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-228- HOW A CAMCORDER WORKS

Everyone does it. When they acquire their first camcorder they cradle it respectfully in their hands and admire how technology can make something so small do so much. The camcorder is a tribute to the ingenuity of mankind: a mixture of physics, electronics, micromechanical engineering, and mass production. It's amazing how something so miniscule can have so many parts that all work together ('til you drop it).

Let's take a voyage through a camcorder to see how it works. This will not be a deep science lesson; that could take hundreds of pages and leave you yawning by the middle of page one. We'll just cover the main parts of a camcorder and tell what they do.

Remember the old song "Dry Bones" ("...The thigh bone's connected to the hip bone, the hip bone's connected to the back bone ...")? Well, in a camcorder, the lens bone is connected to the CCD chip, the CCD's connected to the circuit board, the circuit board's connected to the VCR, and that's the word of the designers.

The lens-

Light, like a rainshower, falls in all directions, bouncing everywhere. Pretty disorganized. Before we can make use of the light to make a picture, we have to organize it. Just as a rain gutter can channel a downpour, a lens collects scattered light, organizes it, and focuses it very sharply into a mini "light-picture."

Just for kicks some evening, turn off all the lights in the house, find the biggest magnifying glass you have, and hold it about six feet from one lit bare light bulb or desk lamp. On the opposite side of the lens, hold a piece of white paper and focus the light from the lamp onto the paper. Move the paper back and forth slowly and suddenly a sharp upside-down image of the lamp will appear. Depending upon the lens and the distances, the image could be small or large. Your camera lens does the same thing, only better. The focus part of the camera lens adjusts for the distance the object is away from the lens. The zoom part of the lens adjusts the magnification (bigness) of the image. Another lens component called the iris, blocks out some of the light, in case the image gets too bright for the camera.

Now that we have a sharp, mini image (about the size of a postage stamp), what do we do with it?

The CCD chip -

Once we have the image focused, we need to have some way to turn it into electrical signals. This is where the CCD (Charge Coupled Device) chip comes in. The CCD, also about the size of a postage stamp, contains about three hundred thousand tiny dots of photosensitive material. Each dot can sense the light that falls upon it and convert it into an electrical charge. Circuits in the camera measure these electrical charges, turning them into video signals.

To understand how a CCD chip works, imagine if everyone attending last summer's Woodstock Festival brought a water pail with them. Imagine three hundred thousand people standing in neat columns and rows (this has to be imagination, it couldn't be the real Woodstock) holding their buckets to the sky. Now imagine a small rain cloud sweeping across the valley dumping a torrent on some of the audience, filling their buckets. Some of the spectators would be on the edge of the shower receiving only a half bucket of rain and a few lucky patrons may hardly see a drop. The band on stage hammers out a rhythm and with each beat, each patron hands his bucket to the person on his right and accepts a bucket from the person on his left. At the end of the rows, someone else weighs each bucket, pours the water out, and recycles the empty bucket to the first person in the row. Since some buckets may be full while others are nearly empty, the scales will show different measurements.

In the CCD chip, it is light instead of rain that falls into the bucket. Light and dark parts of the picture make electronic buckets full of electronic charge or empty. An electronic "clock" circuit is the drumbeat that passes these charges from hand to hand until they are measured at the end of the electronic row.

After measuring the content of each bucket, the CCD empties the pail in preparation for more light, and does all 300,000 buckets at the rate of 30 times per second. There's a lot of fast bucket handling going on, but the CCD buckets are very small and the electrons don't splash out.

Incidentally, it is very unlikely that you would get rained on while the spectator next to you remained dry. Rain showers have gradual edges, and so would camera pictures if it weren't for the lens. The lens focuses the image, making sharp edges. If there were a lens for the showers over Woodstock, you might easily get drenched while your neighbor stayed dry. Maybe he stood under a lean-to with a rain gutter funneling water into your boot.

Now hear this -

Now that we have a video signal, where does the audio come from? Each camcorder has a built-in microphone, usually behind a little grille embedded in the front of the camera above the lens. Inside the microphone is a tiny diaghram, sometimes called an electret condenser. Power from the camera puts a charge of electricity on the diaghram, making it act like the plastic wrap that clings to everything but the food you wish to cover. Sound waves vibrate the diaghram causing the electric charges to get squeezed together, then farther apart as they cling to the diaghram. Since electrical charges don't like to be squeezed, some of them squirt out, running down a wire where they can be measured and amplified (made stronger). Thus waves of sound, vibrate the diaghram in sympathy, and create waves of electricity, called audio. There can be thousands of such waves every second.

