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Mail Bag

Remember when I wrote back in 1988 about why I didn't like CDs? Well, I feel vindicated now that I've seen a number of audio engineering critiques of the medium. (I do mean the true CDs, not this new small-disc format which is apparently really tacky.) Although they lack warmth I buy them because they are a lot easier to play . . . than LPs. But at heart I'm still the Luddite.

John L. Falk, Princeton, New Jersey

CDs are here to stay. You may quote me. For months now I've been transferring my modest collection of about 1,600 jazz LPs (from the 1920s to the 1980s) onto cassettes before passing them on to a successful jazz record auctioneer. Strange as it seems (to me at any rate) there are die-hard collectors out there willing to pay big prices for jazz LPs. I believe in a few years you won't be able to give them away.

Paul Copeland, Seaforth, Ontario

Re CDs

I am replacing my LPs with CDs. I like the sound better. Caution: do not unload your *Miles Ahead* LP. The CD contains some alternate takes that aren't as good as the originals.

"Warm" and "cold" are subjective responses. Not only are musical tastes individual, so is the very process of hearing. Few persons hear with the same efficiency all the way up the audio spectrum. Women are more sensitive to high frequencies than men. As we grow older, we lose the sensitivity to highs. As one recording engineer once put it, "Each of us has a built-in scratch filter, and it improves with age."

Capitol recently reissued some of the lovely Paul Weston "mood music" material on a CD. Paul was startled by the sound. He told me, "I heard things that I hadn't heard since the original record dates."

I noticed the same thing with the Miles Davis-Gil Evans *Sketches of Spain* album, particularly in the percussion. Grover Sales tells me that though he has lived with the *Birth of the Cool* material since the late 1940s, both in its 78 rpm incarnation and then the LP, he heard on the CD all sorts of things he had never noticed before, and particularly the linear details of what Lee Konitz and Gerry Mulligan were doing and the tuba and French horn sounds.

I would be curious to know what various musicians think of their CD reissues.

Just about everything I have heard said about CDs was said at first of LPs and later stereo recordings. Stan Kenton didn't like stereo. Artie Shaw doesn't like it either, but then he has been partly deaf in one ear since a World War II injury and can't really hear it anyway.

The CD assuredly is here to stay, if only because manufacturers have been phasing out the LP for some time and many copmpanies don't even make them. The CD has been a boon in that since it costs a record company almost nothing to make, the labels have been flooding the market with reissues of material that has been unavailable for decades.

In view of all this, I thought you might want to know a little more about how computers and digital recording and CDs work. Hence the following piece. If you have as little ability at mathematics as I do, you may have to re-read some paragraphs. But the information the two men in question offered fascinated me, and I hope it will interest you too.

Table Talk

For me to ask the chairman of the Computer Sciences Department of the University of California at Santa Barbara to explain base-two arithmetic was improbable. That he should have the patience to do it was even more improbable.

It came about because John Bruno once played jazz piano and retains his passion for the music. He has been staging salon jazz recitals at his home in Santa Barbara and invited me to attend one (by Alan Broadbent). That's how I met him.

It is hard to explain complex matters in clear and simple fashion. John Bruno does it well. Perhaps it's his years of teaching. Perhaps it's the love of music. Perhaps it is a gift.

Computers, as one can hardly escape noticing, are revolutionizing our lives in ways that could not have been imagined, except by specialists, even twenty years ago. It will soon be possible through the use of new imaging techniques for a surgeon to perform complicated operations on a patient hundreds or thousands of miles away. It is already possible to make diagnoses at such distances and direct another surgeon in an operation.

The computer is profoundly affecting music, and, again, in ways that one could not have foreseen. I am not enamored of electronic sound per se. It still does not have that precious quality of the human. As Roger Kellaway, who is skilled in the use of synthesizers, said of such music, "It doesn't breathe."

And it doesn't. A few years back the drum machine, notorious for its mechanical steadiness, was modified by the addition of a gadget that introduced a subtle irregularity. It was called the Humanizer. I found that wryly funny.

Two or three years ago, Conte Candoli was talking to friends after a recording date using a large orchestra. As he was quoted to me, Conte said, "It was great, man. Full brass section, saxes, strings, rhythm. Everything. We must have put two synthesizer players out of work."

The synthesizer has caused unemployment among musicians, which problem vexes the American Federation of Musicians. Alas, there's nothing much the union can do. I may hate all those electronic scores for films — though I was told *Miami Vice* was a good show, I could not watch it because I found the music loathsome. But an entire generation of producers, directors, actors, and others has grown up hearing only electronic music. Though there has recently been a trend toward "real" music in film scores, the synthesizer is here to stay.

