Human Engineering the Synthesizer: A Real-World Example

by

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Human engineering, biotechnology, or ergonomics is "the study of the problems of people in adjusting to their environment; esp., the science that seeks to adapt work or working conditions to suit the worker." In some spheres of human activity, human engineering is critical; e.g., reduction of pilot error in aerospace vehicles. Industry has long recognized the desirability of optimizing worker efficiency through attention to principles of human engineering in the design of machines and control panels.

Little attention to human engineering--in the scientific sense--has been given to the design of musical instruments traditionally. Most instruments have evolved through a process of cut-and-try. There are several reasons for this traditional lack of interest in human engineering on the part of musical instrument designers: (1) Musicians are very good at overcoming "bad" design--(practice, practice, practice); (2) Attention to human engineering exercises a side of the brain that is often not the forte of the designer and the musician; (3) Research in ergonomics is expensive; (4) Most musicians are not even aware--at least consciously--of the need for human engineering; (5) Efforts to human engineer instruments are often thwarted by the "star syndrome;" i.e., the ego of a famous performer is stroked by involving him in the "design" of an instrument. The result is often an instrument that reflects the idiosyncrasies of the performer rather than more universal principles of human engineering. Historically, few outstanding designers of musical instruments have been outstanding performers! (This realization does not negate the value--in marketing terms--of asking the opinion of a broad spectrum of performing musicians; it does question the wisdom of "design by committee," however).

In a word, human engineering of musical instruments has been ignored traditionally because it wasn't critical--you don't crash and burn due to faulty design! (But electronic musical instruments offer some new and unique problems.) Acoustic instruments are hardware oriented; there are only so many ways you can configure brass, wood, and other physical stuff and create a successful soundmaker. With acoustic instruments, form necessarily follows function.

Electronics lets us make some real mistakes in the design of instruments; almost everything is arbitrary--from the layout of control panels to the devices that the performer touches. Electronic musical instruments are software oriented; form no longer need follow function. One can program voltage controlled equipment to mimic any variety of acoustic resonators; without regard to the laws that govern physical things. And, unfortunately, the design of electronic musical instruments is somewhat like singing: everybody has an axe! Everyone is an expert--just ask.

Also, there is a tendency to shroud musical instruments in an aura of mystery; it's not much fun to think of them as machines whose design can be improved through the highly rational process of human engineering. But in fact, all musical instruments are machines--highly contrived artifices fashioned primarily for our enjoyment. The question remains whether you wish to be a plumber or an electrician! No one ever saw a guitar hanging on a tree, or trombone growing out of the ground. These instruments--in this sense--are no more "natural" than the voltage controlled synthesizer. Is the lightning bolt less animate than the ore that is refined to produce instruments made of metal? Music-making is a highly intuitive process, and there is much room for intuition in the design of instruments. But there is a growing need to recognize that musical instruments--especially electronic ones-- can be improved through the application of principles of human engineering, guided by musical experience.

Human engineering is not based on logic--it is an empirical process based on experience, experiment, and observation rather than theory. Logically, the typewriter I am using might have keys organized alphabetically, A,B,C,D, etc. But it is not organized theoretically, but empirically according to frequency of occurrence of letters in the English language, relative strength of the fingers, and other real-world factors.

To date, most "human engineering" claims in the synthesizer industry have been appeals to logic: "a neat, logical row of sliders," for example. Neat and logical, yes. A gestalt that aids the performer, no. A control panel is more than the sum of its elements; it makes a picture that aids or discourages finding specific controls, and optimizes the non-rational or intuitive use of those controls. In my opinion, one of the worst mistakes made by designers is the insistence of the "logical" row of controls, when an asymmetrical design with groups of controls on different axes is clearly more consistent with good human engineering. Look inside the cockpit of a small airplane; you will see controls with different shapes and orientations, suggestive of their function. Consider the fact that everything on a trumpet was designed for a trumpet; there are no general purpose devices. On the other hand, on the synthesizer we are still placing general purpose devices (pots and sliders) that may be more suitable for a toaster than a musical instrument! Clearly, in the future electronic musical instruments will evolve toward player controls and panel controls that have been specifically designed for the music-making task. At minimum, the shapes and orientations of controls will receive much more attention than at present.

