The Making of the Ampex ATR-100, Part 2

In this concluding segment, the Ampex engineers discuss the four tape speeds, the development of the electronics for superior headroom and phase coherence, timing accuracy for radio broadcasts, and finally future machines to come from this technology.

The roundtable consisted of Robert P. Harshberger, Jr., staff engineer who did the motors and control systems; Alastair M. Heaslett, senior staff engineer whose responsibility included the signal electronics; and Roger R. Sleger, senior engineer who created the mechanical systems (and whose name we misspelled in the picture captions in part one). Also present, and in whose office we sat, was Frank Santucci, the audio product manager for the project and its marketing.

The ATR-100 is a four speed tape machine, but in practice only two speeds at a time can be selected. The other two speeds are available and require circuit board changes to achieve. What I wanted to know was why this method had been selected rather than making it a simple four speed front panel selection alone.

"Mechanically, with the type of servos we are using, four speed operation was easy to implement. However, it must be realized that for every speed you have you must also have a full set of equalizers for both play and record. So, to have a four speed operation from the front panel you would need two more complete sets of equalizers. This, of course, would raise the price significantly."

"It was the considered opinion of both engineering and marketing that few potential users need four speed operation. Rather, most people tend to work at one dominant speed with another as secondary. In the broadcast field the primary speed is 7 1/2 in/sec and sometimes 15 in/sec, with an equal amount at 3 3/4 in/sec. In the recording field, the dominant speed in Europe is 15 in/sec, and in the U.S. 30 in/sec, with 15 in/sec as a secondary speed."

"All that is required to change to any other speed not already set up is more a jumper on each audio board. For each channel there are two jumpers which select the respective two speeds at which the machine will operate. You only have to reposition those on each channel. Then, of course, you will have to readjust equalization for the speeds you want to use. Incidentally, the machine will only operate at the two speeds selected on the boards. Setting the front panel speed switch to another speed will cause the machine to refuse to function."

"There is no jumpering required for the servos. The audio signal boards control the speed at which the servos will run."

THE ELECTRONICS DESIGN

My basic question to the group was what was done to the electronic design to get the ATR-100 to be so much better than the 440-C model.

"The short, quick answer is that the electronics are designed with margins that accommodate the existing tapes. These tapes may be two or three generations old. The improvements of tape performance over the last five years have been such that these margins have been eroded to the extent that the headroom to electronic saturation above the tape operating level has got to the point where there's not much left anymore."

"In general, however, the ATR-100 improvements have consisted of just attention to detail in each individual element of the signal paths and ensuring that there is enough headroom for today's and tomorrow's tapes."

"Let's put some numbers on headroom. In the reproduce electronics of the ATR-100, the headroom approaches 40 dB and for the record electronics, there is the capability of driving the record head with a signal that is 30-35 dB above operating level (or what we assume as operating level today before any intrinsic internal clipping occurs)."

"This headroom is not fully apparent if you take an ATR-100 and drive it to see what happens. Under that condition we would be talking about 20-25 dB of headroom— with modern tapes. That used to be a pretty good number and still is. The 440 had that number when applied to the tapes of its day, but modern tapes have considerably eroded it."

"There are other factors that give the electronics their
present qualities. We've made sure the system is linear from a distortion viewpoint, all the way to the overload point. From a purely design view, that meant circuits with output stages that are symmetrical.

"In short, it was an effort to ensure that there would be enough margin for today's tapes, while adding a bit more to provide for a few more years of tape development.

PHASE COHERENCE

Intertrack phase relationships on most multi-track machines are pretty poor. Ampex made a special effort to achieve a high degree of intertrack phase coherence on the ATR-100. I wanted to know how this had been achieved.

"Intertrack phase coherence is affected by many factors. In part one we talked about the design and construction of the tape heads. With our heads, mechanical gap scatter is so small as to be difficult to measure even with visible light.

"The precision with which the head and the rest of the machine is aligned mechanically is also important.

"Now if a machine is set up without paying attention to these details, you will end up with a system that has intertrack gap scatter. If phase differences were caused by differing track head impedances, you could still do some correction by careful alignment of the heads. This is, of course, a mechanical correction for an electrical problem.

"Where the ATR-100 is different from other machines is that a great deal of attention has been given to making sure that the performance of the two channels, or any pair of channels, is as identical as possible to each other. Once these electrical differences are worked out, you are left with the mechanical ones. And these can be readily corrected.

"It is fundamental to the process of magnetic recording that there will be phase non-linearity in the channel. The direct effect of this is that if you put a pulse into the system, and reproduce it, and the apparent amplitude response to the system is flat over any desirable frequency range, the pulse comes out the other end distorted. The form of the distortion is not important, but the fact is that the pulse is not faithfully reproduced. One could ask if the amplitude response is flat, why doesn't the pulse response come flat?

"The answer is because the process has nonlinear phase things happening in it due to the process of magnetic recording. Having said that, now we can go back and say why the ATR is different. There have been attempts in the past on professional machines to put appropriate phase equalization circuits into the electronics with the aim of producing a machine which will reproduce pulses correctly as they are recorded: The drawback to these systems has been that the phase equalization has been accomplished principally during reproducing. The factors which influence the nonlinearity in terms of phase recording are intimately bound up with the particular record head (what was its physical gap length, what was the coating thickness of the tape, how did the user choose to bias the tape?) and a lot of other similar factors. Of course, on that particular machine you could adjust this phase equalizer and indeed come out with a very good replica of a square wave coming off the tape.

"The problem was that the recording that you produced is not compatible in the sense that now you take this recording and play it on another machine which is equalized to reproduce the sine wave response correctly, but it would not possess these good phase characteristics. In a similar sense, if you took a recording that was made on another machine, and play it on this machine which had the phase equalization present, it might help the phase response, but it might make it worse because it just depends on the par-

A closeup of the ATR-100 control panel matrix.
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I had the rare privilege of a short interview with Alexander M. Poniatoff, founder of Ampex, still active in the company although in his eighties. He posed for my camera, seated at his desk.

recording. The nice part of it is that the user is totally unaware of the fact that while he is adjusting his record equalizer to produce a flat amplitude response, he is also adjusting the phase equalization of the system so that the overall phase linearity of the system are considerably better than if the classical kind of record equalizer were used. If you adjust the record amplitude response of the system for a particular type of tape, you produce the correct phase response. By having the phase correction on the record side, the result is a tape that is more phase linear and you can benefit from it on any machine on which it is played."

TIMING ACCURACY

The ATR-100 is well suited to the needs of broadcasting. In this field, timing consistency and accuracy is important, and it was toward this that we talked.

"Let's look at the worst possible case—a one hour program recorded on one machine and played on another. Under such conditions the total error in one hour would be less than two seconds. More likely, it will be under one second. If, in fact, the recording is made today, and played back on the same machine tomorrow, the maximum error will be less than one second."

ONE AND TWO INCH MACHINES

The present configuration of the ATR-100 is as a quarter- or half-inch only machine. In an attempt to look into the future, I asked about the probability of machines using the new technology for the larger format. The question was fielded by Frank Santucci.

"It must be understood that any larger format is a totally different machine from the ATR-100. The tape handling is different; the control system is different. If we were to start the design today, it would be at least three years before the machine saw the light of production day. Of course, we are looking at one and two inch machines with the performance characteristics of the ATR-100. But there are practical problems. Two inch ferrite heads are a whole new ball game at the very least.

"Of course, Ampex is looking at this project, but it certainly has a long way to go down the pike before it sees production."

It is easy to become impressed with the product after an interview such as this. But the specifications of the ATR-100 really tell the full story. It's all the story that has to be told.