ELECTRONOTES

WEBNOTE 14 12/2/2013

ENWN-14

<u>MOOG STUFF COMPLIED HERE</u>

It has never been clear to me whether what I am writing is going to end up as an issue of ***Electronotes*** or as an Application Note. Sometimes it changes in the middle of the writing. At still other times the material just seems to float about, and seems to be asking just to be posted in some way – and hence the relatively new “Webnotes” that appear here from time to time.

Recently I was motivated to put together a bunch of “Moog Stories” which I scrounged about to assemble. Once I had most of them cornered I thought of also adding the old interview from 1974. How much trouble could it be to scan and OCR this? Not as much as I feared, and in editing up the scanned version I got to read it in some detail. I was frankly very impressed with how often (almost always) he was right about what he said then, and it continues to be <u>highly relevant today</u>. Such things as true art forms requiring <u>complexity and dynamics</u>.

The interview is the main course here. We start however with favorite Moog stories. Here there are six of them. All six are “new” in the sense that they are not widely available except through Electronotes and/or my personal remembrances.

- Bernie

SIX MOOG STORIES

1a. The Elevator

No “Moog Story” is more famous than his adventure with the elevator in Clark Hall at Cornell. Here we relate this in two parts: (1a) being the text and photo (from EE4436 class) that appears in Paul Hartman’s history.

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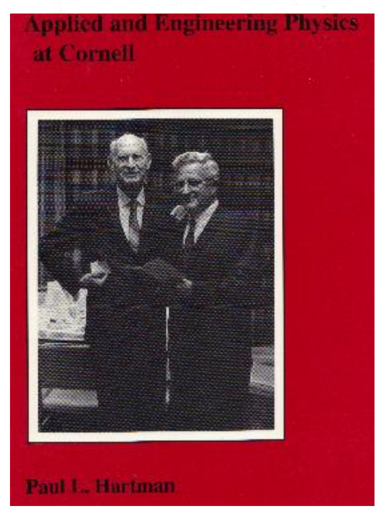
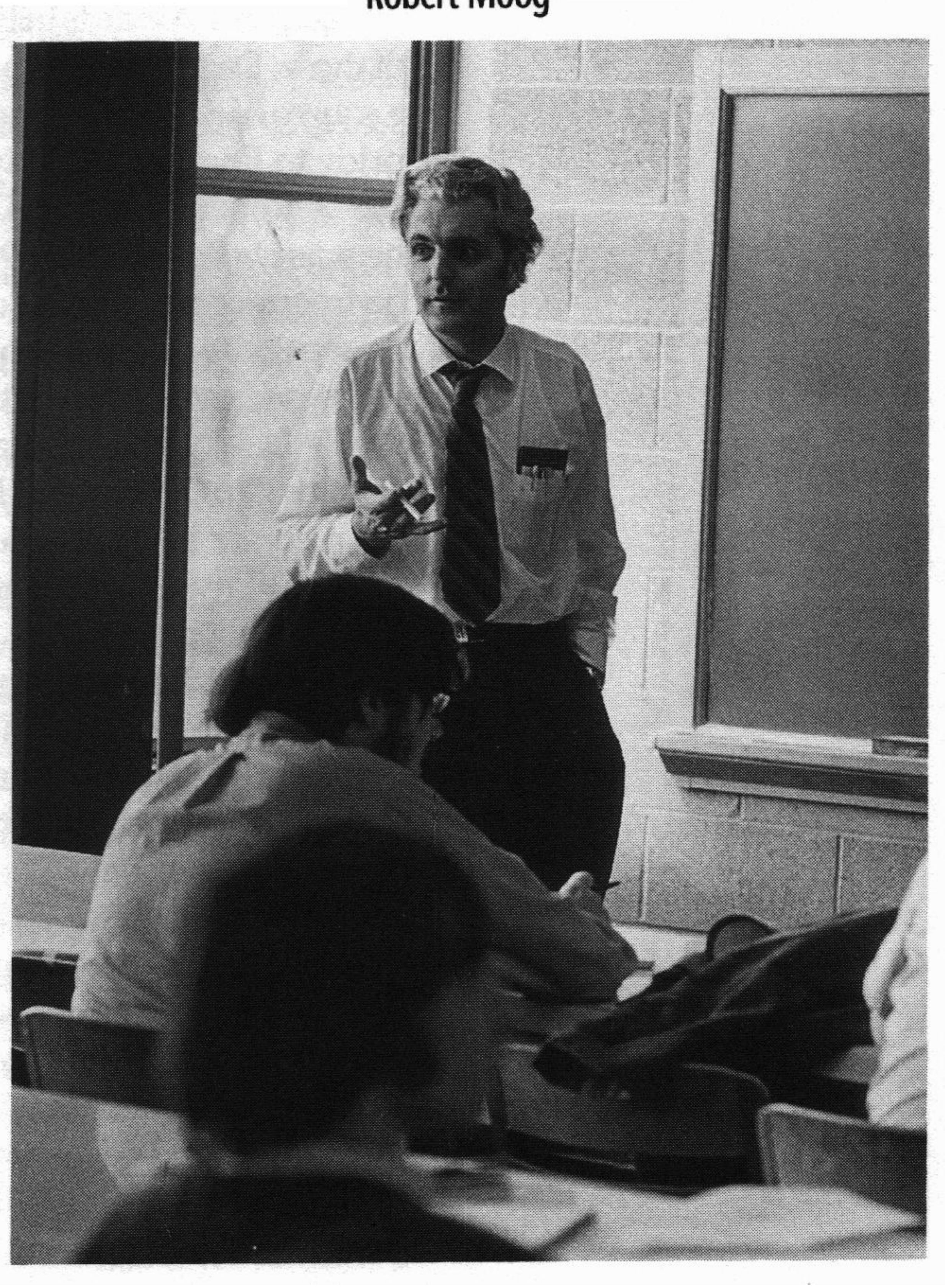
Also among our graduate students who have made innovative contributions in research is one whose name is a household word, at least in musical households: Moog, the inventor of the well-known Moog sound synthesizer. Robert Moog earned his degree with Henri Sack for work in internal friction and dielectric loss, but in the laboratory he was almost as often at work generating sounds in esoteric ways. At one point he contrived a theremin with which he could generate sound of variable pitch, depending on the capacitance between the oscillator and his hand. He could even manage quivery, simple tunes. He played so much with such things that his thesis was in jeopardy of being sidetracked. Sack laid down the law: a first draft had to be in by a certain date. On the day of the deadline, Moog took the Clark Hall elevator up to Henri’s sixth-floor office. En route, Moog tested resonance, as was his wont, by bouncing up and down in the cage. He hit resonance all right; the elevator came to a sudden halt between floors. There he sat for a couple of hours; it must have been a slow Saturday afternoon, for it took some time before help arrived. Sack thought the incident was sort of funny. Today, Moog does also. Later, as a Cornell faculty member in electrical engineering for a year or so, he went on with his sound generation and marketed his synthesizer, which was first made up in Trumansburg. Imitators were not long in showing up and electronic music is to be heard now everywhere, some “instruments” even beating out rhythm “for the left hand.” “Switched on Bach” played on the Moog is pretty serious stuff—really quite something—except for the purists.

