CHAPTER TWO

Cameras

We all have some expectations when making the decision to purchase a new gadget that is talked up by a vendor or by another amateur who may possess completely different equipment, skills, and experience. There is nothing worse than realizing later that what you bought did not meet those expectations. So, in this chapter, we will look at cameras capable of producing deep-sky images and the various essential functions and features that are important to ensuring they are up to this task.

2.1 Image Accumulation Cameras

The great innovation in video cameras for use in deep-sky astronomy has been the development of short-exposure image accumulation technology. This internal exposure co-adding technique makes it possible to observe faint detail otherwise nearly impossible to see at the eyepiece and to make a deep-sky portrait from light-polluted urban areas. Moreover, the short exposures mean less stringent need for perfectly polar-aligned mounts or correcting periodic tracking errors. Providing the amount of image drift is small and occasional recentering of the target is carried out, then images can later be aligned and stacked using popular freeware programs such as Registax.

Among the handful of CCTV manufacturers utilizing this technology, perhaps the two most prominent innovators are Mintron in Taiwan and Watec in Japan. Both have developed such cameras to meet the growing needs of the security and surveillance industry for operation in extreme low-light situations. By using the latest in highly sensitive image sensors such as Sony's ExView HAD, combined with

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Fig. 2.1. Set to accumulate frames, the Moon's Earthshine shows as though fully lit by the sun. Several faint stars can be seen in the background sky.

smart onboard image processing, these new generation cameras produce highly intensified images (Fig. 2.1).

In both manufacturers' models, the number of exposures accumulated within the cameras' internal memory buffer before output is manually selectable using incremental steps from X2 upward. Watec has a model it specifies as its astronomical-imaging camera. The WAT-120N allows frame accumulation rates of X256 and greater, but unlike Mintron cameras, the picture output remains blanked until full accumulation status is reached.

In Mintron cameras the incremental frame accumulation function is known as "SENSE UP," which is also quoted in their sensitivity specifications as StarLight Mode. In other manufacturer models the accumulation function or control is simply referred to as accumulation.

Each individually accumulated image is updated, or rather refreshed, at the camera's output within a specific amount of time according the number of frames being co-added as selected by the user. Once maximum accumulation is reached (taking up to a minute or so), you can simply move to any deep-sky object and see it instantly on the monitor without having to reset this function. When doing so, you will notice a streaked appearance of stars-like meteor trails across the viewing monitor until telescope slewing has been completed. The length of the trails is directly related to the accumulation / exposure time and telescope slew rate.

Another recent entry into the frame accumulation camera market is a company called The Imaging Source. They produce a very good range of compact, progressive scan, Firewire IEEE 1394 and USB 2.0-interface cameras which, combined with their own software, are capable of short and long exposures. They have even tailored certain models specifically for use in astronomy, with frame rates from 1/60 of a second and integration times up to 1 hour! But of course, longer integration time means slower refresh rates, limiting your ability to monitor the progress of each image being recorded. So, you will certainly need a quality tracking mount or autoguiding system to avoid drifted star images when using these extended exposures.

The Imaging Source cameras utilize some of Sony's best color and monochrome square pixel, progressive scan image sensors in 1/4-, 1/3-, and 1/2-inch formats. Internal filters effectively manage unwanted thermal background noise very efficiently, particularly for an uncooled camera. The Imaging Source color cameras are particularly good in applications where the user may not want to fuss with tricolor filtering and wants to produce an attractive color image in one simple step (Figs. 2.2 and 2.3).

Fig. 2.2. The lightweight DBK21A-F04.AS Firewire color camera by the Imaging Source is capable of fast exposures and on-board image accumulation.

Fig. 2.3. Messier 42 imaged with the DBK21AF04.AS through a 100 mm *f*/7.7 ED refractor and Vixen 0.6X focal reducer. Twenty-four stacked images from 5 second accumulation exposures.