A synthesizer, of course, is a computer, though one dedicated to a single task, making alterable sounds.

But I have had only the murkiest understanding of how computers work. I have bought books on the subject with titles like *Computers Made Easy, Computers for Dummies*. Written by computer programmers, they are not in English or for that matter any language known to man. When the powers of communication of their authors reach their limits, the books resort to diagrams that are not at all accurate representations of how the damn things actually work.

And so, with music as our meeting ground, I asked John Bruno some questions which, with patience, he answered. The conversation occurred over lunch on the balcony of the Soule Golf Club in Ojai, overlooking the greens and the handsome green mountain ridge beyond it. John was born on Armistice Day in 1940 — November 11. He looks thirty-eight or forty years old. He is tall, trim (probably from playing squash), and has tightly curled dark hair only lightly dusted with silver, is notably handsome, and smiles quickly and often. He speaks beautifully in a resonant voice with slightly dentalized t's and d's that instantly identify him as being from New York City or its environs, and probably of Italian origin. I do not know what causes that speech habit, but Frank Sinatra and Tony Bennett both have it, as did the late Richard Conte. Even Boston Italians don't have it, and John's father was from Boston.

Older readers will remember stylized glamour photos of movie stars inscribed *Bruno of Hollywood*. There were in reality three Brunos of Hollywood. They were brothers. John's father, also named John Bruno, was one of them. The others were Nick and Tony. They were all born in Boston of parents born in Italy. John's mother was born in New York City, also of parents born in Italy. Though his father came from a large family, John has only one brother, who lives in Long Island.

"Tony was the first photographer," John said. "He went to Los Angeles. I think he was an extra in movies, and he did photography. He built some kind of reputation in Hollywood, then went back to Manhattan and started the studio in Carnegie Hall. He invited his two brothers to come into the business with him. They had a virtual assembly line for prints. All done by hand. My father probably touched every print that came out of that studio. I have a book that they put out."

"Where are their archives?" I asked. "Where are their negs?"

"I don't know," John said. "And I need to find out. They sold the business to another photographer, and I don't know whether the archives went with it."

I asked John about his education.

"I studied music for about a year at Queens College," he said. "I quit and went to work for a couple of years with National Cash Register Company, which was among the first developers of computers. I got the idea that I didn't want to do what I was doing. I wanted to learn about this stuff. It wasn't so much computers as electrical engineering that attracted me. I went back to school, City College of New York. I did a bachelor's there, then a master's, then a PhD.

"In 1968 I got a job at Princeton University in what was called the Electrical Engineering and Computer Science Department, EECS. They wanted to start teaching computer science. So I started learning it. I kind of got in at the beginning, a[illegible] started learning on my own. I've been doing it ever since."

I had read that our little three-dollar pocket calculators can do more than the early massive computers that filled entire rooms. Is it true?

"Yes it is," John said. "The first computers, machines like Eniac and Maniac, were built on a technology that involved vacuum tubes and components that were very large. Computers today are just the opposite — based on a technology using microscopic components. On a computer chip less than half an inch on a side, you can get millions of devices or more. They were lucky to get ten thousand devices in a room. Vacuum tubes are hot, and they fail much more often than these highly integrated circuits which consist of basically only one component with a million of switches on it instead of ten thousand components connected together. The amount of air conditioning needed in those days to cool the equipment was considerable.

"The war effort stimulated the development of computers."

"It's my understanding," I said, "that a vacuum tube functioned essentially as an on-off switch, allowing current [illegible] flow through or shutting it off."

"That's right. That's not all vacuum tubes would do, but that's how they were used in computers."

I was aware that computers operate on binary mathematics, or base-two. I had heard that children grasp the principle quickly and easily, which only convinced me that I could never understand it. But if I were ever going to grasp the rudiments of how our computers — and synthesizers and sequencers and all the new communications technology — work, I would have to come to terms with it.

Two arithmetical systems are in common use in our society. One is the dodecophonic, measurement by dozens. The other is the metric system, adopted in France in 1791 on the recommendation of the Academy of Science. It was adopted by most other nations by international treaty in 1875, with the holdouts being England and its colonies, and its great former colony, the United States. England persisted in its bizarre system of ounces, pounds, stone, tonsimilarly, pints, quarts, gallons, inches, feet, yards, rods, miles, nautical miles, knots per hour, hapence, pence, farthings, shillings, pounds, and crowns — some of them the legacy of Roman legions.