Above text and photo of Moog below are from Paul Hartman’s Applied and Engineering Physics at Cornell (1994) the cover shown at the right. Pictured (right) is Henri Sack, Moog’s thesis advisor. “Moog – what is not on my desk at 5 PM is NOT in your thesis” – Henri. At the left is Trevor Cuykendall, who happened to be Bernie’s undergraduate advisor.



Robert Moog



Bob Moog teaching at Cornell EE, probably a photo from 1970 (?)

1b More About the Elevator

BOB MOOG VISITS CORNELL

Bob Moog returned to Cornell University on Nov. 2, 1995. I'm not sure how long he had been absent - I can only say that, although I had seen him frequently elsewhere (although not for some ten years), I had not seen him at Cornell since about 1971. He entered the conference room on the 7th-floor of Clark Hall to chat with a collection of graduate students and old friends who had assembled, the former group to both see him and to hear his talk, the latter group being enthralled just to see him again.

Indeed, he opened by commenting that the two questions he was usually asked were "Are you still alive?" (apparently) and "Do you remember anything?" (we shall see). To me, of course, he had to be still alive, having only perhaps a dozen years on me, and it couldn't have been that long ago! (Moreover, he looked exactly the same as I remembered him. In essence, there is a certain look that populates his face in the absence of anything more immediate, a mixture of curiosity and amusement that could only be Bob Moog.)

He then mentioned his dissertation advisor, and a particular instance of his advisors unique verbal expression. I smiled, having known his advisor slightly, and a few others did too, but too many others in the room had not known this memorable individual at all. The story did not work this time (likely it had during his lunch with the faculty earlier) - it really had been a long time, a realization Bob immediately adjusted to for this group.

However, it is worth noting that his advisor had been mentioned in the context of one of Bob's most famous adventures: his getting stuck in an elevator in brand new Clark Hall while on the way to getting his dissertation signed by his advisor (even as the clock ticked toward a graduate school deadline, not to mention wife and kids in a waiting VW bus at street level).

But more specifically, he himself had accidently stalled the elevator through his own usual shenanigans: trying to estimate the resonant frequency by bouncing the car up and down. (Likely, this essential experiment had not been done yet!) The story, sometimes presumed apocryphal, often told, and likely improved with each re-telling (including this one), is true, and quite understandable, considering the experimenter involved.

Onward went the talk into the present, while at the same time still embracing the past in the embodiment of the Theremin, his current enterprise, which he had brought along. Bob treated us to "Over the Rainbow" and tells us that in order to intentionally play the Theremin, you first must first learn how to stand perfectly still!

At the end of the question session, the audience was invited to try the Theremin, but many simply rushed forward to renew acquaintances. Individuals pressed forward, many with the usual "I bet you don't remember me?" At a decided disadvantage, Moog remembered few of the faces, but virtually all of the people, in detail, once they admitted a nominal identity beyond the jumble of faces from 25 years ago, and each now 25 years changed.

In my case, it was something like "Are you still here?" and we went on to discuss "business," specifically whether or not the truly random motions of a player (of a Theremin or any other mechanical instrument for that matter) are a contributing element to what we regard as artistic expression. He didn't know, and I was sort of glad to see that there were things he had not yet figured out - there was still much to think about and work on.

As the crowd thinned, Bob packed up his Theremin (he had the required screwdriver on him). His official escort and a few hangers on such as myself headed out of the conference room, toward the elevators!
There were just few enough people to all fit on one elevator, but I guess I had mused aloud as to whether it was a good idea to get on that elevator with that person. But of course, I did. "I just went like this," Bob said, flexing his knees, causing the elevator floor to jiggle slightly but significantly. It continued without stalling. He then indicated "It's up there," pointing to an upper corner of the elevator car, apparently the location of the sensor, which presumably some elevator technician had shown him during his earlier rescue. It was okay to bounce the car, because even if he stalled it, he now knew how to fix it. (Perhaps that was why he really carried that screwdriver!).

- Bernie

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2. Dr. Moog and Teenage Hearing Loss!

I remember hearing Bob Moog relate how he was at a conference, (an ASA meeting in Montreal if I recall correctly), where, among many esoteric scientific papers, there was at least one that the public could relate to – hearing loss in teenagers due to loud rock music. I surmise that the name Bob Moog was likely the only name among the many presenters that was at all well-known. It was inevitable that a "reporter" covering the event should make the connection. "Dr. Moog," the reporter demanded, (shouting into Bob's ear!), "How do you justify producing products that cause young people to go deaf!"

This was interesting enough, but even more revealing was that when Bob complained about this to the event organizers they replied, in essence, that "Any publicity was better than no publicity."

-Bernie Hutchins, August 2009

3. Music System Professional Adjusted by Bob Moog – Not Appreciated

At some time, there was a symposium or something similar at the Berklee College of Music in Boston, I think organized by Bob Ceeley. Bob Moog and I (and if I recall, Bob Morris and David Friend) were on the "panel" and following the panel presentations, there was a dinner in a local restaurant, which was nice enough except for the music they played which was of a "quality" and volume inconsistent with entertaining a group from a music college. Moog simply got up, found the amplifier, and turned the level down, to which someone remarked "an engineer" and another quipped "no – a critic". Soon enough a manager was around to rebuke Bob saying, implausibly as it seemed to the rest of us with the group, that <u>everyone else</u> in the restaurant was enjoying the music. I don't know why he didn't instead put a sign in the window "Our music system has been personally adjusted by the great audio engineer, Dr. Robert Moog".

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4. and 5. That Sounds Like Bob All Right

There are so many Bob Moog stories that have been told which are available. Here are two others, probably not previously told, and not terribly important perhaps, but both of which fit the pattern. In 1971, I took a course, Electrical Engineering 4436 which Bob taught at Cornell. (I got an A+ which delighted me no end, one of very few grades I actually cared much about.) As one of the projects, there was an analysis of a spring reverb. Bob had given out the project and a reference during one class, and suggested how to approach it. What he said seemed wrong to me! But I thought I needed to think about it before saying anything. By the next class I was waiting outside his office for him to arrive, and when he saw me, I said something like "About the moment of inertia of the coil…." I don't know if he had thought about it between the classes, or if his physics training kicked in instantaneously. "You're absolutely right," he said, without my going further. He was very much aware of the way engineering and physics could be so obvious that true practitioners might only need to grunt.