Let's examine the reasons for not improving the human engineering of electronic musical instruments. (1) "Musicians don't know the difference--it's not worth the expense." Not true, if you realize that musicians may not verbalize about such things, but intuitively recognize good design. I base this assertion on countless discussions with performers. (2) "It's expensive." Not if the company tells potential customers the story, tying their R&D efforts into believable marketing slogans. For several years I have been personally successful selling instruments whose success was not necessarily mirrored company-wide. No big secret, just credible details--something the customer could hang his hat on. Sales result.

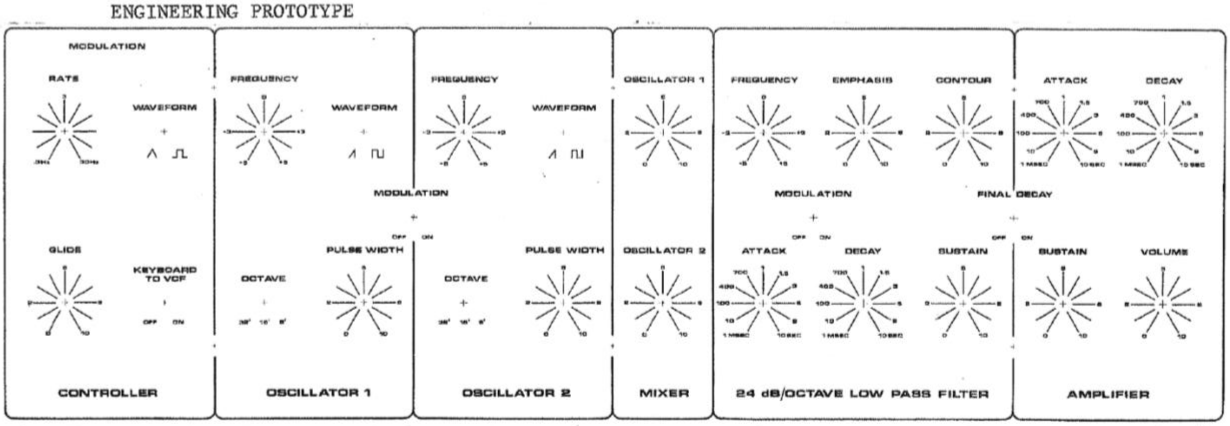
(3) "It's hard to find an expert." This is true. Where do you go to find a teacher? I went to the literature on human engineering, spending almost six months total time at Vanderbilt Library. The principles of human engineering, in general, are well known. Congruence, contiguity, modes of human perception, typical muscular response, optimal knob size for so many foot pounds of torque, error tests in various knob orientations, etc. all are dealt with in the literature. Tempered with some observation at concerts, discussions with performers, and personal experience as a musician, it is not difficult to draw some valid conclusions. The way not to do it is in all-night bull sessions where personality often becomes more important than principle. On this matter (bull sessions) I speak with the voice of experience!