The metric system is based on the circumference of the earth, with the gram defined as the weight of pure water at its temperature of maximum density, which is 4 degrees centigrade. Thus a liter of water in theory weights one kilogram, kilo being the Greek prefix for "thousand". (Actually, it is difficult to measure water that precisely; but the basic system holds.) The metric system is completely logical, with everything — temperature, weight, distance, money — exquisitely interchangeable, and most operations being accomplished merely by moving the decimal point, something we do unconsciously when we refer to a hundred cents as $1.00. When you are driving in other countries, you can run the numbers easily in your head, dividing the distance you are about to travel by the number of liters of gasoline you're going to need into the amount of money it's going to cost you. The system fails in only one area, time; and it would not have failed even there had the day been divided into two periods of ten hours, each of them divided into a hundred minutes. Instead we have clung to a system of two dozen hours.

Because of its simplicity, the metric system is beloved of scientists and engineers. Even our pocket calculators operate not in fractions but in decimals. The United States is the last holdout, although you can buy metric tools in your local automotive supply house and all scientific work is done in the metric system. Even the American military uses the metric system. Full adoption of the system saves immense amounts in educational funds, for children can learn it in days, if not hours, whereas they labor long to learn by tedious rote the ponderous system bequeathed to America by England. Even England has surrendered to the logic of the decimal system. Canadians complained mightily when the government by autocratic fiat imposed the metric system. Now, only a few years later, Canadians under, say, thirty don't know what you mean if you talk about pounds, quarts, gallons, inches, feet, yards, and miles.

"Well," John said, after we had been discussing some of this history, "if you can have a system based on 12 and a system based on 10, then you can see that binary is a system based on 2. It's natural that we would take this direction to represent information.

"It goes back to what a switch does, allowing current to flow or not flow. The switch can be in open or closed position. On or off, like a light switch on your wall. That's it. The base-two system comes into it because the way computers represent information is based on switches, things that can be in two states.

"A switch can only be on or off. But if I have two of them, there are four possibilities. Both off, both on, one off the other on, one on and the other off. Then you get the idea, 'Well, if I had three of these switches side by side, I can have more patterns.' That's the natural beginning of the whole thing.

"It has long been well-known that you could use two as the base of your number system. If you use two as the base, you need only two digits to represent your information. And the digits we chose to use are zero and one. Similarly, when you have 10 as the base, you use the visual symbols 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. When you have 2 as the base, then zero and one are the primariy visual symbols . . . "

"Meaning off and on," I said.

"Sure," John said. "But numbers are not the only things computers represent. Computers using these patterns can also represent character information, like the symbols A and B as we know them, or the digit zero or the digit nine. It is all a matter of conventions.

"We are already teaching kids how to represent numbers in what they call base-two. If you write the digit zero, it means zero, if you write the digit 1, it means one.

"Now how to do you represent two? Two is represented by a 1 followed by a 0. Three is a one followed by a one, 11. Four is a one followed two zeroes, 100."

"And that visual symbol," I said, "does not represent a hundred, it represents four."

The mist in my mind began to clear.

"That's right. Five is 101. Six is 110. It's just like counting using the decimal notation, which is base-ten, except that this is base-two. In the decimal system, what do we do after we get to 9 and run out of symbols? We use one and zero. How do we write eleven? The one remains fixed, and we change the zero to one. Continuing this way we get to 19. To get to 20, we change the 1 to a 2, and set the 9 back to 0 and continue.

"It's the same idea in base-two, except that instead of having ten special symbols, you have only two.

"Now, that's how internally the machines represent numbers, in patterns of zeroes and ones where each pattern represents a number.

"A decimal system is base-ten, a dozen system is a base-twelve. There are other systems used in computers. There is hexadecimal, or base-sixteen. There is octal, which is base-eight. IBM has focused mainly on hexadecimal in its mainframe systems. It gets pretty laborious to represent a pattern 32 bits long in binary. I need a shorthand. Octal is a shorthand. Each octal digit represents three bits. Two hexademical digits can represent a byte.

"A bit is a base-two digit, a 0 or a 1. It's one of these switches, which can be in one of two positions, on or off. A byte is eight bits, arranged side by side. It's like a wall having eight switches. Eight became standard. It's a convention.

"It's also a power of 2, 2 times 2 times 2, or 2 cubed.

"Now, if we write 101, it doesn't have to represent a number. We could associate that pattern with a color. We could have a whole system whereby these patterns represent colors. Or we could have 101 represent letter A in the alphabet, and another represent letter B. And so on. If you look it up in a manual, it will tell you what patterns represent each letter. You need 52 such symbols to represent upper and lower case letters, plus the digits and punctuation marks. Then you can get fancy with italics and bold face and even different fonts.

