A formal Virtual Energy model for Gazer device designs

A Garden of My Own — lyrics and music by Patricia McKernon Runkle

Refrain:

There’s a place where dreams are gathered,
There's a soil where seeds are sown,
There’s a light beyond the shadows where truths are known.
In this light I reach for heaven, In this soil I root my soul,
In this place I have a garden of my own.

Time was I was up at dawn and eager for the field,
Time was I was welded to the plough,
Time was I would work as hard as flesh and bone allow
Till the glory of the harvest was revealed.

(Refrain)

These days I am on my knees with flowers in my hands,
These days I refuse to plant in rows,
These days I can feel a seedling tremble as it grows,
And the heartland deep within me understands.

(Refrain)

Who knows whether time and quiet faith bring something new,
Who knows if I learn to improvise?
Who knows if a flower never seen before will rise
And the world will be the richer for its hue?

(Refrain)

A. Preliminaries and overviews

§ 1. Primitive concepts, models, substances, atoms and energies.

Virtual Energy (VE) designs are constructed in imagination and are aimed towards a goal beyond the reach of this project: Shimmering Sensitivity, a model of a physical principle of freedom that is manifest in movements of animal bodies. For a discussion of Shimmering Sensitivity, please see Contests (sports and games), part B of Domains of Freedom.

Primitive concepts are elements of construction, denoted by an asterisk* at the first structural use. Primitive concepts need not be further defined; or they can be defined by other concepts or implicitly by practice and use.

Sometimes, the construction style of the VE model resembles the rigor of classical geometry, with its primitive concepts of points, lines, axioms, theorems, straight-edge and compass; other times, a looser rougher style of construction expedites development. Like modern geometries, VE designs can use conflicting principles in distinct constructions. Geometrical constructions are built in space; VE constructions operate in time.

Models. Goals of projects include models* called (engineered organisms)* that mimic movements of animals. Other models of organisms are dolls, marionettes and robots.

Generally, a (physical model)* is built using technology; activities of a physical model are organized by a symbolic or (conceptual model)*. Unified conceptual and physical models are found in electrical circuit theory, mechanical engineering and biochemistry; such standard models provide guidance for VE models, which are only conceptual at this time.

Overview of the formal VE model. The formal VE model is developed through construction of (VE devices)*, (VE modules)* and larger systems. Supplied with ample VE and controlled through (signals)*, VE devices perform operations* and functions* that resemble those of electronic components. A module is an assembly of devices, sometimes resembling an integrated circuit. (VE designs)* resemble electronics designs called "schematic diagrams" constructed according to circuit theory; schematic diagrams often define an actual product of electronics technology.

VE devices are organized as (kits of parts)*. A kit of parts has a (primal device)* and devices that are based on the primal device and that may have additional or modified features* and operations. Major kits of parts are projections*, pulsers*, (timing devices)*, bursters*, movers* and the (force fiber devices)* that make up movers.

Larger constructions culminate in engineered organisms. Devices, modules and larger constructions operate in bodies* with specified properties* and processes* that maintain and influence movements. Properties of bodies are foundational in (collective devices)*, e.g., (quadnet devices)*. In anticipated designs, Shimmering Sensitivity occurs during critical moments generated by operations of quadnet devices.

Substances. The VE conceptual model is based on substances* studied in science, namely, H_20 and other molecules, electrical charge and Conserved Energy. (Virtual Energy)* (VE) is an imaginary substance that is constructed from common features of H_20, chemical bonds, electrical charges and Conserved Energy.

Atoms and energies. VE models, like conceptual models of mechanics (Newton's mechanics, statistical mechanics, quantum mechanics), are used to construct movements of elements in imaginary domains, e.g., in a diagram on a chalkboard. Imaginary events are intended to resemble or predict actual events involving material bodies in nature*, in a laboratory or in technology.

VE models lack the universal concepts used in mechanics. Universal concepts such as gravity, elementary particles and random chance are presumed to apply in all situations and at all times. Specific applications only provide useful examples. Concepts in VE models, on the other hand, are tethered to specific applications — even while a researcher seeks to extend concepts to new situations.

I suggest that methods based on specific applications work better for investigations aiming at models of feelings and freedom. Universal concepts imply commitments to uniformity, predictability and eternal, comprehensive Laws of Physics. As discussed in the free-will puzzles project, those who hold such commitments turn their backs on movements of animal bodies that involve feelings; and they exclude freedom.

In *Rational Thermodynamics* (2d ed. 1984) at 424, C. Truesdell observes that such commitments in physics "reflect a failure to come to grips with the real complications of nature. Beyond the easiest and long-mastered special cases, nature is too intricate for any inclusive theory." These observations are also pertinent to theories about movements and feelings of animal bodies.

