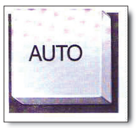

Figure 4.29 *A single button push is often all that is needed to perform camera setup.*

Cameras Become Sophisticated

Cameras and Computers

At the end of the 1970s the microprocessor had advanced far enough that it could be incorporated into the camera control system. Besides greatly reducing the amount of hardware that was needed to implement a control system, the microprocessor was good at one thing that many discrete logic ICs were not — running programs. One such program would be setup. The RCA TK-47 was the first auto-setup camera. Built into the TK-47 zoom lens was an internal test pattern called a diascope. This diascope was an extender position in the lens. In the automatic setup mode, the setup panel would look at the three color channels and the diascope, and would send the proper commands to register the tube camera and adjust various other imager parameters. Numerous other items, such as video levels, could also be adjusted. Later cameras could set themselves up without a separate setup panel. The correct setup parameters determined by the camera would be retained in memory. What up until this time was a knob or switch setting was now a value stored in memory.

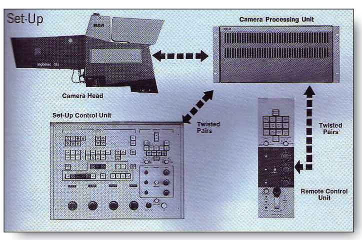

Figure 4.30 *TK-47 camera chain. The setup control unit would look at video from the camera and set up the camera. The values determined by the setup unit would be stored in memory in the camera's CCU. Manual control of parameters could come from either the setup unit or the remote control unit. One setup panel could set up or control six cameras. Now the functions provided by this separate setup panel are incorporated into most cameras.*

The RCA TK-47 had a single microprocessor in the CCU. Most camera chains that followed had a microprocessor in the camera head and in the camera control unit. These two processors talked to each other over an RS-232 link through the camera cable. The CCU would send out a continuous stream of analog values, commonly known as a pulse amplitude modulation (PAM) stream, that the head stored in sample and hold circuits. These analog values controlled everything from registration and geometry, to video level and iris settings. The microprocessors at both ends ensured that the PAM stream could not get out of sync and have the wrong values written into the various sample and holds. The other architectural approach was to have the total camera system reside totally in the head. Instead of splitting the video processing between the head and the CCU, all the processing was in the head

Figure 4.32 *RCA TK-47 and Philips LDK-5, two mainstay hard cameras as the '80s dawned.*

Camera Setup Files

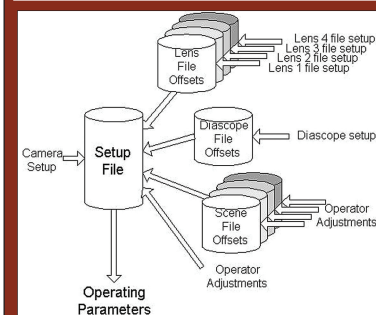

Figure 4.31 Cameras next started to store more than a single setup file. Now files such as diascope files, which remembered the difference in color temperatures between the lens' internal diascope and an external test diascope, could be loaded. When this file was set correctly, a camera run through setup on its internal diascope could be uncapped, and the external chart would not need white or black balancing. Thus if the diascope file was captured on a particular set, after setup no color balancing would be required for that particular set. Lens files could also be loaded on some cameras that would ac-

count for astigmatisms and other distortions between the internal and external diascopes. This is helpful in remote trucks, where lenses are often swapped between cameras. In addition, scene files could be loaded so that a particular color balance or operational mode, like calling up a star filter, could be recalled. These files usually worked in concert by using a setup file, usually obtained by auto setup, as the base set of parameters and adding diascope, lens and scene files as offsets to the base setup file.