"Now, for a computer to be useful, it has to be able to take two patterns and combine them in some way to form another pattern that represents something as well. So let's suppose the first two patterns represent two numbers. If I have an electrical circuit that produces another pattern that is the sum of the first two patterns, then I have a computer that does arithmetic. That's how your pocket calculator works.

"It depends on the machine's ability to take patterns and make new patterns in such a way that it makes sense to us. If the patterns are numbers, the pattern it gets as a result is also a number. If you assign letters to the patterns, you can write prose or even poetry on a computer."

"And," I said, "store huge amounts of information in very little space. An entire book can be stored on a little disc just over three inches wide that you can carry in your shirt pocket. Hemingway once lost an entire novel. When I travel, I carry copies of all my work in progress in my briefcase. And of course the computer can represent music. Richard Ferland, who teaches at the University of Montreal, has developed an entire program that will write arrangements. They aren't necessarily great, but they are not wrong. And of course you can interfere with them on the keyboard — I suppose interface is the new word — and add interesting material. It contains a huge fake book. You can pull up a standard tune with correct changes. You can then ask for the alternative changes, and it will give you all the possibilities. You can then tell it to orchestrate for saxes, and it will do it in the correct registers. If you want to use brass, it will do it, all of it correct. You can write in concert and get the parts in transposition. If you want block voicings, you get them. If you tell it to write open voicings, it does it, and correctly. You can play your arrangement back through any electronic keyboard to see if you like it, and if you do, you can have it print out the music you've written."

John mentioned the Disklavier piano produced by Yamaha, which can perfectly reproduce a performance; the information is stored on a floppy disc. I've seen these machines at work in the store and studio of David Abell in Los Angeles.

David might be described as piano supplier to the stars — piano stars, that is. He sells pianos, and he supplies them for concerts by pianists, jazz and classical pianists alike. He is the major outlet for Yamaha in the Los Angeles area. Two years ago, his store burned down. Jazz pianists staged a benefit concert to help him rebuild, and Yamaha extended him a huge credit to replace the lost pianos. The store is open again at 8162 Beverly Boulevard, Los Angeles 90048. I love to drop in just to look at and try out the gorgeous instruments.

"The first unit of this kind I saw was at Sarah Vaughan's house," I said to David recently. The memory is quite vivid. Sass had been sick and I went by to see her. She'd been in bed, but she got up, wearing a bathrobe, and with a sly smile walked to the upright piano that stood against the wall by the bottom of the bed. She sat down and, with a flourish, throwing back the sleeves of her robe, began to play a tune. She played it through, one chorus, then folded her arms and looked at me with an impish smile. The piano, untouched, began to play — reproducing exactly what she had just played.

"No hands," she said with a grin.

"We sold Sarah that piano," David said. "But what you saw was not a Disklavier. It was an early device called the Pianocorder. I first saw the genesis of it in 1973, but it really came onto the market in 1978. That was a tape-operated device developed by a fellow named Joe Tushinsky. Joe had the Sony Superscope distribution at the time and acquired Marantz.

"None of us ever thought about it, but the old piano rolls were nothing more than long IBM punch cards. Either air went through or it didn't. It was on or off.

"Joe had the largest collection of player piano rolls in the world. He was able to transfer the digital information from the piano rolls to tapes that would play on the Pianocorder.

"At the same time, a man named Wayne Stahnky was a computer scientist involved with the space shots, and also a tremendous music lover. He developed something referred to as the Stahnky reproducing device. He sold the device, which was very expensive, to Boesendorfer. But it reproduced 100 percent. Whatever anyone played on a piano equipped with it, it would reproduce perfectly.

"Wayne went in a different direction from Tushinsky. He went along the line of light paths. When a hammer started to move, a little flag would break a light beam, and when it struck the string it would break it again, and thus measure the time.

"Now that was a direction that Yamaha too was going. While Joe Tushinsky's was a wonderful device in the '70s, now we were in the late '80s, and the technology was moving rapidly. Yamaha ended up buying Pianocorder and all the rights thereto. They have subsequently hired Wayne Stahnky as a think-tank person.

"The Disklavier, however, came more or less from left field. Yamaha, being a massive company, had the resources to make it happen. It's really an incredible company. It has its cars, its electronics division, its motorcycles, its band instruments, skis.

"The Disklavier is a mass device in a plebeian price range, all things considered. You cannot yet attach it to your piano. Yamaha will have it available somewhere down the line as a retrofit device. Now you need to buy a piano fitted with it.