Truesdell compares two methods used by mathematical physicists to investigate flows of fluids. First are continuum methods originating with Claude Navier and George Stokes where a fluid is modeled as a mobile substance with idealized properties (e.g., linear relation between flow velocity and force of viscosity). Second are statistical and kinetic methods originating with James Clerk Maxwell and Ludwig Boltzmann where "the type of material [is] a moderately rarefied monatomic gas" in which "the molecules are mathematical points" and "all collisions are binary even though the intermolecular forces may extend to ∞." (Truesdell at 383, writing about another topic.)

Truesdell continues at 424: "Different models have different uses; they emphasize different aspects of nature, often at the expense of leaving others altogether aside. Such is clearly the case in the kinetic and simple theories of fluids. One leaves out bulk viscosity, the other some effects of non-homogeneity … Each leaves out much more, not the same for either. Each has its virtues…"

Truesdell also notes: "A good deal of misunderstanding seems to arise from the differences in psychic motivation. Researchers in statistical or kinetic theories are inclined to claim a kind of universality for their own results and hence to presume in others like aspirations to empire. Modern continuum mechanics has been, from its start in 1945, frankly a theory of models. No one, as far as I know, has *ever* claimed any universal truth for the theory of simple materials."

This project adapts scientific models based on (1) atoms and (2) energies. Atomic models of H_2O and electrical charge employ tiny identical units with quantities that combine like numbers in arithmetic. Conserved Energy and Virtual Energy invoke abstract powers that cause movements and changes. VE models combine atomic aspects and energy aspects and develop in new directions.

First, an atomic model is constructed by means of "a certain mode of thought, suited to certain subject-matters: that in which an array of primitive elements is subject to specified principles of combination which generate determinate relations between complexes of those elements. This combinatorial mode of thought [] yields a certain kind of novelty in the domain at issue [] and proceeds in a bottom-up style …" (Colin McGinn, *Problems in Philosophy* (1993) at 18.)

In *Rational Thermodynamics* at 353-54, Truesdell applies a combinatorial mode of thought to ordinary chemistry defined in terms of "exchanges of mass among the constituents of a mixture" — that is, a mixture of specific materials such as chemical reagents.

> In ordinary chemistry, the exchanges of mass are restricted to a special kind, according to the laws of "chemical reaction". In such reactions the constituents combine and disassociate only in definite proportions. These proportions are commonly explained by saying that each substance consists of "molecules" and that each molecule is composed of a certain whole number of "atoms" of a few specified kinds. … In the reactions, molecules are created or destroyed, but the atoms are permanent in number and nature. The terms "atom" and "molecule" are merely convenient for visualizing the rules of definite combination and need not be thought as denoting corpuscles, nor need we limit the interpretation to strictly "chemical" changes. All that needs to be assumed is that each constituent is made up by combination in fixed proportions from certain individually indestructible constituents. Nevertheless, the terms "atomic" and "molecular are so familiar that I occasionally use them in describing the pure phenomenology of reactions.

In contrast to the uniformity of atomic models, energy models manifest motley modes of thought suited to specific subject matters. In about 1970, various statements of thermodynamicists were collected and published, including:

> "It is amazing to note the conflicting opinions expressed by eminent scientists." (I. Prigogine)
>
> "We all seem to have a different, a private congenial way of justifying the First Law, etc., and argue about the rationale in each separate formalism." (J. Kestin)
>
> "Thermodynamics is something which develops, which expands, which grows, and it has the capability of growing, and this kind of growing is just like the house that Jack built, by patching on and patching over and mending, and so this is the reason, I believe – the historical reason – why there are so many differences in deriving thermodynamic properties." (O. Redlich)
>
> "The motivation for choosing a point of departure for a derivation is evidently subject to more ambiguity than the technicalities of the derivation. Motivation is tied up with psychological and philosophical factors, and these are nowadays not considered bona fide topics for public discussion." (L. Tisza)
>
> "I hesitate to use the terms 'first law' and 'second law', because there are almost as many 'first laws' as there are thermodynamicists, and I have been told by these people for so many years that I disobey their laws that now I prefer to exult in my criminal status." (C. Truesdell)
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> "...(entropy) is a property, not of the physical system, but of the particular experiments you or I choose to perform on it." (E. T. Jaynes)
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> [Stuart, E.B, Gal-Or, B. and Brainard, A.J. eds. (1970) *A Critical Review of Thermodynamics*, Baltimore, MD: Mono Book Corp., 1, 509, 510; Gal-Or, B. (1974) ed., *Modern Developments in Thermodynamics*, New York: John Wiley & Sons, 435, 436, 439), extracts also quoted in "A Patchwork of Limits: Physics Viewed From an Indirect Approach" (2000) at 18-19.]