2.2 Cameras Modified for Astronomy

Although companies like Santa Barbara Instrument Group (SBIG) (in the United States) produced innovative video systems like their STV unit specifically for use in astronomy some years ago, a number of astronomical equipment suppliers have taken steps to tailor the aforementioned CCTV manufacturers' cameras for use at the telescope. In particular, companies such as Adirondack in the United States, SAC Imaging in Europe, and Binary Systems in Australia have developed hand controllers, cooling systems, and astronomy-specific software for cameras, such as the StellaCam range and the GSTAR-EX. These cameras come standard with C/CS-threaded rings to take specific C-mount adapters and CS-mount lenses commonly used for meteor work and general night-sky surveillance. For use with a telescope they are supplied with various C-mount adaptors such as 1.25-inch nosepieces that are threaded to accept standard accessories such as colored glass Wrattens, Red, Green and Blue (RGB), and infrared (IR)-blocking filters. Other optional items like C-mount focal reducers and tele-extenders are also available.

Indeed, some suppliers custom modify camera electronics to allow for an even greater number of accumulated exposures, but this can lead to more unwanted noise and hot pixels, so cooling the camera becomes a mandatory, cost-adding requirement. Furthermore, output refresh rates are also longer (i.e., 10 seconds and up), so one might ask why not just simply use a standard cooled CCD imager like an SBIG or Starlite Express? A good argument, but on the contrary, there remains the ability to record directly to a VCR and view directly on a standard TV monitor. Furthermore, some cameras allow "only" accumulated picture output, lacking the versatility of "standard" video shutter speed-controlled imaging useful for doing lunar, planetary, and occultation work when required.

One of the goals of this book is to show what can be achieved with the most basic type of frame accumulation video camera without all the bells and whistles, so you can make an educated decision on what will best meet your needs. With this in mind, for much of this book we have used a GSTAR-EX camera to give you an idea of how basic accumulating video cameras (without costly modifications) can perform as a wonderful, simple, and affordable tool for deep-sky imaging (Figs. 2.4–2.6, Table 2.1).

2.3 Basic Camera Features

We have talked about the scanning systems for PAL and NTSC, pixels and video resolution, and lux sensitivity. Because having a well-rounded understanding of the camera's controls will ensure you can obtain the best raw image output the camera can deliver for a given situation, we will now briefly look at the most important camera functions for achieving the best results.

Fig. 2.4. The GSTAR-EX camera with optional hand control.

Fig. 2.5. StellaCam 3 fitted to a Newtonian telescope. Courtesy of Phillip Hinkler.

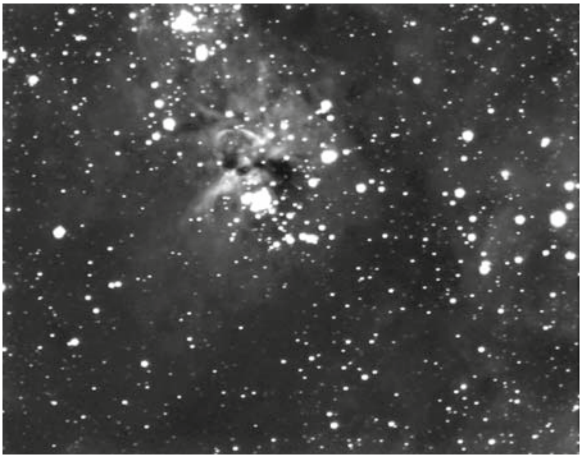

Fig. 2.6. Watec 120N-Plus image of the keyhole at the heart of the Carina Nebula using a 10-second accumulation time. Courtesy of Allan Gould.

Table 2.1. Some typical specifications and features you may encounter.

Important	
TV system	CCIR (PAL) or EIA (NTSC)
Image sensor size	May be 1/4-inch, 1/3-inch, or 1/2-inch depending on camera
Total CCD pixel no.	795(H) × 596(V) CCIR – 811(H) × 508(V) EIA
Scanning system	625 lines CCIR – 525 lines (EIA)
Sensitivity (Lux)	0.02 normal operation/0.0002 accumulation mode @ *f*/1.4
AGC (auto gain control)	Automatic and manual functions
Electronic shutter speed	1/50 (CCIR) – 1/60 (EIA) s to 1/12,000 s
Frame accumulation mode	2–128×, 256× or 512×
Gamma correction	0.45/1.0 selectable
Signal to noise ratio	52 dB (minimum) with AGC set to OFF
Video output	Composite (BNC) 1.0 V peak to peak 75 Ω and/or S-Video
Power requirement	Typically +12 VDC (center positive)
OSD menu	On-screen display menu system
Nice extras	
Grayscale calibration bar	ON and OFF selectable for calibrating your monitor
Digital zoom	2× or more to assist with initial telescope focusing
Mirror function	Nice for flipping images to correct sky view in certain telescopes