"It is an incredibly sophisticated device with enormous calibration circuitry. It even knows when the piano is out of registration and compensates for it."

"Aside from recording your own performances, can you buy pre-recorded performances?"

"Yes," David said. "There are already discs by Oliver Jones, Tommy Flanagan, Hank Jones, Junior Mance, Ray Bryant, Peter Nero, a transfer from the old Pianocorder by Liberace, which is a very big seller, and discs by a number of good concert pianists." (In addition, David has made limited recordings by Lou Levy, Alan Broadbent, Gerald Wiggins, and other Los Angeles-based jazz pianists. He plans to do more.)

I said, "And these discs sell to people who own these pianos?"

"Yes. Distributors, including us, sell the discs. They're being distributed through Hal Leonard. We sell a lot of software now. Yamaha expects that by the turn of the century, 60 to 70 percent of their business will be in this kind of device. Right now, there are, I would imagine. in excess of 20,000 of these pianos in the United States."

"What's the cost?"

"A console lists in the $8,000 range. a baby grand in the mid-20 range, and we have them that go up into 40. I've got the only nine-foot in the country, and that's not really for sale, but that's probably about $90,000."

"Tell me more about how it works. How does it measure the speed of a stroke, for example?"

"When the hammer is at rest, nothing is happening. When it hits the string it's going at a certain velocity. The light beam is broken at both ends of the stroke. The computer then says, 'Okay, it took this long to get from point A to point B, that means that's how much energy is required,' and velocity becomes volume. Tone becomes a mechanical byproduct of it. Of course, the sound is that of the individual piano. If it is made on one instrument and played on another, the sound will be somewhat different."

One of the many amazing things about the device is that it can modulate while keeping the same tempo. Conversely, it can play a piece back at half speed or at higher speeds without changing register. At half speed, it makes it possible to see more easily the contents of someone's voicings even as you're hearing them. The computer exactly reproduces the pedalling, and indeed every other aspect of a performance. And unlike the old player pianos, it produces the individual tone of each player.

It goes beyond reproducing a performance. In a strange way, what you hear *is* the performance, frozen in time. Thus a hundred years from now a major pianist of our time, long gone, will give a "live" concert. It borders on the eerie.

"It's a killer," David said. "The implications are enormous."

(Any Jazzletter reader who wants to see a demonstration of the Disklavier need only make an appointment and then drop in. David's telephone number is 213 651-3060.)

John Bruno continued: "One of the most important features of a computer is its ability to execute a sequence of instructions and carry out extensive operations, including logical operations."

"Even at the level of the PC," I said, "it takes very good sequences of logical instructions." You can make what are called macros that do many things with a single touch. For example, one keystroke will insert your telephone number, fax number, and the date, then move to the proper location for the start of a letter.

"They certainly will do that," John said, "and do it well. Switches give you the idea that you should go to zero-one type systems. Now we're talking about information as patterns. And memories on computers, like the RAM memory, Random Access Memory, are capable of storing these zero-one patterns."

"I've never liked that term RAM," I said. "I think of it as temporary memory."

The information you feed into your home computer is stored only in the computer itself in a temporary form. If you have a power failure, you lose it. All computer users reflexively use a "save" command that takes the information from RAM, or temporary memory, and stores it on a disc. It may be a "hard" disc permanently inside the computer, or it may be a "floppy" disc in a slot on the front or side of the machine. The more experienced users store information both ways, just in case something goes wrong with the "hard" disc.

"I first understood what a computer did," I told John, "when I grasped that a disc is a sort of circular tape. You can store information on it just as you store sound on a tape cassette."

"It's a sort of an LP," John said. "Except that it doesn't spiral in to the center."

"How does it work?"

"Well let's start with tape. With a tape, you've got a recording head and a magnetic surface on a plastic strip. When it passes over the head, the pattern of magnetism in the magnetic surface is detercted by the head.

"What was this pattern of changing magnetic field? That was the pattern that represented a pressure wave. We hear pressure waves. The pressure in the air is changing in a pattern. That comes to our ear drum and, miraculously, causes us to hear sound.

"If you drop a stone into a pool, you see rings go out from that place. These are similar to high and low pressure waves. Our ear responds to them, and we translate these into words, music. All recording devices from day one, up to and including the LP, recorded pressure waves with a needle that made a varying groove. This variation in the groove correspond to the variation in the pressure wave. You retrieve it with another needle, it is amplified and causes your speaker cone to move, and thereby recreates the original pressure wave.