Files have even been used for things that the customer is unaware of. At least one 1980s version camera, the Ikegami HK-322, used its files to store part of the operating system. If that camera lost its battery backup memory, not only would all the setup parameters be gone at the next power up, but it would no longer perform some of its basic functions. This camera's setup control panel had controls that would let you move head or CCU files from one camera to another. More than one engineer got into trouble by moving a head or CCU file from one camera chain to another just to see what would happen. Some thought you could match cameras by setting one camera up and moving those settings to another camera. Only recently, with CCDs and digital processing, is this approach possible. But there is still enough analog in a camera to make an extremely critical video engineer tweak the setup copy. In the '80s, with tube technology and analog circuitry (albeit fairly stable circuitry), moving one camera's setup to another would force a complete re-setup of the camera. Sometimes even a manual setup first, as most auto-setup systems can't perform setup if parameters are too far from where they need to be. The real reason this camera had the capability to move files from one camera to another was to reload the part of the operating system that was lost with file loss.

and the CCU was not much more than a remote control unit.

Most truck cameras that came after the TK-47 took the stand-alone approach, with the CCU serving as basically a base station with operator controls. The Sony BVP-360 and Ikegami HK-357 took this approach. Incorporating microprocessors made the use of triax feasible. As we mentioned in the last section, triax is basically coax with extra shielding. The various signals traveling between the head and CCU, that each used to have its own pair of conductors, now were frequency multiplexed. To power the head, AC or DC with a potential of as much as 300V is sent down the center conductor of the triax. Most cameras have fairly elaborate power safety systems, so that power is only applied if the right load and current draw is sensed. Triax allows a truck to carry miles of camera cable, whereas with the old camera cable only a few thousand feet was the norm. Many stadiums in this country have as much as 30,000 or 40,000 feet of triax permanently installed.

Going Digital

The next generation of cameras was the first to be built around the CCD imager. The early entrants had about 250,000 pixels. By the mid-1990s, they had almost 600,000 active picture elements. HD cameras have millions of pixels. All these pixels meant that resolution was much higher than with earlier CCDs. This helped minimize aliasing (when a tweed suit or a chain link fence breaks out into a pulsating rainbow). More resolution equates to sharper pictures. The cameras at the venue have to have as high a resolution as possible, much more than what is broadcast to the home. This is because every segment of the video path – from the camera, through the truck, the backhaul back to the broadcaster, and then transmission to the home — takes a nip out of all, but especially the higher, frequencies. This has been minimized with increasing use of digital television. With analog, as the video is passed through each device in the truck, handed off for transport back to the network operations center via satellite or fiber, passed through the network facility, uplinked to the local television station, passed through that station, and finally transmitted to the home, slight signal degradation takes place with each step.