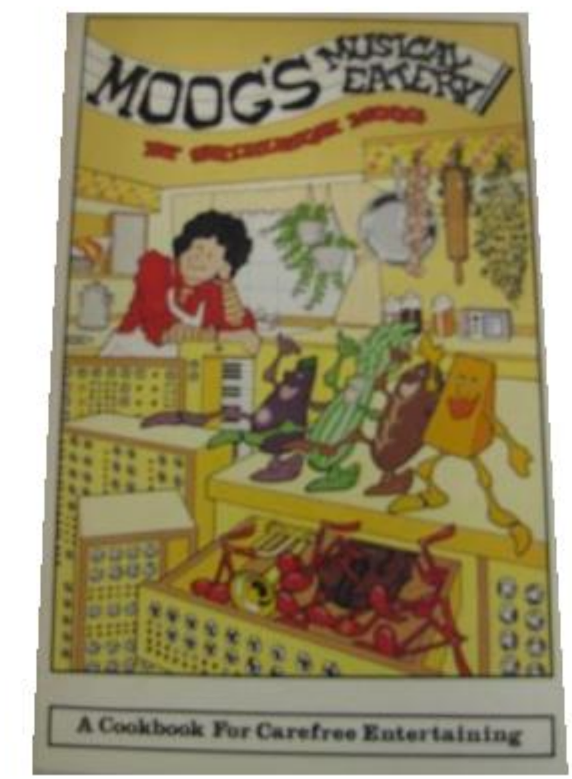
The second story involves sitting with him at a meeting somewhere (probably AES) when a guy came over with a sketch a friend of his had made of Bob; pencil or charcoal I think. The guy asked if Bob would autograph it! That was perplexing enough – why should Bob sign a picture someone else drew? The sketch wasn't all that bad, but, the man in the sketch had a prominent mustache - and Bob did not! This was a problem. Bob looked at it for perhaps a full minute, and then did autograph it. Handing it back he said "Be a good kid and ask your friend to take the mustache off."

Electronotes 205 March 2008 Bernie Hutchins

6. How Do You Pronounce It?

When I first met Bob, I think his name was quite consistently pronounced Moog rhyming with “fugue”, and sounding like the sound a cow is purported to make, which is relevant here. Today it is universally pronounced Moog rhyming with “vogue” (for a while there was a sign “the Moog is in Vogue”).   When and why did it change?   Here is one theory, supported by the fact that Bob told it to me.

Bob’s first wife Shirleigh was the writer of a famous cookbook. Her day job was as a 3rd grade teacher. We all remember, more or less, that when we were in the 3rd grade we were easily coaxed across the line to obnoxious, and such it was that Shirleigh’s limit to enduring the ever lengthening of the double vowel to a more and more cow-like intonation was reached. Upon learning what was going on, Bob told her, “You know, half of our family pronounces it Moog [“vogue”] and that was settled.



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MOOG INTERVIEW FROM ELECTRONOTES

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A few typos have been corrected. OCR may have added some new ones, but it looks pretty good.

INTERVIEW WITH ROBERT MOOG

Part 1, The First Ten Years;

-by Bemie Hutchins

Robert Moog was Interviewed in his office at Moog Music, Inc., Williamsville, NY on Oct. 4, 1974. The first part of the interview, given below, concerns the first ten years since he gave his original paper on the voltage-control technique. Two more parts of the interview (the present state of the art, and trends for the future) will be printed in later issues.

BH: Ten years ago the date of this issue of EN [Issue Dated Oct. 14, 1974], you gave a paper at the Audio Engineering Society convention entitled "Voltage-Controlled Electronic Music Modules." It is evident now, that this paper marked the beginning of not only the Moog Synthesizer, but of the whole voltage control idea. I think that many persons today take the idea of voltage control so much for granted that it is supposed that the choice of general method, that of voltage control, was obvious, and that only the technology had to be worked out. What exactly was the situation 10 years ago?

RM: I don't think that 10 years ago people regarded voltage control as a unifying concept in designing equipment. I can remember reading an article back in 1961 printed in Electronics magazine by Harald Bode In which he described a modular system that he designed and built more or less as a hobby. His modular system consisted of reverb unit, tape delay echo unit, a couple of filters, a diode ring bridge modulator, an envelope follower, and what amounts to a voltage controlled amplifier. So certainly the idea of a modular system to generate and shape sounds was not new. A careful literature search would probably reveal articles like this even before Bode's.

As far as my part in this goes, there was no thinking out ahead of time of what approach would be the most profitable. I was interested in working with musicians, and that's where it began.

The first musician who I met as I was finishing my graduate work was Herb Deutsch. I liked his music. I responded to his interest in making and controlling sounds electronically, and it seemed like it would be fun to get together with him. We talked on several occasions late in 1963 and early in 1964, and we agreed to get together for a couple of weeks during the summer of 1964. As the first half of 1964 progressed, Herb and I had several exchanges of ideas, and by the time he pulled into Trumansburg in June of 1964, we had built two VCO's, and a VCA. The VCO's were very simple extensions of the then new unijunction technology. I had just put voltage control terminals on them to have some way of electronically controlling them. I'm sure of one thing: the idea of keyboards with memory, voltage controlled filters, contour generators, and all that was not in our minds as Herb and I first began to work.

I did have an old dusty organ keyboard and we did in fact begin experimenting with putting the right resistors between the keys to get an equally tempered scale. Herb wasn't personally interested in producing accurate equally tempered pitches, so we just saw the keyboard as a way of changing the oscillator pitch.

I think that it took us a good two or three years to see the application of voltage control as a unifying concept in itself. A voltage controlled filter came into being about a year after the VCO's and VCA's. In our 1967 catalog, for the first time, we asserted in print that voltage control was something really useful and general that musicians could use for musical manipulations.

BH: Over the past 10 years, what do you consider to have been the major successes and failures of the voltage control technique, and which of these were a surprise to you?

RM: I think that every time a good musician got his hands on our stuff, what he produced was a surprise to us. There was no way of figuring out ahead of time that the circuits we were building were going to turn out to be musically useful. We just hoped that we defined the needs of the musicians correctly, and came up with hardware that really met these needs. I can remember the first piece that Herb put together on those very crude prototypes (they were three pieces of vectorboard mounted in a wooden frame powered by a couple of batteries). He took all of that down into the basement of our Trumansburg shop with a Sony tape recorder, and in a couple of days, he had some honest-to-God compositions. They stand as musical compositions even today, not because the equipment was so awful good, but because a real musician who had the ability to adapt to new sound material rapidly, got a hold of these and made the proper use of them.