"There was an advance with the development of tape. The pressure wave of the original sound hits the microphone, which transforms it into an electrical signal, which we cause to change the magnetic field on the tape. When we play the tape back, we do the opposite: the tape passes over a magnetic head, and the changing magnetic field makes a little current that changes just the way the magnetic field on the tape was changing. We amplify it and send it to a speaker, and it makes the speaker or speakers move to reproduce the original pressure wave, or a close approximation of it.

"You can imagine these little magnets on the tape that have their north and south poles changed by the current. All this is called analog, because you're making an analogy to something else. Digital recording does it altogether differently.

"It doesn't try to make something up physically that varies like the pressure wave. It remembers the pressure wave with numbers. It says, 'Look at this pressure wave. At this point it's zero. At this next point it's a half, and the next point it's one, and at this next point it's a little higher.' They have developed devices that can record the pressure wave by converting the pressure at each instant into a number. This device is called an A to D converter, meaning analog to digital. The phenomenal thing about it is that for a second's worth of sound, you need about 50,000 numbers. Per channel. That's a staggering amount of information.

"With the overtones, you get these very high, fast wiggles in the pressure wave. With LPs it was hard to cut the grooves finely enough to reproduce this information. Digitally, you can get all of it.

"This is a conversion from the pressure wave to a sequence of numbers that represent the height of the pressure wave at instants in time. Not every instant, because I can't do it continuously. But I can do it rapidly enough so that nothing changes much in those fractions of seconds. Each number we record is called a sample."

"Is this a little like persistence of image in the eye, which makes the motion picture possible?"

"Exactly."

"And," I said, "the character of an instrument, whether it's an oboe or a guitar, the overtone structure, is itself a complex of numbers, vibrations per second. Sound itself is a mathematical matter. Since it's mathematically-generated information, it should be mathematically recordable."

John said, "Now, the question is: how many numbers per second do I need to represent this information accurately? If I could record only 50 numbers per second, or 100 — which is a lot — it wouldn't be nearly enough."

"The little changes caused by the overtones are happening very rapidly. You need to sample quickly enough, take these numbers down quickly enough, to recreate the pressure. To record speaking voice only, I need far fewer samples per second. The frequency content of spoken language is very low. But a symphony orchestra produces very complex sounds, contraining high frequencies.

"Now, when you make a digital recording, they have devices that take that pressure wave and turn it into numbers instantly.

"Compact discs record digital information in a manner similar to the way magnetic discs store digital information. While a magnetic disc uses a read-write head to detect a varying magnetic field on the surface of the discs, the CD technology uses a highly focussed light beam to detect variations on the surface of the CD. Information is stored on the surface of the CD by creating what we mkight call microscopic potholes. As the CD spins, the focussed light beam detects the existence and non-existence of these potholes — zeroes and ones again."

"It occurs to me," I said, "that inasmuch as all sound is mathematically determined, since the time of the first Edison phonograph, the first cylinder records, the first 78s, they have been trying to find ways to reproduce the pressure vibrations generated by music. All they were doing from the start was recording how many times a second the needle vibrates. And because it was a very limited number of vibrations, you go[illegible] first that rain-barrel sound."

"All the overtones were gone," John said.

"And they gradually improved on the techniques all the way through to the stereo LP. But the actual way of recording the number of vibrations per second didn't really change until magnetic tape came along."

"Sure, John said. "As needles got better, the techniques got better, the sound got better. And with stereo they put down two channels of sound. With tape you got better separation because the sound was being generated not by one needle but by two heads.

"So," I said, "is it correct to say that all that has happened from Edison to the present is the increasing amount of information we have been able to store and retrieve? And in digital recording, we reach a huge amount of that information that can be stored and retrieved?"

"That's correct. Why were these other processes not as good as digital? Because in addition to the information on the magnetic tape that we are interested in, there was noise in the mechanism itself that had nothing to do with the pressure wave. And you got tape hiss and all sorts of extraneous junk. And with records, it was worse, with clicks, pops, and scratches.

"Now, where do you write down these numbers in digital recording? You can record them on magnetic tape. But instead of recording the pressure wave itself, you are recording numbers corresponding to the pressure wave. There is still magnetic fluctuation, but the fluctuations are recording the samples — numbers. And these numbers are represented by zeroes and ones. That's all that's coming off the tape. And every 16 of those zeroes and ones represent a number, the height of the pressure wave at some instant. And the next sixteen represent another number, and the next. And there are 50,000 a second.

"This is the difference between analog storage of information and digital. In one you write an analog of the information; in the other you write numbers. What is the analogy? We have a pressure wave, and we are going to represent it by a varying magnetic wave. It's a picture of it. It is retrievable in an electric signal analogous to the magnetic wave and the pressure wave, and that moves the speakers that move the air that moves your eardrum. It's an amazing transformation, when you think about it that way."