CCIR Comittee Consultatif International Radiotelecommunique, *PAL* phase alternating line, *EIA* Electronics Industry Association, *NTSC* National Television Systems Committee, *CCD* charge coupled device, *BNC* Bayonet Neill-Concelman

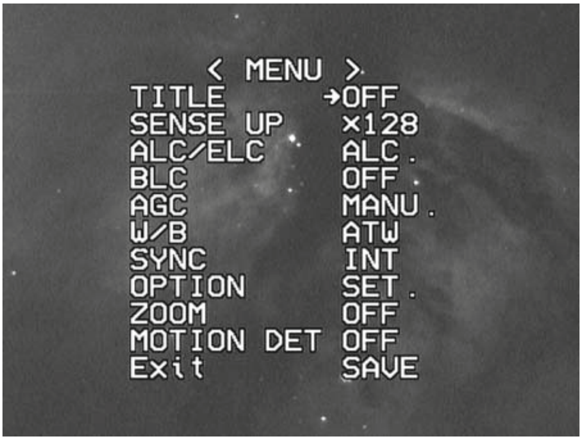

Fig. 2.7. Handy on-screen displays are useful for making changes to camera settings while still viewing the deep-sky subject in the background (NGC 2024).

2.4 Camera Control

Camera functions can vary, depending on the manufacturer's design and dealer product customization. For example, settings may be accessed via physical buttons on the camera itself or a hand control. The GSTAR-EX has an array of push button switches on the back panel, but like a StellCam III, it can be controlled via an optional hand controller. Some cameras can even be controlled via an auxiliary port using an optional RS232- or RS485-interface cable connected to a computer. For making changes, these cameras have an on-screen display (OSD) menu system that still allows you to see what is going on with your targeted object in the background while you enter submenus and make adjustments. Some cameras simply provide rotary switches on the hand control for adjustments to exposure, signal gain, and so on (Fig. 2.7).

One very handy feature of the GSTAR-EX is its mini-din RS232 auxilliary connection which also doubles as the optional hand controller interface. It allows for remote control of the cameras primary functions using free camera interface software and a special cable connected to a computer.

2.5 Shutter Speed

The term shutter speed heralds from the old mechanical system in film cameras. Like a curtain opened for a specific time, then closed to stop any further light from reaching the film, the duration of open time combined with the aperture setting directly affects how much the film is saturated by photons.

The exposure time in a CCD camera is managed on the same principle, although by electronically switching the array on and off. The maximum exposure time is 1/50 of a second for CCIR (PAL) cameras and 1/60 of a second for EIA (NTSC). The duration times for the "on" state are then selectable as shorter or faster exposure

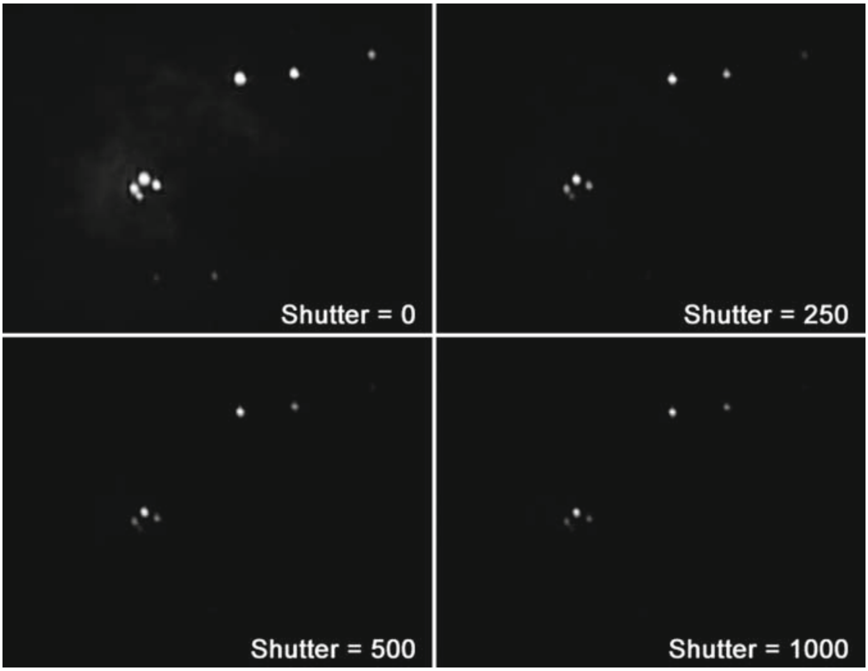

Fig. 2.8. The trapezium at the heart of Messier 42 used here to show the effects of various shutter speeds when frame accumulation mode is set to OFF.

times: 1/100, 1/250, 1/500 of a second, and so on. The shorter the exposure time the lesser the time available for light to build up in the array, thus producing progressively darker images with each step of faster shutter speed used. These standard camera shutter speeds are useful for solar, planetary, and lunar work in particular, as well as occultation imaging and timing (Fig. 2.8).

