CHAPTER 8

ELECTRONIC MUSICAL INSTRUMENTS AND DEVICES

Before about 1920, all the world's work was accomplished by mechanical moving parts. But the development of the vacuum tube – originally for radio – opened an entirely new area of other applications. With the ability to amplify small signals and generate new signals of almost any frequency and wave shape, many things involving information handling and processing, formerly done mechanically, could now be done electrically with enormous advantages in speed and cost.

By 1930 the technology existed by which new musical instruments were possible, in which the notes, of any pitch and tone quality could be generated electrically. What was oscillating was not a string, sound board, or air column; but only an electric current or voltage in some circuit; but after processing it electrically in almost any conceivable way and for any purpose, the final result could be made audible by the loudspeakers developed for radio. The list of potential advantages for keyboard instruments is impressive:

(1) Even large variations in temperature and humidity would no longer throw an instrument out of tune.

(2) One has a much wider variety of pitch and timbre available, so that a single instrument can be made to serve, at the player's will, the musical functions of a piano, harpsichord, clavier, organ, xylophone, carillons, *etc.*.

(3) The quality as a musical instrument can be fully as great – actually far greater – than that of any mechanical instrument. Good timbre can be maintained over a much greater dynamic range than is possible in any acoustical instrument.

(4) The instruments can be much more reliable; broken strings, hammers, worn out felts, cracked soundboards, are things of the past.

(5) The instruments can be smaller and lighter and much less expensive.

One would think that, with all these obvious advantages, they would be exploited at once, and by now a revolution in keyboard instruments should have been long since accomplished. But sadly, our task here is not to explain how these wonderful things are done today; rather, we must try to understand why they have *not* yet been done in spite of our full technical capability of doing them.

Perhaps the first commercial electrical instrument to be made in any quantity was the Hammond organ of the 1930's.† The sound of it became familiar to everyone in the 1940's because it was promoted so vigorously. A radio commercial, played thousands of times, featured a performer named Ethel Smith, playing on a Hammond organ the music of a current little song with a Spanish flavor, "Ticho–Ticho", whose lyrics praised the reliable little cuckoo in a clock. This was repeated day and night with such maddening regularity that every note and intonation of it is burned permanently into my memory. The sound was utterly unlike that of any real organ, and was closer to what would be called today, "vibes." The main result of this saturation advertising campaign was that, although relatively few people ever saw a Hammond organ, everyone could whistle "Ticho–Ticho".

† For a comprehensive review of the state of the art at that time, see B. F. Meissner (1936). Technical details of the Hammond organ are given by L. Hammond (1939).

The Hammond organ technology seems today to be almost of the stone age; to see how far we have advanced, we note that in a small part of it the twelve highest notes were generated by a rotating shaft carrying twelve cogwheels with approximately the right number of cogs,[‡] which induced oscillating electric currents in twelve electromagnets placed near them. Then a cascade of vacuum tube frequency dividers generated the lower octave signals from these, after which many other vacuum tube circuits are needed to supply the upper partials (by borrowing in the proper proportions the voltages in the circuits belonging to higher octaves). Finally, each key must have a switch to turn on the proper note, after which they are all combined and amplified to loudspeaker level.

Thus merely to generate all the required pitches – before we have even started to generate the proper timbres – required apparatus that weighed perhaps thirty pounds (with the motor to drive the shaft and the power supply for the vacuum tubes), must have cost about $200 in 1940 dollars to manufacture, consumed about 100 watts of power; and was highly unreliable, with a dozen potential failure points. Today, all of this is accomplished by a single integrated circuit containing thousands of transistors on a semiconductor chip about the size of an aspirin tablet, which consumes about a milliwatt of power and costs about one dollar in 1990 dollars – perhaps 15 cents in 1940 currency – to manufacture; and has spacecraft reliability. Thus has technology advanced in fifty years.

Despite all its technical and musical shortcomings, the fact that the Hammond organ was the pioneer of a new field made many regard it with affection, and surviving instruments maintained in working order are becoming valuable antiques. Indeed, there is an active market in these old (see the personal ads in the back of such periodicals as Keyboard magazine). Hammond organs are being offered for sale at over $4,000.

Other makes of electric organs (Lowry, Schober, *etc.*) appeared, operating on other principles and producing quite different sounds. Some of these used authentic Rube Goldberg devices; in one the effect of tremolo, which could have been produced so easily electrically if one wanted it, was made instead by the astonishingly crude, ineffective, and costly method of mechanically rotating the speaker so that it faced alternatively toward and away from the listener!

With the advent of solid–state electronics and integrated circuits in the 1960's, all these early efforts became obsolete. It could all be done now with superior performance, in a way vastly easier, cheaper, and more reliable. Again one would have expected high quality electronic pianos to appear. Indeed, an attempt at this was made by the Baldwin piano company, and for a time the result was also promoted by radio commercials, now featuring Glenn Gould playing Bach on the electronic piano (in contrast, the famous organist E. Power Biggs refused to perform on any electronic organ).