I asked, "Is it correct to say that in some ways the digital storing of the information is less amazing? Because you're transforming numbers into numbers?"

"Yes. But it's pretty incredible, a number such as 50,000 samples a second. I think a CD has 44.1 thousand samples a second. For each channel. They represent two separate pressure waves.

"Now a computer disc is just magnetic surface. Like a tape, with a read-write head. If that head stays in one place and the disc spins underneath it, the magnetic field on the surface passes under the read-write head.

"If the disc is spinning, the head stays over one line or track. It's as if the needle on an LP stayed in the same groove and the groove was circular, instead of spiralling in. With computer discs, you move the read-write head to a new place to retrieve information from the disc. It moves to what they call tracks. They use various techniques to find the track where a given piece of information is stored. The information is arranged in a track in groups called sectors. The reason for it is this:

"You want the information on the disc to be addressable, accessible in some way. An address is a physical location on the disc. It's as if I want to play a song on an LP, and the liner notes say it is on track four. You can actually see it on an LP. But unlike an LP, where you go to the track where a song begins and wait for the part you want, on a disc you may have just a short amount of information on each track, called sectors, and you can go more or less directly to each one. They're short arcs on which there is a certain amount of binary information.

"It is simply a way of storing information on the magnetic surface of a disc.

"The early computers actually used tapes, big reels of tape. They didn't have hard discs at that time. The tape would have to turn until they got to the information. It was very slow. They didn't have what we call random access, which is where we get the term random access memory, or RAM. It simply means you can go almost immediately to the information on the disc, rather than waiting for a tape to run past the head. They had serial access; we have random access. A disc is random because it is spinning and you can move the head and find any place on the surface in milliseconds, as opposed to seconds or even minutes.

"You asked earlier if it's true that a pocket calculator can do more than the old computers that filled rooms of space. And it's true. Now a calculator may or may not be programmable. The little ones aren't. You just keystroke what you want to compute into it. That's the limit of what they can do. Now they have small calculators that are programmable.

"The PC is programmable. You can tell it what you want to do, make a visual design, do a complex mathematical program, write a letter, even write musical notation. The PCs are very versatile. The same machine can do many different things, dependent on the software you give it. That was the great invention, that you could program them. PCs can hold an incredible amount of temporary and permanent memory. They are also interactive with the person operating them, and they are even interactive with other PCs over telephone lines.

"In the old days, you had to give the machine a program and it would come back with an answer. They used to use punch cards, not discs. The home computer that you buy for $800 or $1,000 is almost incalculably more powerful than the old computers costing hundreds of thousands or even millions of dollars."

"Now," I said, "getting back to bits and bytes. A byte is eight bits. Now, the quantity of memory appears to proceed in squares."

"Everything is in powers of two, John said. "That's because a byte is a power of two, two cubed. When they say a kilobyte, it means a thousand bytes, from kilo, the Greek for a thousand. But it isn't exactly a thousand, because a thousand is a multiple of ten, ten cubed. A thousand is in base-ten mathematics, not base-two. In computer terminology, a kilobyte isn't actually 1,000, it's 1,024, because 2 to the power of ten is 1,024. And so you just have to know that a kilobyte is 1,024 bytes, and when you say a megabyte, it's not a million, it's 1,024 times 1,024. That works out to 1,048,576 bytes, not a million. That's how much temporary memory you'll have typically in your machine, and much more. On a hard disc, these days, you can have anywhere from 20 megabytes to a gigabyte, which is a 1,024 megabytes. On my disc at work, I have a gigabyte, but mine is not a PC, it's a work station.

"And the memory capacity is increasing, and it's getting cheaper all the time."

"One final subject, at least for the moment," I said. "How do fiber optics enter into this?"

"Fiber optic cables," John said, "are wave guides for light, by which information is transmitted, rather than by lower frequency electro-magnetic waves. You understand that radio waves and light are related. Light is a much higher-frequency radio wave.

"Lasers create what is called coherent light — light of a single frequency.

"The light that we normally get has all sorts of frequencies in it. It's like white noise. It's not a pure frequency, it's not like a sine wave that you could generate with an oscillator. Laser light is pure in that it has a single frequency. And this has some nice properties. They have figured out how to make materials that will channel laser light. The material can bend and the light will follow it. You can't do that with a flashlight in a tube. It reflects all around and soon dies out. The material they make for fiber optics is such that it confines the light to the center of the cable and the light follows it. The strength of the light wanes as it goes through the material, although it goes pretty far.