Herb was the first, and from there on we had the pleasure of working with many other musicians. Our very first customer was Alwin Nikolais, a choreographer with a very well known troupe in New York City. For quite a while before he saw our stuff, he had been working with classical tape techniques, producing sound backgrounds for his choreography. As soon as he saw what a couple of VCO's and VGA's would do, he bought in, and for many many years after that, he made all of his musical scores entirely on our equipment. Once again, it's not because the equipment automatically makes music, or is so sensationally useful. It's just that we were lucky in producing equipment that was attractive to people with talent.

Lejaren Hiller saw and ordered one of the very early systems that we built. He has been instrumental in introducing a lot of ideas on equipment usage to the musical community.

Perhaps the most striking commercial success was the work of Walter Carlos, and as far as the public was concerned, the success of Switched-on Bach just came out of nowhere, completely unexpected. I can guarantee you that the same was also true as far as the commercial music business was concerned.

For Carlos, it was one step in his professional development. He had studied electronic music at quite some length at the Columbia-Princeton Electronic Music Center, and did his stretch as a professional recording engineer, which accounts for his incredible control over mixing console and tape recorder. He purchased the first voltage controlled modules from us several years before Switched-on Bach came out. He built up his system very slowly, and knew exactly what he wanted every step along the way. He was another of these people like Deutsch who had an instant affinity for the instrument. I can remember Carlos watching as I unpacked the first of his modules. He was already making the gestures with his hands to produce certain types of sounds even before he laid his hands on the knobs. Sure enough, when his instrument was plugged in. his initial gestures were the correct ones. He had that much of an understanding of the basic ideas of voltage control and modular organization.

Finally, Carlos and Benjamin Folkman went to work on Switched-on Bach working evenings and weekends in what by today's standards was a rather modest studio. I got to hear the work in progress quite a few times, and I can honestly say that on every occasion I heard a degree of control beyond anything I had heard from anyone else. I'm not talking about the type of music, or the artistic approach, but the way he controlled the instrument.

The conventional wisdom among commercial music producers at that time was that sure you could make cute sounds, and use it for radio and TV commercial sound effects, but you had better forget about trying to make "regular music" with it. There was something about an instrument with patch cords hanging down from it, and all those knobs with the strange words on them, that was basically inhuman and unmusical. For myself, not knowing any better or seeing any evidence to the contrary between 1964 and 1966, I suspected that perhaps they were right.

I was deeply moved by the results that Carlos was coming up with. At the AES convention In October 1968, about a month before Carlos' record was released, I gave a paper describing different types of composition studio (computer studio, multi-track studio, sequencer oriented studio, and a couple of others). The one musical example I played was a section of the third movement of the Third Brandenburg Concerto that Carlos had just finished, as an example of the very best that I had heard to come out of a multi-track studio. Here was this audience of recording engineers, producers, equipment designers, manufacturers: a highly professional and highly cynical bunch. These guys had lived their lives exposed to the attempted sensations that very often permeates commercial music, and they weren't about to get excited over anything. We played Carlos' tape and as it was played, I walked to the back of the audience. There was a rather hush silence in the audience as the tape was being played. At the end, there was a standing ovation - the most incredible thing I ever saw. As I walked back to the platform to call Walter Carlos up, I swear I could see tears In some of these guy's eyes. That's the nature of the major successes: the fact that a musician took this stuff that we had made and showed it to be so very useful musically.

Initially, the limitations and fallings were in our command over the technology. When we began back in 1963 and 1964, very little was known about the logarithmic characteristics of junction diodes, and nobody knew if It was possible to get 6, 8, or 10 octaves of exponential behavior from them. At that time, silicon planar epitaxial transistors were just coming Into use, and It turns out that these had base-to-emitter voltage-current characteristics that were accurate logarithmically beyond anything anybody had tried. So in the early years, it may have been a failure of sorts that we did not recognize the need on the part of a lot of musicians for highly stable and accurate relationship between pitch and control voltage. By the time Walter Carlos came out with Switched-on Bach, we knew it perfectly well. In retrospect, we can see that the first composers I worked with were avant garde composers who by choice ignored quantative pitch relationships as compositional elements.

Another shortcoming was the failure to achieve the proper degree of complexity, and to this day, we are still living with this. This brings to mind a lecture I once heard by Peter Kubelka. Kubelka Is an Austrian filmmaker, an incredible intelligent and cultured guy. It turns out that his hobby is cooking. Someone once asked him if he thought that cooking was an art form. He said that of course cooking is an art form as It has complexity and dynamics. I think this is true of any medium of artistic expression. If It Is capable of complexity and capable of dynamics, then it is a valid medium. With the first voltage controlled elements that we made, we certainly realized the potential for dynamics. The potential for complexity is still to be satisfactorily realized.

As far as musical failures go, I guess we could pin that on musicians who saw Walter Carlos' success and assumed, without cause, that Carlos' success rose from the medium rather than out of his own command over it. Very shortly after Carlos' success, there were dozens of synthesizer records (in those days, they were called Moog records), and some of them would have to be considered failures.

BH: In what ways have the advances in electronics altered the development of the voltage control techniques?

RM: I mentioned the introduction of planar epitaxial silicon transistors and that was the single most important thing that got us going. The device works over a very wide current range, has highly predictable dynamic characteristics as a function of standing current, it's quiet, and it's cheap. It was even cheap in 1964. I remember buying 2N2926's which were loose spec, audio transistors for 30¢ to 40¢.

The VCA's and VCO's that I first built for Herb Deutsch were built from 2N2926 transistors. They could not have been built from earlier silicon transistors, germanium transistors, and certainly not with vacuum tubes. Our voltage-controlled low-pass filter which has to be considered a fairly substantial development, also relies on the very predictable characteristics of these transistors.

Then of course, the advent of integrated circuits has given our technology a tremendous boost. Our first VCO's and VCA's used operational amplifier circuits that had discrete components in them, and cost a lot of money. They had five transistors, about a dozen resistors, and a couple of compensating capacitors. Now the whole thing is done with a single component and costs us less than half a dollar. The relationship between performance and price is of key Importance because musicians are usually not in a position to spend unlimited money on hardware. So the introduction of IC's has enabled us to produce great complexity compared with what we were capable of in 1964 and at rather modest prices.

BH: Over the last 10 years, what changes have you seen in the acceptance of electronic music by a) Avant Garde musicians, b) the more conservative musicians, c) musicians concerned with popular music, and d) The general public?