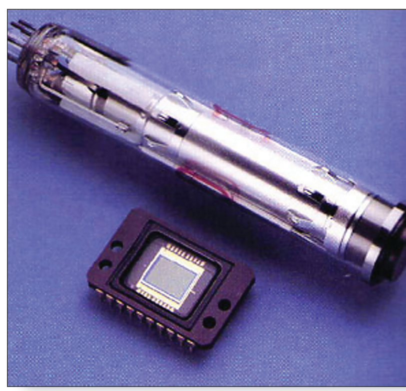

Figure 4.33 *CCD next to a Plumbicon tube*

The CCD Imager

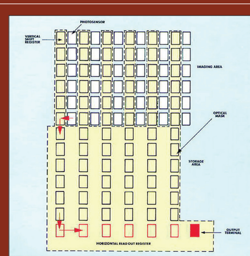

Figure 4.34 The introduction of the CCD imager made digital cameras an eventuality. The CCD is an array of sensors, each of which collects electrons based on the amount of light falling on each cell. Each one of these cell "buckets" is marched out one at a time. These are discrete samples of video. Today, there are two ways to organize the output from the arrays. The first way is to move the collected charges left one cell to the vertical shift registers during the vertical interval. These columns are optically masked and shielded from incoming light. Then during the next field time, while new charges are being collected by the photosensors, the optical mask columns of vertical shift registers are stepped down one row per horizontal line until they reach the horizontal readout register at the bottom, where they are then shifted out as the current video line. These are known as Interline Transfer (IT) CCDs. The problem with this approach is that the photosensors see very bright light leak into the adjoining masked cells as they shift down past the highlight cells. To stop that from happening, CCDs known as Frame Interline Transfer (FIT) CCDs were developed. Instead of marching the masked columns down one line at a time during the next field, the charges are transferred from the photosensors to the vertical shift register and quickly shifted down to another complete array, which is also masked from incoming light, all during the vertical interval. IT CCDs are seldom used in remote situations because of the vertical smear from bright lines. FITs are almost universally used. The only drawback to the FIT over the IT is price; the FIT is generally two to three times more expensive than the IT CCD. (Source: Sony)

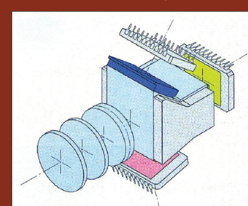

Figure 4.35 Prism with three accompanying CCDs and associated electronics comprise the camera's optical block. The CCDs are soldered to tabs on the prism block. This eliminates registration problems. Usually the green CCD is offset by half a pixel from the red and blue CCDs, which increases the spatial information captured and leads to higher camera resolution. The photosensors in individual CCDs occasionally fail or change sensitivity. To compensate for that, CCD imagers look for cells that have problems and use information from surrounding cells in their place. This check is performed every time the camera is black balanced. The prism, CCDs and pre amps, along with CCD control and compensation circuitry, comprise the optical block. Many cameras today are constructed so that the optical block can be easily removed from the front of the camera. This allows the same camera to use either 4:3 or 16:9 imagers, as well as switching from IT blocks to FIT blocks. (Source: Canon)

Now the television signal is increasingly spending its time as a digital stream. Trucks often produce digital video right out of the cameras, and it stays digital throughout the truck. The network's centers are commonly digital, and many local stations are being upgraded into digital facilities. For a few today, the broadcast transmission to the home is even digital, as DTV slowly increases its foothold. Finally, the transmission paths between truck and network, network and local station, and station and transmitter (most television transmitters are located apart from the studios, because they need to be in high places) are becoming digital. Once a signal is converted to digital, if it stays in that domain and undergoes no processing, then its quality should stay the same as it travels from box to box on its journey to the viewer.

Figure 4.36 *FOX used 14 hard, 12 handheld, six super slo-mo, and 15 unmanned point of view cameras for the Super Bowl in 1997. For their 2002 telecast, Super Bowl XXXVI, they used about the same number. For a normal NFL game FOX normally uses eight hard, four handheld, and five point of view cameras. This means that approximately 180 cameras are used between ABC, FOX, ESPN and CBS for each week of NFL football. With FOX paying more than $500 million a year for NFL rights and ABC and CBS paying a little more and a little less than $300 million per year respectively, the amount of hardware used to televise what has become so dear is not skimped on. (Source: Martin Eibeck - NEP)*

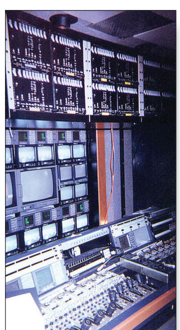

Figure 4.37 *The NMT truck used for ABC's* Monday Night Football *can handle as many as 25 cameras. Whereas ABC used 13 cameras to cover the 1985 Superbowl, today they commonly use more than that for a normal Monday night game.*

Digital Signal Processing

Digital signals are quantum, or discrete, in nature. They can only have a fixed number of states. In a one-bit system, signals have only two states possible. A two-bit system offers a total of four states. An eight-bit system can represent 256 states. Early digital systems were eight bits. As we just mentioned, once in one of those 256 states a purely digital word in theory (with no processing - just handed off from box to box) will not change. But to represent video levels as one of only of 256 values does not provide the rendition that a good analog signal would produce. In addition, how often you convert the analog video into digital values — in other words, how often you sample the video — has to be taken into consideration. The more often you sample, the higher the resolution. High-end analog cameras could provide more video information than digital sampling and standard-definition rates could capture at the time. So the decision had to be made whether to take the analog-to-digital "hit" as the video came out of the camera, or downstream somewhere, when the video encountered its first digital segment? Remember there was a positive trade-off here: Once digital, the signal usually wasn't degraded further. So there was a short period of time when the highest end cameras were analog, while many slightly downscale were all-digital internally.

