Advanced Note: Convolution devices -- a separate class of timing devices

1. ***Timing devices*** denotes a class of proposed devices that might be manufactured and used by electrical engineers and similar technology professionals. Timing devices are intended to mimic essential activity of neurons in brains. Assemblies of timing devices are intended to mimic essential activities of brain parts, e.g., those that use sensory inputs to control muscular action. One project is to design a six-legged engineered organism with equivalents of pressure and stretch sensors and equivalents of muscular bands. The organism would use a variety of muscular coordination patterns (“shimmering gaits”) to find a path through, over and around obstructions in a terrain through which the organism is moving in a fixed overall direction.

Timing devices are defined as electrical engineering devices in the same style as circuit elements in circuit theory.

Circuit theory starts with a small set of simple devices, namely, resistances, inductances and capacitances. The devices are defined mathematically and are ideals; and they are also embodied in physical devices, namely resistors, inductors and capacitors that can be purchased and soldered together. The definitions are stated in terms of voltage and current of electrical signals passing through the elemental devices, both mathematically and on the workbench. An engineer learns methods of construction to assemble circuits from the simple devices. After the engineer learns simple methods, additional devices can be added to “kit of parts,” e.g., switches, transformers and transistors.

Similarly, the timing devices system starts with the set of devices set forth in *an Ear for Pythagorean harmonics*. Signals are made up of pulses. At this time, timing devices are only conceptual, but my intention is that the concepts should be embodied in physical devices that are manufactured and made available to engineers. The idea is that useful assemblies of timing devices can be constructed that mimic the activities of brains. Working on timing device constructions becomes a means of researching brains.

2. ***Convolution devices*** are a new class of timing devices that are different from and in addition to those defined in *an Ear for Pythagorean harmonics*, now the standard statement of timing device principles. Convolution devices embody a method of electrical engineering, called “the convolution integral.” Discussion of the convolution integral is beyond the scope of this note and knowldge about it is presumed.

3. Formal definitions: A ***timing device*** is a constructional element that engages in activity involving ***pulses***. As a “constructional element,” a particular timing device participates in ***assemblies of timing devices*** that are constructed by an ***engineer***. The “activity” of a timing device is that it ***receives input pulses*** and ***produces output pulses***. A “pulse” is a uniform packet of energy that is received within a time interval (denoted “α”) that is much shorter than all other relevant time intervals. Similarly, production also takes place within α. In comparison to all other time intervals, $\alpha \rightarrow 0$. The relationship between input receipt and output production must be defined for a particular kind of timing device.

4. Begin with a timing device with one "projection onto" that carries input pulses to the timing device and one "projection from" that carries output pulses away from the timing device. There is a "laboratory clock" that provides a uniform time reference. Each pulse occurs at a ***pulse moment*** that is defined as an instant in time. Let pij=tj where pij is the j-th input pulse and tj is instant of the corresponding pulse moment,e.g., tj=3' 2.00" on the laboratory clock. Similarly pok=tk is the k-th output pulse.

Let $\pi ij = pij - pi(j-1)$ and
$\pi ok = pok - po(k-1)$.

This set of definitions turns "pulse moments" into "pulse intervals."

3. Suppose

$\pi ij = \pi i(j-1) = \pi i(j-2) = \pi i(j-3) = ...$ That is, the input consists of a steady stream of pulses, separated by a uniform pulse interval, πij.

Then, it is reasonable to define the operations of a timing device so that the output is also a steady stream of pulses:

$\pi ok = \pi o(k-1) = \pi o(k-2) = \pi o(k-3) = ...$

This activity is, of course, realized when $\pi ok = \pi ij$.

I call such activity ***dwelling***. Dwelling is like a "0" signal on a line. It is the point of origin and point of reference for all other activity.

[This Note is being written along with "Shimmering Silences in Beautiful Music" in which dwelling is extensively explored in a larger context. Dwelling activity includes the "beat" of music, the "tonic" of music and "muscle tonus" in the bodies and lives of animals.]