The *Feynman Lectures on Physics, Vol. I* (1963) develops atomic models for most of the book. Chapter 44 on "The Laws of Thermodynamics" starts:

> So far we have been discussing the properties of matter from the atomic point of view, trying to understand roughly what will happen if we suppose that things are made of atoms obeying certain laws. However, there are a number of relationships among the properties of substances which can be worked out without consideration of the detailed structure of the materials. The determination of the relationships among the various properties of materials without knowing their internal structure is thermodynamics, Historically, thermodynamics was developed before an understanding of the internal structure of matter was achieved. (Page 44-1.)

At page 45-7, *The Feynman Lectures* presents a "comparison [that] shows the advantages and disadvantages of thermodynamics over kinetic theory." Summing up the comparison is the conclusion:

> When knowledge is weak and the structure is complicated, thermodynamic relations are really the most powerful. When the situation is very simple and theoretical analysis can be made, then it is better to try to get more information from theoretical analysis.

Powerful thermodynamic relations include "activation energies" that relate the rate of a chemical reaction to the temperature of the body or environment. Many reactions go faster when the temperature is hotter; an activation energy expresses this relation mathematically. Activation energies are used in metallurgy and biochemistry. Svante Arrhenius (1859-1929) constructed the original activation energy by extending experimentally-based thermodynamics methods. Similar activation energies were later constructed using statistical methods.

In the domain of engineered organisms, the subject-matter for models is "interactive muscular movements and feelings of animal bodies." Applying Feynman's criterion, "knowledge is weak and the structure is complicated." Therefore, Virtual Energy models are constructed along the general lines of thermodynamics with atomic forms incorporated in various aspects such as pulses on projections, combinatory twitches and stepwise arrays of stationary positions.

2. Common features of certain substances (H_2O, electrical charge, Conserved Energy) are combined in a concept of formal substances. Virtual Energy (VE) is an imaginary substance that incorporates such common features and resembles such substances.

The Virtual Energy ("VE") substance. Like H_2O, electrical charge and Conserved Energy, the VE substance has a unique character* and is defined by features: form*, quantity*, spatial location* and distribution*. Changes* in features are constrained by (conservation principles)*.

<u>Steps in the construction</u>.

a. Substance: character, form, quantity, location and distribution.

b. Initial VE conservation principles apply to changes in location and distribution of the VE substance, changes called, e.g., "transport," "movements" and "flows."

c. VE conservation principles are extended and applied to changes between static forms (stored in VES) and action forms (forceful twitches and VE sources, pulses and currents).

d. An energy potential is a capacity to produce changes.

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a. Substance: character, form, quantity, location and distribution.

H_2O. The symbols "H_2O" refer to both atomic-molecular models and continuum models; and they label all forms of the material substance "water," while restricting use of the word "water" to the liquid form. A (material substance)* is derived from stuff found in nature; often, it has undergone processes of isolation and refinement to bring it into closer correspondence to products of human imagination.

The character of a substance is a unique and expansive collection of aspects*. As one aspect of its character, H_2O has "mass" that is subject to forces arising, e.g., from gravity, hydraulic pressure and vortices. "Form" is an aspect of character that is based on practical experience. Solid forms of H_2O are ice and snow; gaseous forms are vapor and steam. Often, knowledge applicable to one form of a material substance does not apply to other forms; and knowledge about changes between forms may be sketchy, e.g., changes occurring when a cloud of water vapor condenses to form symmetrical snowflakes, as discussed in the free-will puzzles project.

In this first step of construction, each body of H_2O has a single such form, which does not change. The form is static* when the body is stationary; and the form is fluid* when liquid or gas is moving with respect to a stationary constraint, e.g., inside a tube.

The "quantity" of H_2O in a body can be measured as a certain number of molecules. In ideal measurements, each cup of water or pound of ice has a specific number of molecules.

Quantities are subject to rules of arithmetic, with perfect additions, etc. To start, the number of molecules in a body is constant. Inside a body, molecules may be fixed or vibrating or mobile. At each moment, each molecule has a specific spatial "location" in the body described by a tiny (submicroscopic) volume. A "distribution" is a mathematical relation that assigns a specific number of molecules to each specific tiny volume of the body. Such distributions are combined and organized using differential equations with standard features and operators.