Tall circuits and short circuits -

Once the camera makes video signals, it passes them to circuits that control the brightness, contrast, color, and other aspects of the picture. A sample of this signal is sent to your viewfinder, a tiny TV monitor in your camcorder. The audio signals are automatically adjusted so that the volume doesn't get too high or too low. A sample may be sent to your earphone output.

At this point, the audio and video signals could pass from the camera to a different VCR, a switcher/mixer, or to a TV monitor, if your camcorder had audio and video output connectors. Audio, video, and S-video (also called Y/C representing two signals, one for luminance or brightness, and the other for chrominance or color) signals are standardized. A TV monitor or VCR doesn't care whether these signals are coming from a camera and microphone, camcorder, VCR, or from a TV tuner. Video is video. Audio is audio. That's it.

When you pass standard audio and video signals from one machine to another, you can do things with them. Video signals can be enhanced (made to look crisper), brightened, darkened, time base corrected, color adjusted, combined with other images, twisted and turned in unimaginable ways. Audio can be faded up or down in volume, mixed with music, sound effects, narration, and sweetened in numerous ways. Some camcorders with special effects can modify the audio and video signals inside them; you don't have to run wires from gadget to gadget.

The VCR makes heads spin -

Inside your camcorder is a miniature videocassette recorder. It doesn't have a tuner and a timer to record programs off the air, but can do most anything else your home VCR can do. It records audio, maybe with high fidelity, and records video. It doesn't care where the audio and video come from. Normally these signals come from the microphone and camera circuits, but in advanced camcorders, the audio and video signals could come from another VCR, a separate camera and microphone, a switcher/mixer, or from a TV tuner. Once the VCR receives audio and video signals, regardless of their sources, it has the job of recording them on the tape.

Video signals consist of many electrical vibrations. Remember all those measurements taken from hundreds of thousands of electrical buckets 30 times per second? Each piece of data represents an electrical vibration, and somehow that vibration needs to be recorded on the tape. Audio, on the other hand, consists of only several thousand vibrations per second, making it easier to record. Since audio is easier, let's explain audio first.

On VHS and SVHS VCRs, audio can travel to a stationary "head", a tiny electromagnet that converts electrical vibrations into magnetic vibrations. Tape, which is a long ribbon of plastic impregnated with metal particles, slides over the audio record head allowing each of the magnetic vibrations to magnetize a tiny portion of the tape.

Let's use our imaginations again. Instead of a head making electrical vibrations, picture a dripping faucet with each drip representing a "water" vibration. Now imagine someone pulling toilet paper off a roll and passing it under the faucet so that the faucet dripped along one edge of the paper. If the drips came at a constant rate and you pulled the paper at a constant speed, you could see their marks forming a regular pattern along the edge of the paper. If the drips came faster, representing more vibrations per second (a higher pitched tone), the spots would be closer together. If you wanted to, you could turn off the water, roll the paper back onto the roll, then pull it off again and "read" how fast the drips had been coming. You could tell if the drips represented a high tone (drips positioned close together) or a low tone (drips far apart). The good thing about videotape is that the magnetic drips don't dry out or make the edge of the tape soggy, and the tape is a lot easier to wind into the cassette than winding toilet paper back onto the roll.

Audio, you remember, represented a few thousand vibrations per second, or drips per second. If you move the toilet paper fast enough, you can easily tell one drip from the other. Video signals, on the other hand, consist of millions of electrical vibrations per second (a relative flood). There is no way you could pull the toilet paper past the faucet fast enough to separate one drip from the other. This is where the spinning video heads come into the story. In your VCR and camcorder is a spinning drum, about the shape of a cat food can. At opposite ends of the drum are video heads, tiny electromagnets that change video's electrical vibrations into magnetic vibrations. The drum spins as the tape moves passsed it. Because the drum is tilted a little, one head will slide across the tape in a diagonal path and when it slides off the edge of the tape, the next head on the drum begins to touch the tape and takes its own diagonal swipe across the tape. Each head creates a diagonal line of magnetism on the tape. If you could see them they would look like diagonal candy stripes.