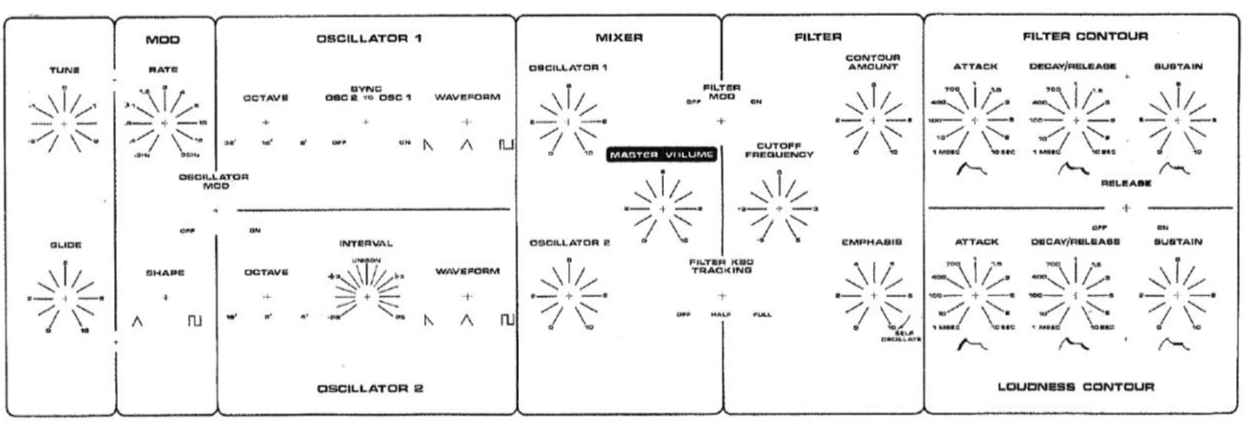
After this lengthy preamble, let me get down to a real-world attempt to improve the human engineering on an instrument. In 1979 I was a consultant to Moog Music, and was named project coordinator in the development of the Prodigy, a monophonic synthesizer targeted toward the low-end in price. Although I was empowered to essentially "make all decisions" about the layout and format of the instrument, I was constrained by the necessity of using parts on hand (unfortunately), and the requirement of maintaining a 40+% gross margin for the factory at a retail figure of $495.00. At this point I would like to acknowledge the outstanding design by Rich Walborn and Tony Marchesi of Moog Music as a critical factor in successfully meeting financial goals. My role was to make the instrument successful, musically and ergonomically.

I entered the project after the engineering prototype had been built. This was unfortunate for several reasons. I felt that the instrument should include a noise source and a longer keyboard; I believe that this could have been accomplished with the cost/function requirements intact. The targeted cost for material and labor was eventually bettered substantially. Also, I felt that the instrument could have been the basis of two spinoff products, an expander module and an electronic drum. However, I accepted the job of optimizing the instrument within several constraints regarding overall size, p.c. board geography, and available panel controls.

The following pages display several figures, labeled EXHIBIT A, EXHIBIT B, and EXHIBIT C. These illustrate "before and after." EXHIBIT A is for reference; it shows a photo of the Prodigy as it appears on the front cover of the Prodigy's User Manual (which I authored), as well as the configuration of the engineering prototype when first received and the final configuration after my work. EXHIBIT B illustrates 5 points regarding changes to the overall layout. EXHIBIT C relates primarily to the tonal resources of the instrument, mostly oscillator features. I will discuss the points in order.