RM: Avant garde musicians are not a well defined or well organized group, since they are at the edge of an area that has a lot of surface. There are composers who are concerned primarily with tone color manipulation as a compositional element, and these composers are the ones who have most enthusiastically gotten into electronic music, and you can see why. With voltage control equipment, modular equipment, and the ability to modify by more conventional electronic techniques, musicians can now systematically and rapidly change tone color over a wide range with as much precision and ease as they could change pitch and loudness with traditional instruments.

There are a lot of musicians who are still deeply into pitch structures and new types of pitch structures, who don't see the electronic medium as being important to them.

There are also people like Morton Subotnick and Suzanne Ciani who are concerned, as Cage was, with production of music as a process, where to realize your music, you would organize a very complex system. The Buchla modular system was designed with this sort of composer in mind more than ours was. It has a lot of capability for triggering sources in sequence, for turning on and off different sources, and for creating a very complex organization of a modular system. You can literally set up a machine that will produce an interesting sounding piece of music by itself. This sort of avant garde composition of organizing a system and then setting it in motion (usually some manipulations are performed while this is in progress as well) was something that musicians just could never do with traditional musical media.

This gives us two groups of avant garde composers who embraced the electronic medium, and one group that saw no significance in it.

Among more conservative musicians, there has been an awful lot of opposition, and I think it has been specious. They don't like the idea of it, and they also insist that their ideas are right. So they feel they are right about the medium not being any good. Its typical of a group of people like this to assume that because a musical instrument is made out of wood and is 300 years old, it's automatically more musical than something one year old that is made of wires and transistors, Of course that's ridiculous because there was a time when shaping wood, stringing catgut, and producing a long lasting varnish was high technology, and there is nothing inherently musical about a combination of things like that. It’s only the way the musician uses it. It's exactly the same thing with our equipment.

The musicians involved with pop music are generally a more open minded group than the so called more conservative musicians. They are open minded not to true musical value, but to commercial success. Of course, Walter Carlos broke that open with an honest-to-God commercial success of a serious work of musical art. The pop musicians watched the scene very carefully in the year or two after Switched-on Bach, and came to the conclusion that maybe the synthesizer wasn't all It was cracked up to be because nobody else seemed to be able to achieve the same success Carlos had. Of course, this sort of thinking is ridiculous too.

These times were very trying to the commercial music business because recession was about to begin, the great days of the Beatles and whatnot were definitely undergoing a transition, and things were in a state of flux. Through all of that, quite a few musicians stuck to the medium, mastered the synthesizer enough to produce pop music which would be accepted by the listening public on its own terms. These people are now well known as pioneers of the pop idiom.

Of course we can't forget the performers, especially Keith Emerson, who in his own way had an Insight as rare as that which Herb Deutsch and Walter Carlos had. He bought a synthesizer and worked with it at great length and with great frustration until he finally mastered it enough to take it on stage. The result is that today, five years after he bought his Instrument, he is the virtuoso pop synthesizer performer as far as I'm concerned.

As far as the general public goes, I don't think that the average John Q. Public realizes what electronic music is. He still doesn’t realize that 60% of everything he hears on TV commercials is electronic music, and that most of the sound logos and background music for TV, and more and more for film, are electronic music. Just about every rock record is in the most general sense, electronic music (it couldn't exist without electronics).

Electronic music means different things to different segments of the public, and if any one person in the "general public" has had a favorable listening experience, then he likes electronic music. If he has had an unfavorable listening experience, then he doesn’t like electronic music.

END PART 1

AN INTERVIEW WITH ROBERT MOOG

Part 2, The Present State of the Art;

-by Bernie Hutchins

This is the second part of a three part interview. The first part appeared in EN#45, Oct. 14, 1974

BH: About four years ago, you suggested to me the possibility that synthesizers might become obsolete in a few years. Are we approaching that point or have we avoided it?

RM: Four years ago, things were in a state of flux as far as making money from synthesizers goes. Our business at that time was based on modular equipment, and for a brief period, people stopped buying modular equipment, as the music business itself was badly depressed, and universities were short of funds. This fact may have influenced my comments on possible obsolescence. Taking a longer perspective, what happened was that the main use of electronic synthesizers switched from modular equipment in conjunction with tape recorders, to smaller instruments in conjunction with live performance.

Today, I would have to say that the basic musical resources that we associate with synthesizers are not obsolete, and may never become obsolete since these basic resources can be utilized to a much greater extent than they now are through the generation of more complex control signals. For instance, in a typical synthesizer sound today, one would combine an oscillator or two, feed the combination through a single filter which is swept with a very simple contour, and then through a VCA which is swept with an even simpler contour. By increasing the complexity of these contours and the number of oscillators and filters, and by using additional modifiers such as frequency shifters, Walsh function generators, of that sort of thing, we will be able to produce musical material of arbitrary complexity. Then the question comes up: How do you get a handle on it? This leads to the need for more work on controllers.

BH; Do we know what it is about conventional musical instruments that make them musically useful? What are the important factors as we see them today?

RM: Yes, I think we know what the factors are - but only in the most general terms. Our hearing mechanism is extremely complex, and is capable of resolution of incredible detail, especially in time. Traditional musical instruments are successful to the extent that they accommodate the strong points of our hearing mechanism, and to the extent that they can be controlled by musicians. The two most general things that we get back to over and over again are the complexity of the sound and the control of this complexity that the musician has.

Take for example the violin, a basically simple structure. The sound changes in time in response to the musician's actions, and this relationship is extremely complex. The musician can change the way he holds the bow and the force on it and in this way produces an initial driving waveform that travels through the bridge and into the violin box. This driving vibration can vary quite a bit in harmonic content. Next, the characteristics of the box itself are complex, and can be simulated by no fewer than 30 to 40 two-pole filters. The fingerboard provides a means of intimate contact with the pitch control of four tones simultaneously. These are the specific factors that are important in the violin.

The same thing is true of the piano, another very successful instrument. The sound is rich and fat and complex, and there is no simple way of duplicating it electronically. We are closer to duplicating a violin sound electronically that we are a piano sound. In the piano, the control means is really superb. Through tactile feedback, the musician is able to accurately control the total amount of energy imparted into a string over a wide dynamic range, and at a total rate exceeding 20 notes per second for a virtuoso pianist. That's what you call control.

Contrast this with the sort of idealizing that some people interested in the brain wave production of music are into. These people describe how nice it would be to not have any mechanical instruments at all, but to simply have brain waves control the production of sound directly. Then you have to realize that the signals you get out of the brain through such conventional paths as the top of the skull have a maximum bandwidth of 10, 20, maybe 30 cycles a second. When you contrast the rate of information flow from a pianist with that from brainwaves, you then realize that the piano is a tool for extracting or processing an enormous amount of information that comes from the performer. I think this is true of every successful musical instrument. When you discount cultural transient effects such as the novelty of a sound catching the public's imagination for a brief period of time, you see that these important factors are going to have to be a part of electronic instruments if the medium is to grow.