The diagonal stripes is how the engineers got around the problem of too many drips too close together. The spinning video heads spread the magnetism out over a wider area on the tape. VHS and SVHS sound can be recorded two different ways on the tape. The first way, which I've already described, involves linear audio tracks (the sound is recorded in a straight line of magnetism along the edge of the tape) but yields moderate fidelity. Being separate from the video, the audio tracks can be independently erased and redubbed with new sound. Or the picture can be changed without touching the linear sound tracks.
The second way sound can be recorded on the tape yields high quality, hi fi stereo sound. The method involves taking the audio signal and mixing it with the video signal so that the video head records audio and video at the same time. Thus the spinning video heads while recording high frequency video magnetism on the tape, are simultaneously recording the low frequency audio magnetism along with it. Since the two magnetisms are mixed, it is impossible to separate them. That's why hi fi sound and pictures cannot be edited separately, whereas the linear audio tracks along the edge of the tape can be erased and rerecorded; they have a place of their own.

Like their VHS brothers, 8mm and HI8 VCRs record hi fi sound mixed with the picture (a technique called AFM - audio frequency modulation). Once recorded, the two are inseparable.

The 8mm and HI8 formats allow sound to be recorded another way which is editable, a method called PCM (Pulse Code Modulation). Here, the video head, as it swipes across the tape, records video (and hi fi AFM audio) for most of its swipe. Then for the remainder of the swipe, it stops recording those things and begins recording PCM sound. Here the sound waves (converted to electrical waves by the microphone and amplifier circuits) gets recorded as pulses of magnetism. Since the PCM tracks represent only sound and no video, editing VCRs can erase them and rerecord new sound without touching the picture. The stereo PCM tracks have respectable fidelity.

Playback, the recording process in reverse -

Just as you could "read" the drip spots on the toilet paper, the audio and video heads can "read" the magnetism from the tape.

First the audio: On VHS and SVHS VCRs, the tape slides over the stationary audio head. Magnetism on the tape generates electrical vibrations in the head. These vibrations may be fast or slow depending on what was recorded, and thus mimic the original signal.

After amplification, the audio signal passes out the VCR or camcorder's audio output to an earphone, another VCR, an audiocassette recorder, or a modulator (described shortly). Hi fi VHS and SVHS VCRs can "listen" to the linear audio tracks or to their hi fi audio tracks, depending on how you throw a switch. The hi fi sound is read off the tape along with the video. A circuit separates the two and sends the audio to one place (audio and/or earphone output) and video to another (video output).

Similarly, 8mm and HI8 VCRs may have a switch to select whether the AFM sound or PCM sound is read off the tape. Video, you recall, was recorded as diagonal swipes of magnetism. The spinning video heads can sense the magnetism as well as record it. Tracking circuits assure that the spinning heads follow the diagonal magnetic paths perfectly (in fact, when they get off --- playing between the magnetic stripes --- you see bands of snow in the picture called "mistracking").

Circuits separate the picture signals from the hi fi sound and send video to the camera's electronic viewfinder, its video output, and/or to a modulator.

RF, RF, said the dog -

Camcorders with audio and video (or S-video) outputs allow you to send these standardized signals elsewhere, perhaps to another similarly equipped camcorder, VCR, audiocassette recorder, TV monitor, or sound system. Independent audio and video (preferably S-video) signals are the best way to pass picture and sound from device to device. For instance, it's best to connect audio and S-video directly to your TV to view the sharpest picture. Connect audio and S-video from VCR to VCR to copy a tape with the clearest sound and picture. If S-video isn't available, use regular video.

But discrete audio and video require two wires. Connections would be easier with just one. Further, some devices --- simple TV sets with antenna terminals only --- lack audio and video inputs. What then?

Enter the modulator (also called RF generator --- RF stands for Radio Frequency). This gizmo changes audio and video signals into a TV channel. It combines the audio and video with a high frequency signal (like radios use --- thus the term radio frequency) and sends the combo down an antenna wire. From here it can be fed to a TV set (tuned usually to channel 3 or 4) or to a tuner (a device that decodes TV channels back into audio and video) or to a VCR's antenna input.

The modulator muddies up the picture and sound a little, and the TV tuner may soften it a bit more, the whole process perhaps losing 10% of your picture quality. That's why it's better to stick to straight audio and video, and leave RF to situations where you have no other choice (like playing back your day's recordings on a hotel room TV).

RF modulators are sometimes built into the camcorder, (it may have 3 outputs: one audio, one video, one RF). They're always built into household VCRs. Most camcorders, to save weight, have separate modulators you connect to your camcorder.

This takes us the whole route from the lens bone to the video head bone to the modulator bone.
And that's the word of the designers.

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