ENGINEERING PROTOTYPE



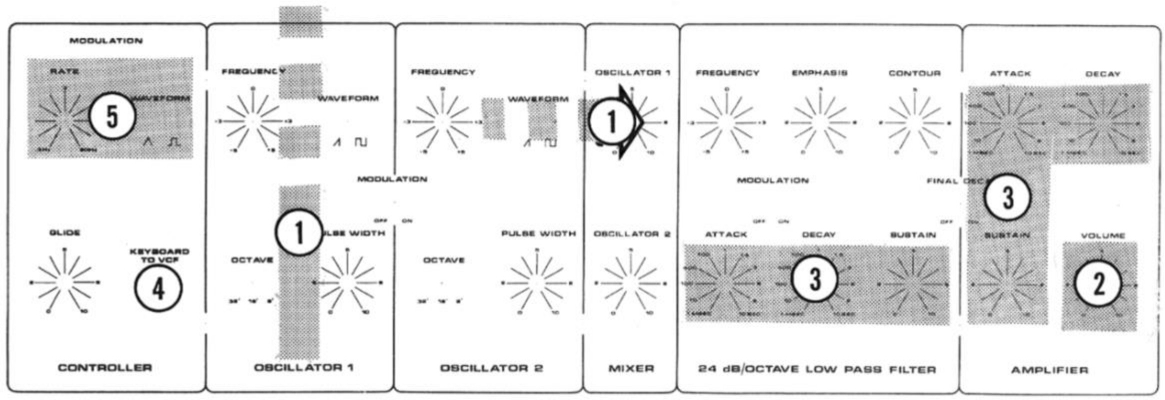


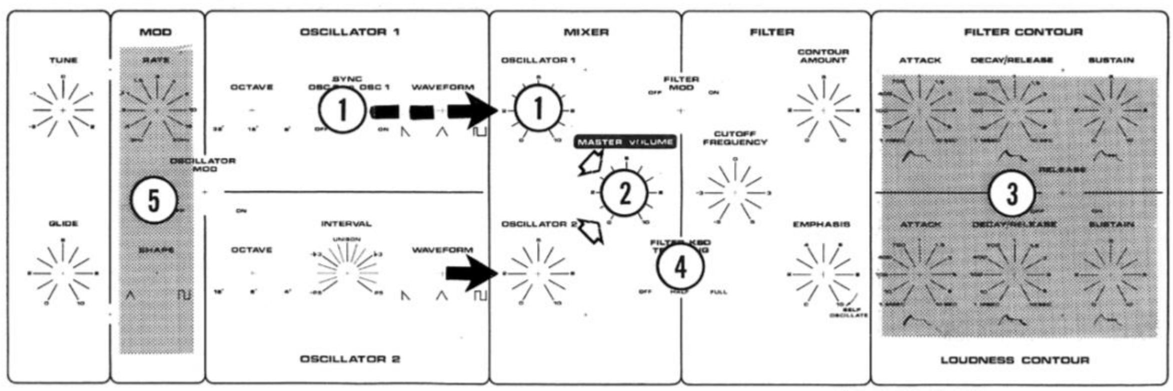
FINAL CONFIGURATION

PRODIGY

Exhibit A: Front Cover of the Prodigy Manual (upper), Initial Engineering Prototype (middle), and Final Configuration (lower).

ENGINEERING PROTOTYPE





FINAL CONFIGURATION

Exhibit B: Changes to Overall Layout

#1

On the prototype, the layout of the oscillators was not congruent to the associated mixer controls. (Oscillators laid out north-south; mixer controls laid out east-west). Since I wished to economize on number of controls in each oscillator for other reasons, it was easy to orient both oscillators to directly face their associated mixer volume controls. Such <u>contiguity</u> of organically related controls is good human engineering, and agreed with other Moog models such as the Minimoog.

#2

Following the dictates of "logic," the final volume control was placed at the end of the sound chain--at the extreme right of the panel on the prototype. This is possibly the worst place for it, since it is one of the two controls that is used with the greatest frequency. (I have confirmed this using binoculars at various performances). I placed it in the mixer, grouping it by function with the volume controls for the individual oscillators. Note that the MASTER VOLUME and CUTOFF FREQUENCY controls appear in the center of the instrument (available to either hand) and are off axis compared to other controls. The MIXER-FILTER configuration is a gestalt that makes location of specific controls very easy--even in semi-darkness where shapes can be discerned and words cannot. I wanted to put the TUNE control on the rear of the instrument (the oscillators were very stable), and have a triangular-shaped MOD section (apex of triangle at top) consisting of only three controls, but was eventually overruled due to production considerations. Note that the final configuration places the CONTOUR AMOUNT contiguous to the FILTER CONTOUR.

#3

In the prototype, placement of contour generator controls allowed no correlation of attack and decay times, or sustain levels. It is the relationship between individual elements of the two contour generators, not memorization of absolute setting on the six controls involved, that makes sound settings a visual--not a cognitive (rational) process. The icon, or image is more important than is generally credited. Note that one attack lies over the other, and so forth in the final configuration.