BH: Do you feel there has been enough research of a scientific nature done on traditional musical instruments?

RM: People such as Carleen Hutchins and Arthur Benade are going back to traditional instruments that we know are successful, and over a lifetime of study, research, and listening are pinpointing these musically important factors. They are analyzing instruments that already exist. I think that designing new instruments is still intuitive to a great extent. We can use rational analysis to arrive at the best solution to a circuit problem, but determining what the circuit should do in the first place is still a matter of feeling what is right, and then trying to do it. I don't think there is any way of scientifically determining what is right for musicians.

BH: What are the major things that we have learned from the voltage-control technique (or from other investigations), concerning the factors that make electronically produced sounds acceptable as musical sounds.

RM: When people use the term "electronic sound" in a derogatory sense, they usually mean a sound that has a very static nature. If you turn a sine generator on and then turn it off later, that's a very static sound. Or, if you frequency modulate one sine wave with another, that's also an electronic sound. They're all right as musical sounds as long as they are short sounds, or are not the only musical sounds used within a musical composition. This is simply because the ear gets tired of listening to very simple sounds. It's the same as though we had to stare at a blank wall all day - our senses have to be stimulated enough to keep things changing between our eyes and ears on the one hand, and our brain on the other hand. When things don't change, our sensory organs get bored and tired, and the sensation is that of unpleasantness. Sounds that are not static include those that have varying loudness - that is, they have an attack time and a decay time associated with them. They also have a variable set of overtones, perhaps one or more filter formants. Their frequency varies in some interesting way, and whatever other specific parameters define the sound are also time variant.

This is not to say that random variation of all parameters will automatically produce more desirable sounds, because randomness in itself is a quality that the ear very quickly perceives. It's devastating to realize how quickly we get bored with the random output of some sound making process compared with how long it would take for all our clever instruments, computer programs, etc. to detect that the process is in fact random.

So I guess the general answer to this question is that first of all, the sounds have to move in ways that are comfortable to our hearing mechanism. Thus refers to the sounds themselves, not the musical material that results from putting the sounds together.

BH: Has anyone found it makes much difference which waveform you use? It seems to me that too much emphasis has been put on the engineering of precise waveshapes.

RM: Oh, you're absolutely right. In this business one sees a huge difference between people who think about things and the people who do things. People who think about things like the idea of an infinite number of waveforms. The fact is that a couple of waveforms when skillfully handled cover a lot of ground. No less an authority than Walter Carlos states that all he needs is a waveform with small harmonic content (such as the triangle) and one or two of high harmonic content such as the saw or rectangle. When you vary the rectangular waveform width, you get a sort of variation that is different from anything you can do by treating the sound after the waveform is shaped, so in that sense, it is nice to have voltage variable rectangular width.

I think that having a variety of waveforms is generally useful only when you have associated a variety of ways of changing the waveforms. There is a very nice program that Chowning has worked out which Buchla has incorporated in his "Music Easel" where you perform linear frequency modulation of one oscillator by another, and this gives rise to a new class of sounds, but it's the variation rather that the waveform that is important.

BH: In light of the advances in electronics, and the subsequent development of electronic music systems of great complexity, are there any electronic music design experiments that haven't been done in the past for lack of time or resources that could and should be done at this time?

RM: The way things of this type usually work these days is that some people such as those using Music V on a computer will set up a program to do an interesting experiment that can't be done with hardware. The computer music people were the first to do linear frequency modulation and other things such as pitch-changing illusions where overtone strengths are varied to give the impression of a continually rising or falling tone. Another experiment that was done some time ago was to put a separate and very complex envelope on each overtone. I think that in this respect, interesting experiments do not depend too much on available hardware, since these can be done by computer without going to the trouble of creating a lot of hardware and not knowing if it will be useful when finished.

I think that experiments in instrument design that make sense today are those concerned with control devices - working out which types of interface between musicians and electronics make the most sense.

End of Part 2

AN INTERVIEW WITH ROBERT MOOG

Part 3, Trends for the Future;

-by Bernie Hutchins

This is the third and final part of this interview. The first part appeared in EN#45, Oct 14, 1974, and the second part in EN#47 , Dec. 15, 1974.

BH: Most electronic music engineers seem to feel that the future will see a great increase in the use of digital devices. Do you agree?

RM: In general, yes - but the question is "How much?" as a function of "When?" Computer generated music by direct digital synthesis is the ultimate, but it takes a large computer. In systems that are in use today, control is via some form of conventional data entry like punched paper cards which contain numbers representing the parameters of the sound. To do the same sort of thing in real time takes an even larger computer.

I think the next important step is going to be computer control of analog synthesizers. This sort of thing makes a lot of sense because a small computer can produce a large number of slowly moving control signals; just the thing you use to control an analog synthesizer. A control signal that determines pitch has to be accurate to 8 or 10 bits, but most of the controls such as attack time, filter Q, waveform, etc. need to be accurate to only 6 bits or so. Most of these parameters are neither high accuracy nor fast moving parameters. Their control is within the capabilities of many desk-top computers, and some computers designed for process control. We are currently looking at the Texas Instruments 960 which is designed for a load of slow moving analog outputs.

From a musical point of view, it is very desirable to have an instrument where you can get the sound you want and then just push a button to store the sound in terms of its parameters and have it available for later recall. Right now, this can't be done with analog systems. That's just the beginning of what you can do with a moderate sized computer connected to accurate and stable analog components.

Microprocessors will become very useful for electronic music. But once again, for generating complicated control voltages. I can see, even today, a synthesizer that has no analog control voltage generators except for the keyboard or other controller. Envelope generators, modulating voltages, and sample-and-hold circuits would be inside the microprocessor. It might be cheaper too. For all I know, it might be competitive now, but there is a lot of engineering that has to be done first.

BH: What about special purpose digital devices?

RM: There is a class of digital waveform producing and modifying devices which are hard wired to do certain things, and which will probably be used in the future. For example, a digital ramp generator could be formed from a digital counter that produces a series of numbers that increase by a number that you can program in. If this is reset at the top; you get a sawtooth oscillator. If you have an accurate clock, and if you have control over the number that is the increment, then you have a very accurate way of controlling pitch. It's also possible with the appropriate buffers and programming to take a digital sawtooth generator like this and generate many digital waveforms at one time by multiplexing the generator and storing the results for one waveform while values for the other ramps are being determined. This sort of hardware already exists at Bell Labs.