And when it gets too weak, they regenerate it.

"And how do you send information on it? You know how battleships send information by turning light on and off. Well you can do it that way. Binary mathematics again, on and off. But you can turn that light on and off very fast. Millions and more times a second.

"If I speak into an instrument, and the message is going to be sent by fiber optics, it has to be changed into numbers and transmitted in some coded way.

"There's another thing about light. It's less susceptible to interference. An electrical signal on a wire can experience interference from an electrical disturbance. Inside a fiber optic cable, electromagnetic waves don't matter. There's no cross talk. You can't get light in there to interfere, because these cables are completely shielded. So the sound is noise-free. With long-distance carriers who are using fiber optics, you find the transmission is great. There's no noise on the line at all."

I said, "So if a message passes through fiber optic cables in Paris and is bounced up to a satellite, and then comes back down over here to be picked up and run through a fiber-optic system, there is very little loss."

"They can do pretty well," John said, "especially if it's all digital. Another advantage of digital is that they can have error correcting codes. They send the information in a redundant fashion, so that if they lose a little of it, they can retrieve it from other parts of the message. And there are very sophisticated ways of doing these things."

Back in the 1960s, when Wendy (then Walter) Carlos, a neighbor of mine in New York, explained to me how a Moog synthesizer worked, I made a prediction: In another 50 years, a child would say, 'Daddy, what is a symphony orchestra?' and Daddy would answer, 'A primitive synthesizer that took a hundred men to play.'

We are not at that point yet. Indeed, I am no longer sure the prediction will prove accurate. There may be fewer orchestras in future, but the sound of them will be all the more precious.

I began using a computer around 1985, after resisting the new technology. Almost every writer I know resisted the computer. I felt I could never master one: I felt it was a technology that only the young could grasp. This of course was nonsense. And when I got my first computer, a Kaypro that I still have, I was enamored of it within days. I would awake in the night thinking about it, and turn it on, and study it and seek to master it. It gave the strange illusion of increasing my intelligence. As a hammer is an extension of the hand, it seemed as if the computer was an extension of the mind. And I am not sure that is wrong. The use of one alters your way of thinking; it makes you more logical for, despite all the talk of artificial intelligence, a computer is brainless. It can do only what you tell it to do. If it seems to have made a mistake, you can assure yourself the mistake was yours. It is not only incapable of thinking, it is incapable of error, barring a serious breakdown of the equipment. But you have to adjust to its limitations, and this introduces an extraordinary discipline into your thought processes. I believe, in the end, that the computer does alter the way you think. And it may indeed increase your intelligence, as a gun increases your lethality.

Though they resisted initially, all the writers I know who started using computers now mutter something to the effect, "I don't know how I ever got anything written before." The computer comes as close as we're going to get — short of sticking a couple of wires into your ears and having them transpose your very thoughts into printed words — to taking the pain out of writing.

It seems to me that the benign applications of the computer far outweigh the sinister.

Many persons, when they first get interested in computers, fall into an almost hypnotic fascination with the equipment and its processes. It is something like rapture of the deep, an almost hallucinatory phase. It passes, and in time the computer becomes just a tool.

But what a tool it is, and who can tell where it will take us?

Records

One reason I don't review records is that I distrust the process of criticism. What one person likes may not be what another likes, and neither reaction is a "fact" about the art. One reader wrote to suggest that I might at least recommend some interesting things I have heard lately. Maybe he had a point, even if my tastes and opinions are not definitive.

You might want to look into a four-CD package titled *Charlie Parker: The Complete Dial Sessions* on the Stash label. It is a vitally important historical package.

Andre Previn once said to me, "Hank Jones is my favorite pianist, *regardless of idiom*." Hank has an exquisite solo album on the Gitanes label, called *A Handful of Keys*, on which he plays music of Fats Waller.

Three other solo piano albums have also blown me away recently. Two are from the Maybeck Hall solo series on Concord Jazz. *Adam Makowicz at Maybeck* comprises mostly tunes by Cole Porter. What he does with them is amazing. The other Maybeck album is by Cedar Walton. This album shows us what a magnificent pianist he really is.

Finally, there's *Dick Hyman Plays Duke Ellington*. Although I shy from calling anyone "best," I sometimes think that Adam is technically the best living jazz pianist, maybe the best ever. Then I listen to Dick and think he's the one. It's a futile argument. Dick's new album, on the Reference Recordings label, is incredible. Anyone who thinks CD sound is "cold" should listen to it. I have never heard piano so accurately and magnificently recorded.