2.6 Signal Gain Control

Often called AGC (automatic gain control), it is preferable that the user be able to manually adjust this function as well. This signal control plays a significant role in revealing the faint stuff we seek as astronomers in extended objects, such as nebulae and galaxies. AGC is, in essence, a signal-boosting amplifier, but in doing so it also increases unwanted background noise and the intensity of hot pixels. In other words, it amplifies the entire signal detected and output by the CCD.

In deep-sky imaging the use of AGC at maximum is generally mandatory, and the unwanted noise it amplifies can later be minimized by stacking images. In conjunction with the exposure accumulation rate setting, manual adjustment of signal gain can be the defining factor between a burned out core in the nebulosity around the Trapezium stars of the Orion nebula or defining them as individual stellar objects. It can mean the

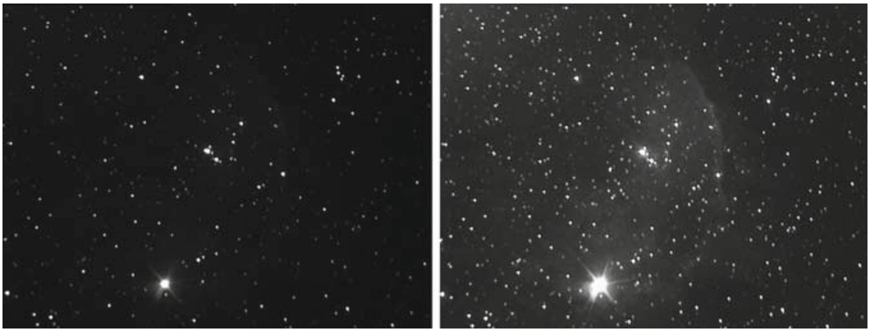

Fig 2.9. Left image of NGC 3324 in Carina is full camera gain and normal software gain. Right has the software gain increased to easily show much more nebula in the live view.

difference between detecting a faint comet or not or seeing a very faint nebula or other object live on the monitor beyond that which can be seen through the eyepiece.

By increasing the gain further with your capture software, very faint objects can be seen on screen. Although the view will be much noisier, the object will be revealed positively. This mode of operation can really help when trying to find or identify a very faint target. Then change back to a standard or less noisy setting for the image-recording session (Fig. 2.9).

2.7 Gamma Settings

The faint detail we all seek in features like the wispy festoons in the cloud tops of Jupiter or the spiral arms of a galaxy mostly reside in the middle gray regions of an image. This detail is often difficult to reveal using only the brightness and contrast adjustments of image-capture software drivers. Gamma adjustment can be regarded as a supplementary contrast enhancement that can yield improved visibility between darker gray levels (where outer spiral arm information exists) and brighter levels like stars or the central core of a galaxy, thus enhancing the overall pixel dynamic range. Some cameras have built-in 10-bit A/D analog to digital converters that provide better contrast or gamma correction in the image by sampling two extra bits of data, effectively yielding four times more discrete shades of gray.

The gamma control is a switchable or variable function usually ranging from 1.0 (no difference) to 0.45 (widely stretched mid tones), the latter being the desired setting. A manually adjustable stepped setting is very desirable, providing a more flexible control over the amount of total mid-tone brightness level adjustment.

Gamma adjustment is also one of the most important tools in post-processing of images to reveal the faintest middle gray tone detail in an image. This will be explained further in our post image-processing chapter (Figs. 2.10 and 2.11).