Digital filters are attractive, and digital multiplication to get enveloping is also possible. It may be that some semiconductor manufacturer will decide to tool up to make a piece of committed digital hardware to do the sort of jobs that analog sound generating and modifying circuits are doing now.

Of the digital applications that I have discussed above, I would rank them in order of importance as follows : Computer control of analog synthesizers is most important, with similar control by microprocessors right behind that. Specific digital devices would be third. Direct digital synthesis of the entire sound will require more generations of digital computers.

BH: Are the type of sequencers that are programmed directly by recording information off the keyboard useful?

RM: A recording sequencer makes a lot of sense for certain applications where long sequences must be entered and stored. For this sort of application, they are much more useful than other types of sequencers. However, you eventually have to compare them to small desk-top computers which can do the same jobs. Right now the computer costs three to ten times as much, but is much more versatile than the recording sequencer that only does one job.

BH: What about programmed patching systems?

RM: It turns out that programmed patching is easy, but not all that useful. If you want a certain sound or a certain operation, the most critical things are not the patch but the control settings. In practice, you might spend five minutes putting in all the patch cords, and the rest of the afternoon setting controls. It would be much more important to be able to store and recall the control settings than the patching scheme. The control settings determine 90% of the sound.

BH: What about the musician-circuit interface: the controller? Where would you rank this problem in order of importance?

RM: Frankly, I would rank this problem number one. What we have right now in the way of generators and modifiers is fairly mature, is basic, and is economical. It's everything it should be as part of the musical instrument technology. However, even in the fanciest synthesizers, we are still using standard organ keyboards which were designed for a completely different sort of instrument. Other types of manual controllers are still incredibly crude, at least when compared to the amount of control a guitarist has for example.

Manual control is the most important thing. I attach little general importance to the idea of using the brain itself as a generator of controlling waveforms. The fingers are probably the most important - what else do we have that can control an instrument as well? The breath, the feet, the voice; all these can be used as controllers, but the hands are the most important terminals on our body for getting information out fast.

We are interested in touch sensitive keyboards, and we are just beginning to find out how keyboards should feel - what the electro-mechanical response should be, and what the pure mechanical response between the players hands and the keys should be. You can analyze a piano action and try to plot force versus velocity versus distance down, but the relationships among these three parameters are complicated and non-linear as well. Undoubtedly, through further development, we will get to control devices as complex as the piano keyboard for use with electronic instruments. This is not saying that these will replace piano keyboards, or even be keyboards, but they will fit nicely between the capabilities of one's hands and the capabilities of your ears.

BH: What about the sort of controller used by Max Mathews in his electronic violin-the sort of thing that uses a mechanical bow and strings with a magnetic pickup?

RM: There are a lot of instruments that start with acoustically vibrating elements and before the vibrations get out into the air, they are fed through electronic circuits that process them. Why not? I don't think that we should be purists about this. We do not have to stick strictly to numbers and voltages, and avoid anything that seems to involve the acoustical generation of sound. The fact is that the strings and bow of a violin are a very efficient system for transferring information from the fingers to a device that can get the information out. One of Mathews' goals was to make a fat violin sound that comes out of a loudspeaker, and he has done that very well, but that's just the beginning. You don't have to use a violin simulating formant filter with this type of controller. Any sort of processing can be used.

BH: If we assume that our goal is to make "acceptable musical material," should we assume that our electronic instruments should produce some essential characteristic that is possessed by traditional instruments, or should we be looking for new ways of using the electronic devices we have?

RM: Right away we have to acknowledge that what you mean by "acceptable musical material" is a function of whom you ask and when you ask him. Things become acceptable over a long period of time. Synthesizer sounds have become popular over about half a dozen years, but this may not have been possible fifty years ago when most people were not conditioned to listening to sounds over loudspeakers. I don't think that any of us can predict what will become acceptable musical material in the future, but whatever it is, is will develop slowly and in gradual steps.

I think Walter Carlos has the right approach. He says that, sure he knows how to approach the synthesis of a trumpet sound and a stringed instrument sound, but his ability to do this is important only in that it gives him a place to start. From then on, it is an exploration of sounds that are similar. As he works with them they begin to assume a certain musical importance that can be built into his

People who insist that today's electronic medium can't be related to the acoustical medium just don't know how musical material develops. I think that we are very much in the mainstream, just as listeners were 200 years ago when the transition from harpsichord to piano was being made. Or, going even further back, consider the transition from the very quiet and subtle tone colors of the Renaissance instruments to the louder, brighter sounds of the classical orchestra. If you listen carefully to a group of Renaissance instruments you will discover that each instrument produces interesting, but quiet sounds. Ensemble playing with these instruments tends to be used for the sort of music that is fairly constant in dynamics. For this reason, the assumption is often made that these instruments are crude, unrefined, and not highly developed. In actuality, it was just that musical tastes have changed quite a bit. A loud trumpet would be as much out of place playing Telemann as a cornetto would be in Tchaikowski.

Electronic sound generation provides a radically new means of producing sounds. However, the types of musical material that will become important will be determined by musicians and listeners rather than by us instrument designers. The most we can do is to keep these new materials available, not in the sense of setting on the table ready to go, but of being easily manipulated by musicians in terms that they understand right now.

We can also interpret your question as asking if we should fit the music to the electronics, or the electronics to the music. Both approaches will be fruitful. If you adapt electronics to existing music, as most commercially available synthesizers do, then there are bound to be some capabilities that the instruments have that were not in the mind of the designer, which the musician will explore. On the other hand, on large systems, especially modular systems, it is always going to be possible to do things that are brand new. I think that in studios that are designed primarily for experimentation, (in schools or among private composers who consider themselves to be artists), the system should be kept as general as possible. From the beginning, we have tried to do this, and then hope that these experimentally minded musicians would come up with music that is listenable and esthetically valid. Looking for new ways of using things is something a musician does naturally. When a designer builds a system, he has to explain the basic logic to the musician. The explanation is generally oriented toward the production of conventional types of music, because nine-tenths of our customers use their synthesizers to make music that sells, and this is conventional music for the most part. However, none of this prevents the musician from using the same hardware in new ways. Many musicians do work by trial and error, and do use patches that may be contrary to the logic the designer intended. Some extremely complex sounds are generated in this manner. Thus, it is important for the instrument designer to build the hardware so that nothing the musician does will actually destroy the instrument.

BH: In the synthesizer field, we have seen a strong trend toward the small portable synthesizer. Also, advances in microelectronics make it easy to suppose that before long the circuitry will take up very little space, and we will be left to consider how best to use the room for controls. How much capability do you think can be fitted into a suitcase sized unit, and with what mode of user control?

