LARRY ZIDE

The Making of the Ampex ATR-100

A visit to Ampex's Redwood City, California headquarters, and a talk with the development people, reveal the work that went into this state-of-the-art tape machine.

WE WERE SEATED in the office of Frank Santucci, the Ampex Audio Product Manager who, in many ways is the "godfather" of the ATR-100 project. Seated around the microphone of my cassette deck were Frank and the three engineers responsible for the development of this system: Robert P. Harshberger Jr., staff engineer who did the motors and control systems; Alastair M. Heaslett, senior staff engineer whose responsibility was the signal electronics; and Roger R. Sleger, senior engineer who created the mechanical system.

The resulting transcript of this talk took 31 typewritten double spaced pages but there was some doubling back and over-detailing that is not important. What follows will show the brain work that went into the ATR-100.

The first area of discussion centered on the use of ferrite tape heads on the machine. Ampex is not the first such user in pro audio, but ferrite has yet to be common as a replacement for classic metal laminated heads.

"The answer has to be multifold. The first reason is the very greatly improved longevity of the head. From a professional user's point of view, what this means is that adjustment of the machine to maintain a certain level of performance need not be made as frequently as with a metal head. It is no longer necessary to compensate for the fact that its performance as a transducer is changing during its life as the metal is worn away.

"The second reason is that it becomes possible to create a reproducer head where the noise and the high frequency region is not dominated by intrinsic noise generated by the head.

"The third reason is that because of this low loss, it becomes possible to use a biasing frequency which is sufficiently high, so that at the higher tape speeds (high in level or high in frequency), we can avoid or substantially reduce the effects of bias modulation noise at the higher tape speeds. Now, as tape's short wave length capability gets better, a greater and greater amount of bias signal is left recorded on the tape. In this respect, the bias is no different than any other type of signal that produces modulation noise.

"For example, at 30 inches per second, you can use a bias frequency of 150-250 kHz, which is common today (ATR-100 uses 432 kHz). When you take a tape you just recorded at 30 in./sec. with no signal going into it, rewind and then move it slowly past the head, you will actually hear a discrete signal coming back off the tape—recorded bias. True, when you play it at 30 in./sec. this frequency is 150-250 kHz, so one might say therefore that it doesn't matter. But the point is that the discrete signal having been recorded is saturating the tape. The effect on the over-all signal-to-noise ratio (the bias noise signal to noise ratio) at 30 in./sec. is really quite substantial.

If you attempt to produce a conventional laminated metal head with any kind of lifetime at all, that had to run with 400+ kHz bias frequency, you will find that you require an exceptionally large amount of bias power pumped into the head, most of which would be dissipated as heat losses in the head and very little of which would arrive at the gap as a useful plus. That's another reason why ferrite head technology was turned to. It permits us to realize significant performance improvements, particularly at the higher tape speeds."

TAPE AND MACHINE

One of the main points brought out in the discussion was the interrelationships that existed among divisions of the company. The development of the ATR-100 was interfaced with the construction and marketing of Ampex Grand Master tape—with the tape actually hitting the market place sooner.

Frank Santucci at his desk.

It came out that the tape division and this group worked closely over more than two years in which tape samples flowed in, were evaluated and changed, and a machine took shape as well.

It turns out that the machine did not really take final shape until the tape existed, then the final stages could be completed and an ATR-100 launched.

MECHANICAL CONSTRUCTION

The pinchroller-less design of this new machine is an obvious feature. It was revealed that this was a design feature that was sought right from the beginnings of design.

The ATR-100 is capable of handling 14 inch reels—though it is to be admitted that they are not yet readily available to studios. It is expected as more machines enter the field—as is now happening—these reels will come forth as well.

As for the mechanical construction, it was decided that a constant tension transport was needed, tension to be held constant regardless of reel size or position of tape on the reel.

"Once we made that decision, we looked at the tape transport and realized that the tension differential across the capstan is going to be constant since friction is relatively constant in tape. And once this is studied for a while, you become aware that a pinchroller isn't really needed because you can control that differential tension closely with pure electronics means by servo controls, so you can then do away with the pinchroller.

"Essentially this is what we did. We went a step further. Most machines would normally have a pinchroller covered with rubber, a high friction material. We don't do that, in fact, we use an anodized capstan which is relatively low friction. You can be running along in a play mode and grab the tape and the capstan will slip, even though the wrap is 135 degrees.

Alastair Heaslett, invariable cigarette in his hands, talks while Roger Siegel listens.