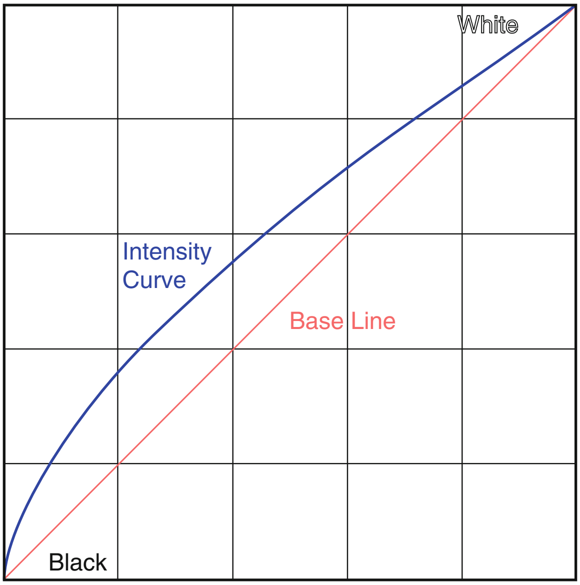

Fig. 2.10. Gamma curve chart showing how the mid-brightness regions are increased in value while the black and white ends are left normal.

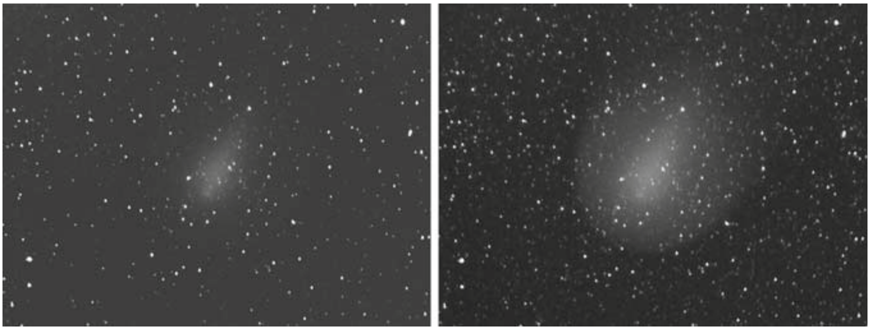

Fig. 2.11. These images of Comet P/17 Holmes were taken with gamma setting of 1.0 (*left*) and 0.45 (*right*). 135-mm lens and 200 video frames with GSTAR-EX.

2.8 Accumulation Mode

Now we come to the most important function that makes the inherently short exposures of a video camera capable of recording faint deep-sky objects, the frame accumulation mode. Not to be confused with long exposures achieved with extended open shutter/array on times, this is a simulated long exposure and is based on the number of co-added exposures taken at the maximum video exposure capability time of 1/50 of a second for CCIR (PAL) or 1/60 of a second for EIA (NTSC). In other words, the exposure time itself is no greater than 1/50 of a second; however, the camera electronically accumulates and co-adds a user-defined number of these short exposures to yield the equivalent result of a picture produced by a "still" picture-integrating camera capable of taking "true" longer-duration exposures. The user selected setting for the number of exposures being co-added within the cameras memory buffer determines how fast the picture is refreshed at the camera's output as seen on a video monitor.

How exposures are treated in the accumulation process varies from one camera to another, depending on its circuitry and programming. One process is to co-add each interlaced field and use interpolation techniques to generate the second field, making up the entire video frame or image. Other models may co-add both unique fields, resulting in longer picture refresh times but with improved resolution (Fig. 2.12; Table 2.2).