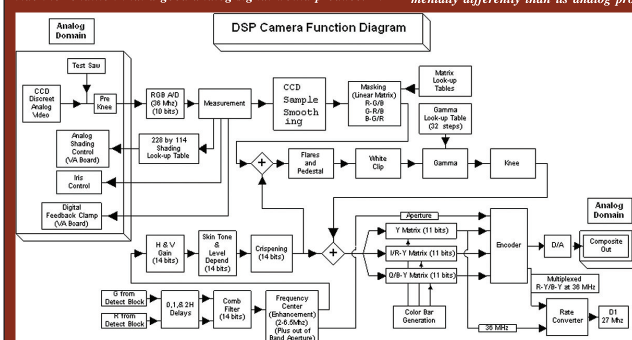

Figure 4.38 Block diagram of a typical DSP handheld camera

Camera DSP technology works fundamentally differently than its analog processing counterpart. Analog works in the frequency domain. It generally does its work based on frequencies of interest. DSP generally works in the time domain. This means that DSP works based on what comes before and after a point of interest. It mimics what the analog frequency domain circuitry does, for instance, manipulating a video element in a certain way, only in the time domain.

Figure 4.39 *Camera RCPs being installed into ABC's* Monday Night Football *truck in the late '90s. This truck still does MNF, but is now owned by NMT.*

Figure 4.40 *Handheld camera with large lens viewfinder and triax adapter (box hung on the back of the camera) added to "buildup" the camera into a "hard" or "studio" camera.*

Cameras today have become extremely stable and versatile. The decreasing space they take up, not only with the head but also in the truck itself, has made it possible to load many CCUs onto today's trucks. Often trucks carry more CCUs than camera heads. Twelve to 16 CCUs installed into the trailer is not uncommon. Today five to seven cameras is common for local baseball games. FOX often uses 11 or 12 when they do baseball. The World Series generally involves a couple dozen cameras. High cameras are not the rage anymore. High home, and maybe high first survive, but now low cameras are used. High first often doesn't even have shot assignments anymore. Its operator sells beauty and interest shots to the director. Cameras at low first and third cover right-handed hitters and left-handed pitchers, or left-handed hitters and right-handed pitchers respectively. Center field is considered indispensable for pitcher/batter shots. Cameras are also added from various angles in the outfield. The object today is not to just cover an event, but to tell the story of the game. Many directors feel the low cameras give the game a bigger look. Indeed low cameras put the viewer on the field. You get a player's perspective, not a spectator's perspective.

Figure 4.41 The v*ideo operator actively controls the camera lens' iris setting and the camera's black level during the show. Often there is more than one video operator when the number of cameras increases above four. In a large shoot involving many cameras, there is often a lead video operator, known as the senior video operator, who keeps all the cameras looking the same. This can be a large task as the sun sets on outdoor remotes, creating constantly changing color temperature conditions. Our eyes and brain filter out color temperature changes, but the camera doesn't. You have a high color temperature on a bright sunny day, meaning lots of blue light. As the sun heads toward the horizon, the color temperature drops, meaning lots of red light. A combination of changing filters in the camera, done by remote control by the video operators, and automatic and manual white and black balancing keeps all the cameras looking alike. White and black balancing refers to making all three color channels (R,G,B) have the same value when the camera is looking at a white, gray or black object. Sometimes a director or producer will want a warmer look (more red) or a more pastel look (more blue), and the video operator will manually adjust the level controls of the three channels to accomplish this. This process is known as "painting" the camera.*