"This system, however, absolutely eliminates slip during normal motion. In fact, the grab from the capstan to the tape is so good that if you misadjust the tensions on the machine deliberately, you'll find that while the machine itself won't function suitably, it will still pull the tape. So there's a lot of margin."

FLUTTER

One of the demonstrations done at the recent AES show was to take the two reels and deliberately move them off center and run them, and still no wow or flutter was created.

"The servo is a lot more powerful than it need be for normal operations. The motors are a lot bigger than are really required to move that tape, they are rated at ¼ horsepower. It is a bi-direction servo in that you are never required to use the tape to pull the reels around. There is much less transient type of tension disturbance. The force that you're able to get with a reel servo is approximately 130 inch-ounces in either direction, which is twice as much as you can get on any other ½-inch mastering type of machine. Therefore, it can keep up with the offset reel.

"Another part of the servo is the way that the tension is sensed. The tension arms are actually driven magnetically, they are not spring-loaded. They are driven by a rotary solenoid and the force that they exert on the tape is controlled by the current throughout the solenoid. The force is also relatively independent of the position of the arm. So, while the position of the arm is used to sense the tension, it indirectly actually senses the actual position of the arm—which then controls the motor. The fact that the arm can move slightly does not affect the tension. It just controls the position of that arm and the reel will feed or take up in that position."

This time Heaslett, cigarette still there expounds while Bob Harshberger listens. But in spite of these appearances, both Harshberger and Siegel also contributed heavily to these discussions.

CAPSTAN SYSTEM

My next question had to do with whether the capstan itself enters into the servo operation.

"Yes. It is a phase lock capstan. The capstan moves—it is being directly driven—the reel servo control logic senses that the capstan is moving in a particular direction, programming these torques for the proper tensions. The tape will then follow by virtue of the errors created in the reel circle. It will just follow the capstan in either direction.

"On the fast modes (fast forward or rewind) the capstan functions as a velocity servo rather than a phase-lock servo. It goes to a certain velocity at a constant acceleration. When it reaches that velocity it stays at that velocity. The reel servos follow in the same way that they did in play modes. So that no matter which direction it is going, it creates the same error. In fast forward the tape simply accelerates to the maximum speed that the motor is capable of.

SERVO RELATIONSHIPS

"Now there is a control action as well. Under ordinary circumstanceces (10 inch NAB reels), ¼ inch tape) it accelerates at a fixed acceleration to a top speed, stays there, decelerates if you press the stop button, at the deceleration that it accelerated at. However, there are conditions such as with a 14 inch reel with ½ inch tape, where it is not advisable to accelerate that big of a pack as fast as the capstan can accelerate. Remember that there is no control given to the reel servos, it's only applied to the capstan.

"So if the capstan is told to accelerate at this fixed rate, you do not want the reel to accelerate at that rate. It senses the extra large error in reel servos and controls the rate of acceleration of the capstan so the capstan will never accelerate faster than the reel can.

"You also have the opposite extreme where if you have a very tiny hub, or if you wound tape right on the spindle, the reel would be going much faster than the voltages in the reel servo would allow. So the capstan servo also senses that the voltages on the reels have risen to a high level and slows down the capstan. So if you have a very small reel on one end, as you are rewinding it actually does slow down."

MECHANICAL ACTION

One of the most impressive things about this new machine is its mechanically smooth and quiet operation. My next questions had to do with these aspects.

"We should talk about the guiding and the acoustic quietness of the machine. The tape lifters on the machine are conventional type solenoid operated lifters, but they are damped. So when you operate, you don't get any clunk

A closeup of the ATR-100 deck.

at all from the machine. In fact, the lifters are adjustable in the setup—so set them so you just don't get the clunk.

The capstan noise factor is down because the rpm of the motor is down. Note that the size of the capstan itself is about 2⅜ inches in diameter. It happens that one revolution of the capstan is exactly 7½ inches of tape. We wanted it to be intervals of time, 30 in/sec being four revolutions per second. The size of the capstan is significant for many other reasons. One is the area of the capstan's circumference. Because with the small diameter on most machines, you're very subject to run-out effects from the capstan. A run-out is when (as the shaft rotates) it is not really rotating around the center.

"It may be slightly bent so the effect of the driving radius to the tape varies. The shaft simply can't be made or supported in its bearing perfectly. That run-out translates directly to flutter. It becomes a velocity error around the tape. The larger you make the capstan radius, maintaining the same number for the run-out, say 1/1000 inch, the more you proportionately reduce your flutter."

Next month we will conclude this discussion, beginning with the four speed operation of the recorder. ■