RM: Do you know that many years ago Leopold Stakowski postulated an orchestra of electronic instruments that would exist some time in the future? He said specifically that all the instruments would be the size and shape of a typewriter. How did he know?

The big question in my mind right now concerns whether or not it is going to be natural for a musician to encode his commands to an instrument in a digital form. The only way you can work with an instrument as small as a typewriter is to have some small keyboard such as a computer input terminal and have a code for everything you want to do. For example, a cutoff frequency could be set for 1.2 KHz, and then moved to 1.3 KHz, to 1.4 KHz, etc. What this means as that an obvious physical gesture such as turning a knob may be replaced by a series of keystrokes, or by punching in a set of parameters that specify a change to be made automatically. I really wonder if it is natural and efficient for a musician to do that degree of encoding.

In all conventional musical instruments, the interaction between the musician and the instrument is a physical visceral thing. A pianist doesn’t really digitize anything or encode anything. He bangs on the keys and feels the energy being transferred through his fingers to the keys and eventually the strings of the piano. It's going to be hard to get any sort of visceral feeling in a small sized, high capability instrument. There may be ways of controlling an instrument other than relying on large, visceral gestures that have a lot of tactile feedback, but right now it looks as though complexity and small size together will require a lot of encoding.

It is true that the circuits are getting smaller. The microprocessors will make another huge step in this direction. But what then? No matter how complex a circuit is inside, a knob that is one inch in diameter is a lot easier to use than one that is 3/4 inch diameter. Likewise, if you are using a keyboard, it is a lot easier to use one of normal proportions rather than a cramped version.

At the moment, we are not asked for small portable suitcase sized synthesizers except for special purpose ones. People seem to like to thrash about on their pieces of equipment, particularly in live performance where size is part of the show. It's impressive to be surrounded by a lot of equipment that is under your command.

BH: What specific lines are you and your company planning to follow?

KM: Certainly we are going to get into interfacing small process oriented computers with our analog modules. Probably the analog hardware will not have to be the more expensive modular line - the small performance stuff is sufficiently accurate and stable now. I can see live performance groups using programming devices to help them make changes fast.

Everyone asks about polyphonic instruments. My own opinion is that a polyphonic instrument is a different animal entirely from a monophonic instrument, and I have always looked at our synthesizers as monophonic. We are going to build a polyphonic instrument, and it will use what we can call "synthesizer technology." Each key will have associated with it a waveform shaping circuit that will change the waveform from sawtooth to square to narrow rectangular. Each key will have a simple VCA, a simple low-pass VCF, and a couple of simple envelope generators. One pot will control all the filter center frequencies, another pot will determine the degree of touch sensitivity of the keyboard, another will control the decay time, and so on. We will be using synthesizer technology as a means of achieving a reliable polyphonic instrument with a palette of really good fat sounds.

We can do this not because of our increased knowledge of the circuitry art, but because of the state of the integrated circuit business. So many IC manufacturers have knocked on our door asking to make custom IC's for us that we checked it out. We found that all the circuits associated with one key can be put on a single chip, except for a few capacitors that have to be external. This six octave instrument which we are now designing will sell for the price of a good organ. Still, this sort of thing is only possible where a fairly large quantity of IC's are expected to be used. A small business just beginning probably couldn't sell enough to justify a custom IC.

A third area that we are interested in is the improvement of control devices. We have a velocity sensing circuit for a digital keyboard, but as yet no product in mind to use it on. I have also developed a force sensitive design. There is already a company called Computone that is making a breath controlled synthesizer called the Lyricon. It looks like a big fat clarinet. The keys are just switches, and these are followed by a digital encoding like the standard clarinet key combinations. There is then a control output proportional to how hard you are blowing, and how hard you bite down on the mouthpiece. Wind musicians are used to controlling these parameters.

There are all sorts of possibilities, It's one thing to get a device that works, and another thing to get it proportioned so that it works smoothly and naturally to control the relevant parameters over their natural ranges.

A fourth area we are interested in is long term reliability. There are now over a dozen companies making synthesizers, and generally their advertizing thrust is oriented toward pointing out "features". In the long run, what makes an instrument useful is not something that can be demonstrated on the floor of a showroom, but how well the instrument stands up electrically and mechanically. This is the most difficult engineering problem, and one on which we have made great progress. We hope to further improve this so that the only failures that occur are the occasional component failures over which we have no control. In the final analysis, the most important factor is reliability.

I can remember that when I was still a graduate student at Cornell, Virgil Fox came for the inauguration of the new Allen organ in Statler Hall. Allen has always had the reputation for being insane about reliability standards. I, on the other hand, knew from my graduate work and my own experimenting that most of the time, things didn't work. At any rate, Virgil Fox come out, addressed the audience with a few cryptic statements, turned around, and put his hands on the organ seat. He then catapulted himself over the seat, and with not a second though he brought his hands down on the keys and - - the organ sounded. I couldn't have been more surprised because there had been no evidence that (a) the thing was even on, let alone checked out, and (b) that Fox had a thought in the world that it would be otherwise. I can still remember being completely dissolved by that. Most musicians will do something to check things out before starting to play. Fox had every confidence in his instrument. I am looking forward to the day when synthesizers will be in the same category.

BH: What progress of others have you seen that you consider useful?

RM: I've seen the Eμ Systems synthesizer. In the first place, Dave Rossum, the designer obviously started out with the idea that the most important thing is: the instrument should work all the time. It's a ruggedly built system that seem to be devoid of marginal circuitry that would cause problems for the musician using it. I really admire what Dave has done in this respect. The hardware really works, it works the way he says it does, and it should keep working because it is well made.

I have to admire what Don Buchla has done. He hasn't allowed himself to limit the complexity of his instruments to meet the demands of the so called "market place." It has been the conventional wisdom for some time that a complicated piece of electronic music equipment can't be sold off the music store floor. Buchla has chosen not to worry about this. He has a few people who represent him, but for the most part, he deals directly with musicians. As a result, I think of all the systems that are available, his can be organized in arbitrarily complex ways most easily.

Among the large commercial companies, ARP has realized more than any other the importance of user education. They have spent a lot of work and money showing people what the capabilities of the instruments are and getting them used to the idea of making music with synthesizers.

The Electrocomp synthesizers from EML, like the Eμ Systems, are ruggedly built, and their circuits work well. They are filling a need for inexpensive but reliable instruments for educational and live performance purposes.

Among people who are not actually making commercial hardware, I have to admire the Bell Labs group the most. Max Mathews has continually supported musicians who are inclined to work with electronic media. He has worked with interfaces between musicians and computers and with interfaces between computers and analog hardware. Also, the Bell Labs people have developed some very elegant programs. First there was the Music IV and later the Groove program.

End of Interview