The writer, after many years of playing a Bösendorfer grand, acquired one of these electronic Baldwins largely out of curiosity; and found it so unacceptable as a musical instrument that one could not understand why the Baldwin Company had bothered to manufacture it at all, much less why they would allow their name to be put on it. The tone

[‡] Exercise for you to ponder: explain why it is not possible, with this arrangement, to produce an exact equal tempered scale, although an eight–note diatonic scale is possible. Thus the Hammond organ produced thirds smoother than equal tempered thirds, at the price of making some other intervals worse.

quality varied greatly across the keyboard and at no point was it anything like acceptable piano sound. The sound was so muffled by insufficient harmonic content – particularly in the bass – that it was almost impossible to recognize a note unless it was played staccato. Glenn Gould's performances partially hid this defect because he played everything staccato anyway. Not only in articulation, but also in maximum volume and dynamic range – all of which would have been trivially easy to accomplish electrically – it was hopelessly deficient, in a way that could not be corrected by any further amplification or filtering of the output. Although it was in a sense also a pioneer in a new field, nobody could regard it with affection and it will never become a valuable antique.

More recently, other manufacturers – Roland, Kurzweil, Casio, Yamaha – produced portable electronic piano keyboards, of which the writer proceeded to acquire a 1985 vintage Roland HP–100, and a 1992 Yamaha YPP–50. They showed a slight, almost negligible improvement in quality. The Roland went to the opposite extreme of too much harmonic content in the bass, making it sound cheap and tinny, while the treble notes had a shrill, unpleasant peanut–whistle quality. At least, the balance between bass and treble was acceptable.

The Yamaha actually approached acceptable piano sound in the bass, for perhaps the first time in any electronic piano, but now produced dull treble notes with insufficient harmonic content, lacking the brilliance of piano sound. Astonishingly, the user was given no way of controlling brilliance, although the Roland offered this in a sequence of steps. Even worse, the Yamaha preserved the worst defect of the acoustical piano, about which Johann Sebastian Bach had complained already in the first piano – bad balance across the keyboard, with booming bass and weak treble, just the opposite of what a good piano ought to give us for reasons explained in Chapter 3.

Equally exasperating, the volume could not be turned up to normal piano loudness without great deterioration in sound quality – what the experienced hi–fi ear recognizes at once as distortion due to nonlinearity in the electronics. It would have been so easy to design the electronics to give greater dynamic range than an acoustic piano without departing from good piano tone; but in fact, it had far less range, making effective crescendos almost impossible. In addition, the decay was far too fast, making it almost impossible to play anything legato (the designers were apparently unaware that an acoustical piano note has two decays; a fast and a slow one, and any acceptable electronic instrument must duplicate both of them).

In short, like the proverbial Japanese tailor, the Yamaha piano keyboard faithfully copied the defects of the acoustical piano, while failing to copy its good features. But we found that this could be compensated, bringing the result up to the border–line of acceptability, by passing the output through a hi–fi amplifier set for maximum treble emphasis and bass suppression.

Although it is possible to do anything electrically millions of times faster than mechanically, in all of these attempts at an electronic piano the response is so sluggish that it is impossible to execute a trill at anything like the speed of an acoustical piano. It seems to us that there is something deliberately perverse in the design of those circuits or the keys (in particular, the lack of tactile sense of when the key rises to the point where it can be repeated, and rate of key rise when the finger is removed; perhaps this needs to be speeded up).

In addition, there is something too 'rigidly fixed' about the sound of the above electronic pianos; the original acoustical piano has a kind of flexibility and expressivenness that they all lack. Perhaps the stretched octaves of acoustical pianos actually give an enhanced melodic quality to the high notes. Bear in mind also that on an acoustical piano a more loudly struck note automatically has not only a greater brilliance (harmonic content) but also a slightly higher pitch (the average tension on the string is increased by the greater amplitude of its motion, which stretches the string just as would tightening the peg by a tiny amount). Of course, if psychological experiments should show that this is indeed an important factor in musical expressiveness, it could be duplicated electronically.

However, with all their defects, the quality of electronic keyboards of the type discussed above, is already about equal to that of the cheapest 'spinet' acoustical pianos. And the price of the former comes down while that of the latter continually increases; the spinet piano is already more expensive than an electronic keyboard of comparable musical quality, so we think that the low–end spinet pianos are headed for swift obsolescence. But the high–quality acoustical grand piano is as yet unthreatened.

In summary, there is no technical reason why one cannot make an electronic piano that has a musical quality surpassing the finest concert grand, can be folded up and carried as easily as a cello, has all the above practical advantages, and sells for about the same price as the TV – VCR combination in most living rooms. But the history of attempts to produce this much–needed instrument is one of persistent failure to achieve even the most elementary necessities of a piano from a musical standpoint. We do not yet have any electronic instrument – of whatever size and price – that is a satisfactory substitute for a good acoustical grand piano.

