating the proper integration time for the autoguider.
Q. How about color imaging with the Pictor Series. Is this possible?

A. The Meade #616 Color Filter System connects directly to Pictor Models 216XT, 416XTE, and 1616XTE and enables superb tri-color imaging, fully automatically, without the tedious trial-and-error approach of other CCD systems.

 Specifications and Features: Meade Pictor Series Autoguiders/Imagers

<table>
<thead>
<tr>
<th>Feature</th>
<th>Pictor 201XT</th>
<th>Pictor 208XT</th>
<th>Pictor 216XT</th>
<th>Pictor 416XTE</th>
<th>Pictor 1616XTE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CCD sensor</strong></td>
<td>Texas Instr. TC-255</td>
<td>Texas Instr. TC-255</td>
<td>Texas Instr. TC-255</td>
<td>Kodak KAF-0401E</td>
<td>Kodak KAF-1602E</td>
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<tr>
<td><strong>Dimensions</strong></td>
<td>3.30 x 2.40mm</td>
<td>3.30 x 2.40mm</td>
<td>3.30 x 2.40mm</td>
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<td><strong>Pixels</strong></td>
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<td>336 x 242</td>
<td>336 x 242</td>
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<td>10.0 μm square</td>
<td>10.0 μm square</td>
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<tr>
<td><strong>In 8&quot;/10 telescope</strong></td>
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<td><strong>Pixel size</strong></td>
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<td>1.0 arc secs.</td>
<td>0.9 arc secs.</td>
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<td><strong>Field of view</strong></td>
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<td>5.6' x 4.1'</td>
<td>5.6' x 4.1'</td>
<td>11.7' x 7.8'</td>
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<td><strong>Dark current</strong></td>
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<td>&lt; 8e-/5 secs. @ -5°C</td>
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<td>36e- rms</td>
<td>36e- rms</td>
<td>&lt; 15e- rms</td>
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<td><strong>Digitization</strong></td>
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<td><strong>A/D conversion</strong></td>
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<td>8-bit</td>
<td>8-bit</td>
<td>16-bit</td>
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<td><strong>Brightness levels</strong></td>
<td>256</td>
<td>4096 or 65,536</td>
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<td><strong>Full frame</strong></td>
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<td><strong>Low-Res: 0.4 secs.</strong></td>
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<td>Low-Res: 1 sec.</td>
<td>Low-Res: 4 secs.</td>
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<td><strong>Faintest guide-star magnitude In autoguider mode</strong></td>
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</tr>
<tr>
<td><strong>Transfer to host computer</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>9 secs.</strong></td>
<td>12 bits: 10 secs.</td>
<td>w/compress'n: 5 secs.</td>
<td>serial: 65 secs.</td>
<td>serial: 260 secs.</td>
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<tr>
<td><strong>16 bits: 13 secs.</strong></td>
<td>w/compress'n: 35 secs.</td>
<td>w/compress'n: 7 secs.</td>
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<tr>
<td><strong>Temperature control</strong></td>
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<tr>
<td><strong>Change from ambient</strong></td>
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<tr>
<td><strong>Thermostat accuracy</strong></td>
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<tr>
<td><strong>Shutter</strong></td>
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<tr>
<td><strong>Minimum exposure time</strong></td>
<td></td>
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<tr>
<td><strong>With LX200 telescope:</strong></td>
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<tr>
<td><strong>Auto-focus capability</strong></td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td><strong>Auto-mosaic capability</strong></td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td><strong>Host PC programs</strong></td>
<td></td>
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<tr>
<td><strong>On-Board programs</strong></td>
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<tr>
<td><strong>Accepts #616 Color Filter System</strong></td>
<td>no</td>
<td>yes</td>
<td>yes</td>
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Power Requirements

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<tr>
<th></th>
<th>0.5 amp;</th>
<th>1.0 amp;</th>
<th>1.0 amp;</th>
<th>2.0 amp; 12vDC</th>
<th>2.0 amp; 12vDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>12vDC</td>
<td>12vDC</td>
<td>12vDC</td>
<td>12vDC</td>
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Dimensions: Head

<table>
<thead>
<tr>
<th></th>
<th>5.5” x 2” x 1”</th>
<th>4” dia. x 2”</th>
<th>5” dia. x 2.2”</th>
<th>5” dia. x 2.2”</th>
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</thead>
<tbody>
<tr>
<td>Controller</td>
<td>-</td>
<td>-</td>
<td>9” x 7” x 1.2”</td>
<td>9” x 7” x 1.2”</td>
</tr>
</tbody>
</table>

Select a section below for more information on the Meade Pictor Series CCD Autoguider/Imagers:

- Meade Pictor 201XT CCD Autoguider
- Meade Pictor 208XT CCD Autoguider/Imager
- Meade Pictor 216XT CCD Autoguider/Imager
- Meade Pictor 416XTE CCD Autoguider/Imager
- Meade Pictor 1616XTE CCD Autoguider/Imager
- Meade Pictor 616 Color Filter System
- Meade CCD Equipment System
- Meade Pictor CCD Imager Software Downloads
- Meade Epoch 2000ip Image Processing Software
- Testimonials

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- Instruction Manual
- Product Information Index
- Meade Product Repair and Warranty Information