Basic Camera Optics

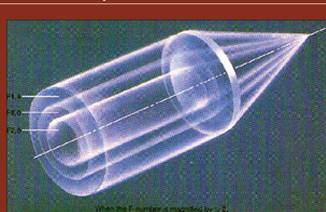

Figure 4.42 In television the brightness of an image is related to the F-stop number. Lenses generally have F-stop numbers with values of 1.4, 2, 2.8, 4, 5.6, 8, 11, 16 and 22.

These numbers all have a ratio relationship with the square root of two. This is because the amount of light entering the lens is proportional to the square of the diameter of the lens. For instance, an F-stop change of 1 to 4 to 5.6 reduces light through the lens by ½. Conversely an F-stop change from 11 to 8 doubles the amount of light. F-stop = focal length/effective aperture

The brightness is inversely proportional to the square of the F-stop number. Lens with the same F-stop setting might not have the same brightness because different lenses transmit different amounts of light. Because of this, the film industry tends to use a value called T-stop that takes this into account. Two different lens with the same T-stop values transmit the same amount of light at the same T-stop.

Zoom lenses also have an attribute known as F-drop. This is the light change that occurs when a lens is zoomed from all the way out to all the way in. As the lens is zoomed in, the entrance pupil changes size to allow more light in. When the pupil is as wide as it can go, the light level will start to drop. To reduce the size and weight of the lens it is common to allow some F-drop. The auto-iris circuitry in the camera will usually open the iris to prevent this effect from affecting the video levels. Many studio lenses have focus groups that are wide enough to minimize F-drop. (Source: Canon)

Optics

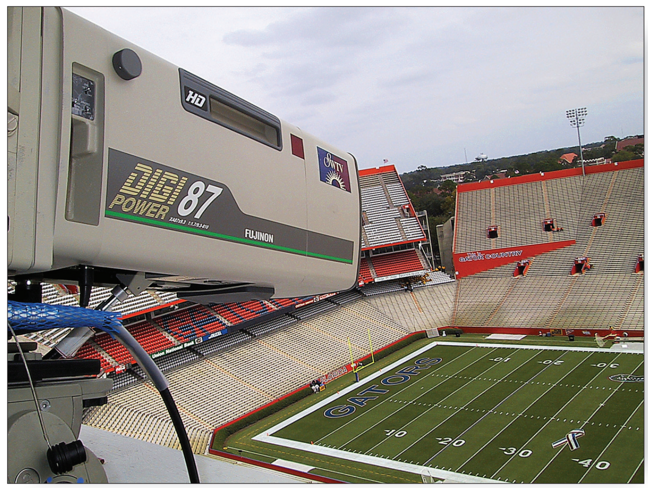

Figure 4.43 *With today's emphasis on getting up close and personal, the zoom lens has become central to camera operations. Lenses are often larger than the cameras themselves. Here is an 87:1 (13.2-1150mm or 26.4-2300mm with 2x extender) that weighs just under 50 lbs. This lens has its own internal microprocessor that senses lens vibration and controls a rear lens element to compensate. The microprocessor also controls a floating system of relay lenses within the overall zoom lens, which minimize spherical aberration and peripheral image field curvature. The camera's microprocessor and the zoom lens microprocessor can now talk over a serial communications path, which allows the camera to issue preset zoom and focus commands for quick camera moves. Another option available in today's zoom lens is an internal rotating turret with internal lenses that compensate for image size differences delivered to the camera's optics as aspect ratios are changed. Some cameras have 16:9 image blocks that are switchable to 4:3. When these blocks are switched the image size changes, although this isn't true for 4:3 images that are switched to 16:9. (Source: SWTV)*

As cameras lost weight and became more rugged and ubiquitous, new avenues and platforms for their use came forth, as we will see in the next section. ■