4. Define a ***time averaging timing device*** as follows:

$\pi ok = [1/M] \{ \pi ij + \pi i(j-1) + \pi i(j-2) + ... + \pi i(j-M+1)]$. "M" is called the ***span*** of the average. If M=2, πok, the interval between two output pulses, will be the average of a ***pair*** of intervals between two input pulses. A steady but irregular two-beat, -tə-DAH-tə-DAH-tə-DAH-, delivered as input, will result in a steady and regular output, dah-dah-dah-dah-dah-dah-. Longer spans result in more smoothing but may also show long term trends in erratic patterns. The similar method in stock market analysis is called, e.g., a "30 day moving average."

It is possible to conceive of applications for time averaging timing devices in systems of timing device assemblies that control the activities of an engineered organism. A rise in activity that persists through time averaging can trigger action while a short rise will not, allowing for selection on the basis of long-term changes over short-term changes.

5. The time averaging timing device is the simplest case of a convolution device – just as a

“30 day moving average” is the simplest type of convolution integral.

To define a more complex form of ***convolution timing device***, re-write the definition of § 4 as follows:

Definition 1: $\pi ok = [1/M] \{dj \cdot \pi ij + d(j-1) \cdot \pi i(j-1) + d(j-2) \cdot \pi i(j-2) + ...$
$+ d(j-M+2) \cdot \pi i(j-M+2) + d(j-M+1) \cdot \pi i(j-M+1)\}$

The new terms in Definition 1 of the convolution device,

$dj, d(j-1), d(j-2) ... d(j-M+2), d(j-M+1),$

are ***coefficients***. Each coefficient is a non-negative real number. The “ · “ means multiplication and the coefficients all start out as “1,” in which case the convolution timing device reduces to the time averaging timing device. However, the coefficients can vary, so long as there is maintenance of an invariance constraint:

$dj + d(j-1) + d(j-2) + ... + d(j-M+2) + d(j-M+1) = M.$

Define a ***convolution function*** by stating its terms $c0, c1, ..., cM$. The c’s are like the d’s and also collectively satisfy the invariance constraint, expressed as:

$c0 + c1 + c2 + ... c(M-2) + c(M-1) = M.$

A convolution device is defined by stating its convolution function. Given the convolution function of the device and the set of input pulse moments up to a given instant, {pij}, the definition suffices to calculate the time of production of the next pulse. For concrete specificity, let the convolution timing device work in the following fashion: at the instant that an output pulse is produced, the time of the next output pulse is set based on input pulses up to that instant. Although input pulses may be received by the timing device (or not) after production of an output pulse, such receptions do not affect the time of production of the next pulse.

We need to get the definition of the convolution function to work in Definition 1, the definition of the convolution device, which means matching the d’s with the c’s. As a practical matter, this means “flipping the convolution function” in a fashion learned by engineering students when they do convolution intergrals. The key is that the most recent pulsings, measured by πij, $\pi i(j-1)$, etc., involving the latest times, are to be evaluated according to the earliest part of the convolution function, using c1, c2, etc. Accordingly, matching the defining values of the convolution function with the appropriate coefficients in the definition of the convolution timing device calls for:

$c0 = d(j-M+1), c1 = d(j-M+2), ... , c(M-2) = d(j-1)$ and $c(M-1) = dj$. Hence, when calculating the next output pulse with Definition 1, use:

$dj = c(M-1), d(j-1) = c(M-2), ..., d(j-M+2) = c1$ and $d(j-M+1) = c0.$

Convolution timing devices are a means to enable past activity to influence present activity. If the convolution function has a peak near c0, c1, etc., the most recent activity will be most influential. If the convolution function has a peak near the middle of the convolution function, middle-aged activity will be the most influential. And if the convolution function has a peak toward the end, the oldest activity will be the most influential. The peak of the convolution function can be changed during operations, giving the engineer another kind of control.