This is not a failure of our currently available technology; it is a human failure. The engineers who designed those instruments, although they presumably knew their electronics, simply lacked the musical perceptiveness to comprehend what is important in a piano.[†]

Since the electronic keyboard manufacturers never produced a satisfactory piano, they never attracted many buyers and their interest shifted to other electronic instruments of the "synthesizer" genre. Here the attempt to imitate a piano was abandoned, and one concentrated instead on special effects that are possible only in an electronic instrument. In 1993 rather elaborate synthesizer keyboards could be bought for about $2,500. A new synthesizer is the Yamaha VL–1; it can reproduce a quite realistic oboe sound, and also crazy things like a "bowed flute". Indeed, synthesizers can produce an amazing variety of weird sounds made to order by the user, and thus make instructive demonstrations of some principles of acoustics and sound perception. But in our view there is no musical reason to want such weird effects, so these devices are expensive toys, not serious musical instruments.

It is problematical whether this situation will ever be corrected, short of a new producer entering the field with a new philosophy. We think that only a person who has in the same head a thorough understanding of both electronics and classical piano music – at

[†] Worse, the writer knows one competent electronic engineer for whom the terms "music" and "rock and roll" are synonymous. I do not think that this musical illiterate has any conception of what classical music is; he appears never to have ever heard a Beethoven sonata, or even to know what that means, or who Beethoven was.

the level of actual competent performance – can do for the piano what Theobald Böhm did for the flute; so the high quality acoustical grand piano will continue to be with us for many more years. It might remain the instrument of choice almost indefinitely if some of the improvements noted in Chapter 6 were made.

MIDI

However, another intriguing possibility is beginning to appear, developing in a different direction than the synthesizer, in the passage of music through computers, in which the musical response is determined by the particular software that is controlling the computer. The MIDI (Musical Instrument Digital Interface) system carries full information about what the player is doing on a piano keyboard, essentially instantaneously, over a single coaxial cable, making it possible to accomplish the functions of keyboard, piano action, and sound production in three separate and separated components, each of which can be designed separately for any number of different purposes.

For each key, a signal is sent indicating the pitch, the exact time of key depression and release, and the velocity of the key at the point (about 2/3 of the way down) where the escapement would disconnect the hammer from the key on a conventional piano. This provides all the information that is available to the Érard piano action, therefore it must be possible for a computer, given that information, to reconstruct everything the Érard action does.† Equally well, one can make the computer do anything else one may want with that information, which no instrument has ever been able to do before. Once this information is available as input to a computer, then merely by writing different software, one can make the computer process it in any way we please, to produce any volume, timbre, attack and decay pattern, we want; and these parameters may be chosen differently for different keys, reproducing the piano's bass, midrange, and treble response and reproducing the piano's variation of timbre with loudness, if that is what we want. With experience, one could surely make the computer deliver response far superior to what the Érard action gives.

With the MIDI interfaces a single keyboard could suffice, once and for all, to emulate any number of different musical instruments. A single hi–fi speaker system suffices, once and for all, to deliver any sound the human ear is capable of perceiving. The individuality of the instrument would be determined entirely by the computer module connected between them, which can be replaced with a different one at any time (or more easily, one replaces the software with new kinds). Obsolescence itself would be a thing of the past.

RECORDING

The place where modern technology – electronic and otherwise – has made a really big and valuable impact on music is, of course, in the making of recordings, which started with Thomas Edison's wax cylinders. These mechanical/acoustical machines arrived too late to

† Or, for that matter, what the Stein or Streicher pianos, Beethoven's Broadwood, the Späth non–piano, the Cristofori piano, or the harpsichord did; or what the organ or xylophone do now, since the MIDI information includes everything that they use concerning what the player is doing. But, interestingly, one could not emulate the clavichord, which makes use of extra information (variation of finger pressure on the key after it has sounded) that the present MIDI system does not transmit.

preserve the performances of Liszt, but just in time for others such as Enrico Caruso and Camille Saint–Saens. The play–back machines were of wretched musical quality by today's standards, but with their long flaring horns, often imitating trumpets or flowers, they had a very elegant appearance, fit for the finest salons. Probably the world's greatest collection of fancy old phonograph and gramophone machines is in the museum at Burgdorf near Bern, Switzerland.

With the invention of the electrical microphone all the existing electrical technology could be applied at once to development of both radio and greatly superior recording devices. These evolved from the wax cylinder to flat 78 RPM disks to 33 1/3 RMP disks, to tape recorders, and finally to our present laser–operated Compact Disks with digital computer electronics, which seem to leave nothing to be desired as far as quality of reproduction is concerned. We doubt whether anybody's ear is able to distinguish between a live performance and a reproduction on a modern hi–fi system properly set up.

Musicians need to know a little about this technology in order to make good recordings of their own performances. Reverberation, etc.

********** MORE HERE ON RECORDINGS **********