Electrical charge. Basic features of H_2O (character, forms, quantities, locations and distributions) re-appear in initial models of electrical charges. The charge substance is said to subsist in stuff found in nature and resembles a material substance. It co-exists with mass (in protons and electrons) and interacts with mass but with a character different from that of mass. Like H_2O, charge has multiple forms, e.g., static charges in storage batteries and capacitors and fluid currents in copper wires.

Electricity has additional features. (1) There are two kinds of electrical charges, namely, positive charges and negative charges. (2) In static arrangements, two charges of the same kind repel each other forcefully. Two charges of different kinds attract each other with a force equal to that produced by charges of the same kind but in the opposite direction.
(3) Moving charges produce new forces that are more complicated than forces produced in static arrangements.

In initial static models of a standard atom, a number of positive electrical charges are associated with material particles called protons, and the same number of negative charges are associated with particles called electrons.

Protons and electrons have the same invariant quantity of charge but they are distinguished by "positive" and "negative" labels. Charges can be combined; in a combination of charges, positive and negative charges are added like positive and negative numbers. Sums of positive and negative charges cancel* each other with a result that often has no net charge, so that the body is electrically neutral. Charges in an electrically neutral body (e.g., a storage battery) can be separated* to produce equal numbers of positive and negative charges.

As with H_2O, static distributions of electrical charge are assigned by mathematical relations to locations in the body. Methods of differential equations that apply to water and steam also apply to static charges and steady current flows. Standard features of differential equations that describe such forms of H_2O also describe charge, e.g., gradient and laplacian operators.

Actual Energy. I presume that there is "something" called (actual energy)* that pervades our bodies — and everything else in the immensities of external nature — a "something" that reaches by means of a food chain from the radiance of the sun to the beating of my heart and the thoughts of my brain. I presume that actual energy is beyond our capacity to understand fully but that we can construct useful models of some aspects through methods of Conserved Energy and Virtual Energy.

An overall view of actual energy suitable for an initial VE model was set forth in *The Phenomenon of Man* (1955, 1959 English transl.) by Teilhard de Chardin. I have revised his statements by substituting “body” for his “atom” and “change(s)” for his "transformations" and “synthesis.” A few of his words are omitted as unnecessary distractions. (The original version is quoted in the paradigms project.)

> … Energy is the measure of that which passes from one body to another in the course of their changes. A unifying power, then, but also, because the body appears to become enriched or exhausted in the course of the exchange, the expression of structure.
>
> … Hence we find our minds instinctively tending to represent energy as a kind of homogeneous, primordial flux in which all that has shape in the world is but a series of fleeting ‘vortices.’ From this point of view, the universe would find its stability and final unity at the end of its decomposition.…
>
> Let us keep the proofs and indisputable measurements of physics. But let us not become bound to the perspective of the final equilibrium that they seem to suggest. …(pp. 42-43.)

> First Principle. During changes of a physico-chemical type, we do not detect any measurable appearance of new energy. …
>
> Second Principle. In every physico-chemical change, adds thermodynamics, a fraction of the available energy is irrevocably lost in the form of heat. Doubtless it is possible to retain this degraded fraction symbolically in equations so as to express that in the operations of matter nothing is lost any more than anything is created, but that is merely a mathematical trick. As a matter of fact, something is finally burned in the course of every change to pay for that change. (pp. 50-51.)

Conserved Energy. (Conserved Energy)* (CE) is not derived from stuff found in nature and is not a material substance. The term denotes a collection of mental inventions drawn from diverse physical phenomena. [See C. Truesdell, "The Tragicomedy of Classical Thermodynamics" (1971); T. H. Kuhn, *The Essential Tension*, "Energy Conservation as an Example of Simultaneous Discovery" (1956).]

In other words, common features of such Energy appear in very different domains of investigation, e.g., moving massive bodies, high-altitude lakes, electrical devices and chemical reactions.

In *Thermal Physics* (1964) at 35, Philip M. Morse identifies important features of Conserved Energy:

> Both the first and second laws of thermodynamics are most simply stated in differential form. We are not often interested in the total quantity of energy possessed by a body, even if we could define or measure it. What is important is the relationship between the amounts of different sorts of energy which are added to or taken away from the body. The first law says that there is a generalized store of energy, possessed by a thermodynamic system, called its internal energy U, which can be changed by adding or subtracting energy of any form, and that the algebraic sum of all these added or subtracted amounts is equal to the net change dU, of the internal energy of the system. Put another way, it states that U is a state variable of the system, that dU is a perfect differential, that when the system is in equilibrium in a given state, its internal energy always has the same value, no matter how the state was reached.