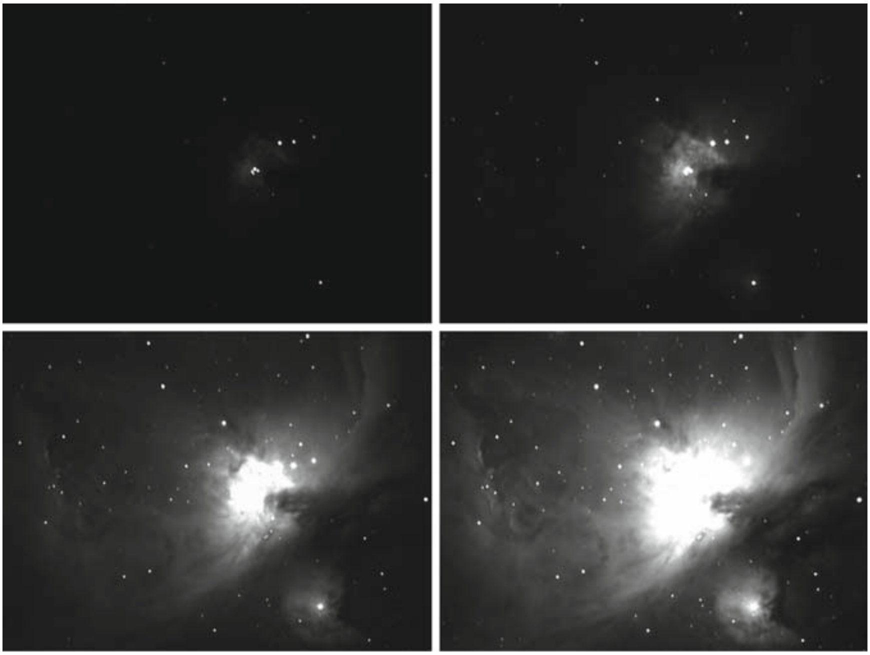

Fig. 2.12. Center of Messier 42 shown with no accumulation used then X8, X48, and X128 sense up.

Table 2.2. A guide to accumulation rate versus screen refresh times (PAL) for a basic video accumulation camera using field interpolation.

Accumulation mode	Picture output refresh rate (in seconds)
X2	0.04
X4	0.08
X6	0.12
X8	0.16
X12	0.24
X16	0.32
X24	0.48
X32	0.64
X48	0.96
X64	1.28
X96	1.92
X128	2.56
X256	5.12

Fig. 2.13. Back panel connections of the GSTAR-EX camera.

2.9 Video Cables and Connections

While CCD surveillance-based cameras most typically used in astronomy process internal signals digitally, the standard analogue signal amplitude from camera to interconnecting devices is 1 V peak-to-peak into 75 Ω (Ohms). The video signal may be either Composite [using Radio Corporation of America (RCA) yellow socket or chrome-plated twist and lock Bayonet Neill Concelman (BNC) style connector] or Y/C separated S-Video [a 4-pin Deutsches Institut für Normung (DIN) connector].

Disregarding all the timing, bandwidth, and other aspects encoded into a video signal, which are mainly of interest to TV technicians, composite video is essentially a modulated signal containing the (Y) luminance and (C) chrominance information. This signal must then be demodulated or decoded by a receiving device such as a VCR or a video monitor. But it is considered that losses to signal integrity can occur during this encoding and decoding process, particularly over long distances. S-video connections, on the contrary, pass the Y and C components along separate wires in order to maintain source (camera) signal quality that might otherwise be compromised as a combined modulated signal.

For monochrome cameras, where only a luminance signal is produced, a visually detectable difference in quality between composite and S-video is pretty much indiscernible in the "real" world when it comes to creating your aesthetically pleasing deep-sky portraits.

It is best to maintain the shortest cable length possible, since long cables can act like an antenna and become more prone to external signal interference over increased distance. And since copper wire is not a perfect conductor, the voltages required to maintain good signal integrity are reduced by resistance over longer distances. The thickness of the conductors and quality of the braided shielding inside the cable will govern the maximum practical length before the signal starts to noticeably degrade. Lengths of up to 15 m with quality 50 Ω cable (typically used for general consumer audio and video connection) is considered acceptable. Much longer distances can be achieved with well-shielded 75 Ω coaxial video cables. It is also vitally important to keep video cables well separated from other cables, such as shared AC mains power, where switching in the motors of a fridge, washing machine, or clothes dryer, for example, can create unwanted noise spikes. Poorly shielded equipment with microprocessors or electronic switching devices like the motor drives of a telescope mount can also induce unwanted noise.

When it comes to USB and Firewire cameras, the main advantage over analog designs is that power is provided from the computer, meaning one less cable and plug pack power supply you need to juggle with at the telescope. On the down side, high-speed digital interfaces, such as these, limit the workable distances between camera and telescope. Depending on the camera, most USB and Firewire leads are limited in operation from 2 to 3 m. However, in our trials using one Imaging Source Firewire camera, a cable of 5 m worked without error. If you need to achieve greater digital cable lengths for more remote use, there are affordable "active" extension cable systems available to maintain digital signal integrity over longer distances. You should check the specifications to ensure they have nickel plated corrosion-proof connectors and gold-plated contacts for maximum conductivity with twisted pair impedance matched wiring to avoid electromagnetic or radio frequency interference (Fig. 2.14).

Fig. 2.14. Various camera connector interfaces including composite, S-video, and digital.

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