#4

In the prototype, the switch that feeds the keyboard (control) voltage to the filter in order to have the filter track the keyboard is (logically) placed in the CONTROLLER section. It was an off/on switch. This is a rather subtle, but powerful point. I moved it to the filter; the result of its use is perceived as a change of filtration (timbre). My experience has indicated that most musicians are destination oriented when they consider the source-destination concept of using a control voltage. Anytime you ask that they "stand" at the source of a control voltage and make the leap on the panel (and mentally) to the voltage controlled device you are asking for trouble. Remember the Electrocomp 500? It is the only example of a source oriented instrument I can recall—it failed. The receptor style of ARP products stands worlds apart from the source-destination Moog concept; mode of handling control voltages is the most important distinguishing characteristic in the layout of competing brands of synthesizer. I hope we can discuss this at greater length; it has some definite implications for design.

#5

I'm not real happy about either version (more detail on request), but some features were dictated by production requirements. Note that I renamed WAVEFORM to SHAPE to prevent confusion between functions of audio waveforms and subaudio waveforms. Things that function so differently should be named differently, even though they are the same in the sense of a signal. Most musicians relate to perceived function better than they understand signal characteristics. Note improved (non arbitrary) calibration of RATE control.

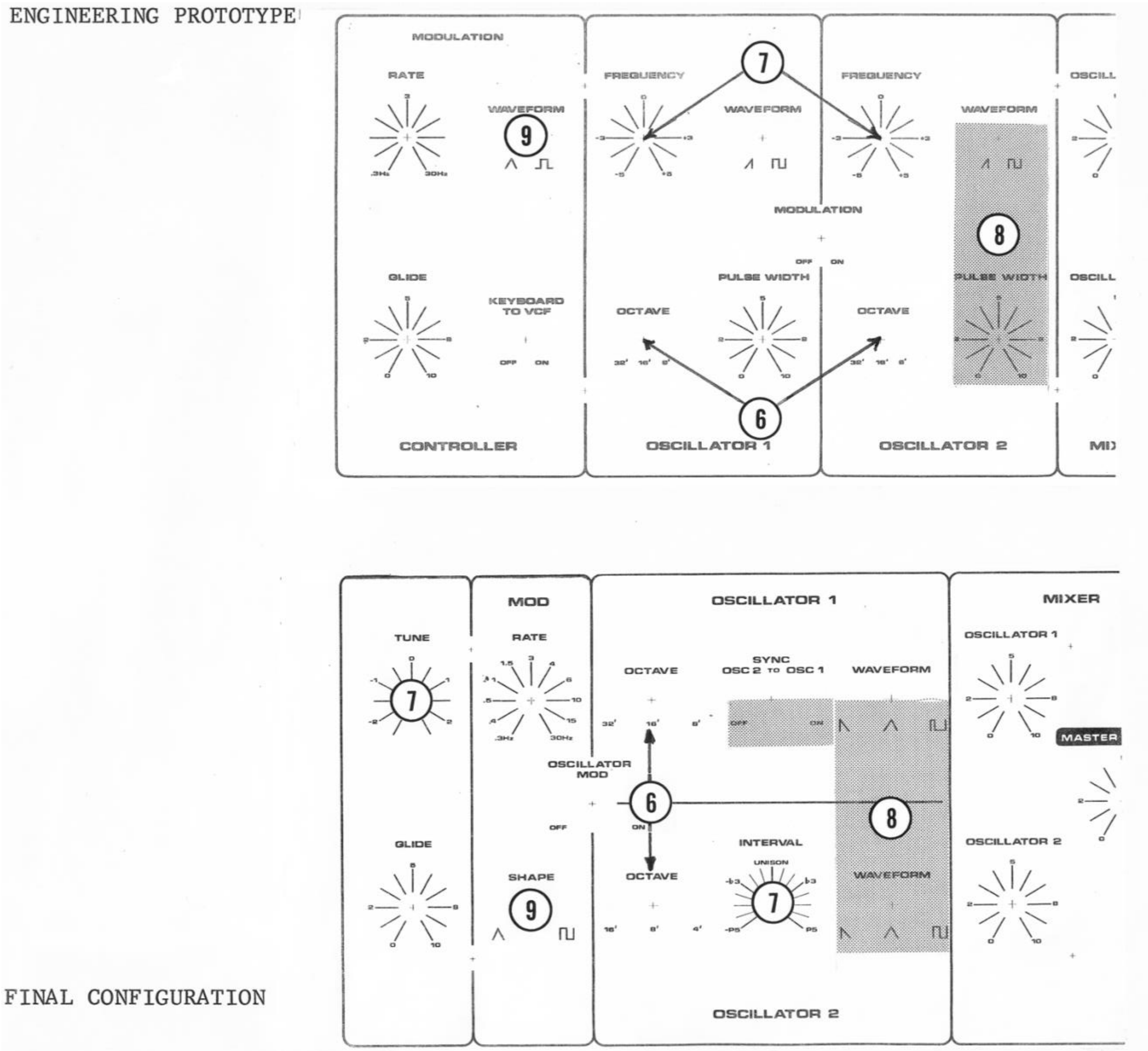


Exhibit C: Primary Tonal Sources

#6

The Prodigy has a short (32 note) keyboard. The proto-type further restricted oscillator range by having only 32', 16', and 8' ranges. I "staggered" the oscillator octave ranges to provide one oscillator with 16', 8', and 4' ranges. When using a single oscillator, the net effect is to increase the range of the instrument by one octave. When using both oscillators, wider intervals may be tuned and played in parallel. When you wish to play in the 32' range with a two oscillator ambience, the OSCILLATOR 2 triangle waveform may be selected and mixed with a complex waveform on OSCILLATOR 1 and the octave differential will be negligible--sounding like multiple oscillators at 32'.

#7

The only advantage (on the prototype) that individual FREQUENCY controls on each oscillator offers is the ability to transpose the instrument's overall pitch. Since the instrument can be voltage controlled externally, this was considered an unimportant advantage. Instead, an overall TUNE control was added to provide tuning over both oscillators simultaneously, and an INTERVAL control acted to tune only the second oscillator. All intervallic tunings for parallel intervals are still possible, and overall tuning is doable. Try tuning an interval on several oscillators, and then tuning to a new overall tonality when pitch changes in the band! Holding the intervals while retuning to the new pitch level is almost impossible unless a master tuning control is available. I would have preferred to have the TUNE control on the rear--to avoid accidentally brushing it, but this was deemed impossible.

#8

On the prototype waveform selection was limited to the sawtooth and variable rectangular waveforms--all complex. Four controls were required in this arrangement. I called for the inclusion of the triangle waveform--a fundamentally different class of sounds was therefore added. To further increase the palette of timbres, sync was added-·in conjunction with the pitch bending wheel which was made to control only OSCILLATOR 1 when the SYNC switch is ON. This made possible a wide range of static and dynamic unusual timbres.

#9

I don't like slidepots. They are hard to see; that is, their status is difficult to see. On the prototype this problem was exacerbated by graphics and legends that were printed too close to the center of the slider. Note the difference in spacing; for instance when the square wave is selected on WAVEFORM on the prototype, it is hard to confirm this visually. On the new arrangement, when the square wave is selected, the graphic for the triangle wave falls outside the leftmost edge of the slidepot. This makes it easy to see that the triangle wave is not selected. A negative utopia to be sure.

POSTSCRIPTS

Note that, on the final configuration that the duty cycle for the two rectangular waves is not the same. (OSCILLATOR 2 is a square wave; OSCILLATOR is a narrow rectangular).

Numerous nomenclature changes were made also. For example, the dual function of the DECAY/RELEASE control was made explicit with that designation rather than calling it simply DECAY. Also, legends for sections were placed at the top so they could be seen even when the hand roams the panel.