Formal Substance. Definitions of form, quantity, location and distribution of CE follow the familiar outline. In a thermal system (e.g., a steam turbine), an "energy substance" appears in static and fluid forms and is described by variable quantities, locations and distributions that are organized by differential equations.

A (formal substance)* is defined by said features. Restricted models of H_2O, electrical charge and CE qualify as substances under the definition. Initially, VE is constructed to qualify under the definition so that concepts of scientific substances can be adapted to new uses.

Simple models of diffusion for the four substances manifest common features. A single set of concepts is applied in different versions. The original version was invented by Fourier to describe changing temperatures in bodies that conduct heat. Other scientists extended his methods to model movements of charges in electrical wires and movements of salt molecules in water. VE device models of diffusion are constructed in §8(h) below, including VE device operations that resemble gradient and laplacian operators in differential equations.

Virtual Energy. The formal substance VE is like a primal device that is developed into more complex devices. Initial VE constructions start as a variant of CE, including features of form, quantity, location, distribution and mathematical representation. Initial models incorporate additional atomic features, e.g., the one-bang pulse.

The quantity of VE stored in the body of a VE device ($\mathcal{V}(t)$) serves functions like those of Internal Energy (U) in CE. Basic VE conversions and flows resemble those of H_2O, electrical charge and CE.

In further developments, features of VE are modified. Production of unquantified waste heat overrides "Laws" of conservation. Dissipation principles are used to control certain operations. New features are added to models based on physical principles imputed to bodies, e.g., principles of synchronization and entrainment. Constructions extend to arrays, modules and assemblies of devices with interactive and collective repertoires.

Certain aspects of VE differ markedly from those of CE. There is no global energy law in VE but only a patchwork of a few specific principles. Anticipated applications will not depend on state variables with perfect differentials participating in a network of well-defined relations. Instead, tiny changes in inputs will suddenly cause big powerful movements.

In contrast to the maintained equilibrium and quasi-static processes of CE, rapidly changing input streams of VE can participate in wide-ranging processes where output streams of VE go through sudden transformations. Processes pass through (critical moments of Shimmering Sensitivity)* that resemble eddies and turbulence in fast-flowing waters. At the climax of a critical moment, multiple possible "next movements" co-exist and can change easily into one another; this is a Shimmering condition. As the process runs to completion, multiple possible next movements change into a few selected* actual movements that exclude all others. Such a result can depend on tiny influences arising from multiple kinds of Sensitivity. VE models of such selections are chief aims of construction of this model.

In the first VE models, VE fits requirements of mathematical distributions; but I do not presume that VE is locatable in submicroscopic spaces under all circumstances. I anticipate that, during critical moments of Shimmering Sensitivity, VE is unlocalized within a momentary action form that extends over multiple modules containing collections of devices. A shimmering VE distribution condenses to a specific actual distribution and then to specific actual movements like water vapor condenses to form a snowflake.

I suggest that, during a critical moment, a whole-body change of form can also generate a flicker of an image*, e.g., a feeling*. (Thoughts* are another kind of imagery.) I suggest that the feeling participates in the change; a different feeling accompanies a different change.

In device assemblies, a steady stream of feeling can be generated when multiple uniform bodies flicker in a cyclical sequence. In an assembly of bodies that pass through critical moments together, images in certain bodies can control movements of other bodies. A selective change in imagery causes a selective change of movement. I suggest that this activity ("changes in images control changes in movements") resembles that of "free will."

b. Initial conservation principles apply to changes in location or distribution of the VE substance, changes called, e.g., "transport," "movements" and "flows."

In common experience, the quantity of physical material in a body remains constant during changes in location ("transport") of the body, e.g., dirt being carried in a wheelbarrow or liquid water flowing in a pipe. No new material appears without a source. Perhaps a small quantity of material is lost in transit; the loss is reduced to zero during ideal movements. Thus, a conservation principle applies to material transport with zero loss.

Scientific models of substances include concepts of transport that are based on common experience of conservation. At p. 108 of *Thermal Physics*, Morse discusses a situation where moving matter (n), energy (U) and entropy (S) encounter a semipermeable partition D; and he asks what happens when "one of the 'fluids,' S or U or n, flows through D."

Conservation principles are applied in models of H_2O, electrical charge and Conserved Energy where they are called mass conservation, charge conservation and energy conservation respectively. These conservation principles are sometimes said to be laws of nature.

In the domain of animal bodies, principles of actual energy are stated above in my version of de Chardin's principles: "As a matter of fact, something is finally burned in the course of every change to pay for that change." An appearance of conservation is " merely a mathematical trick."

In this construction approach, an appearance of VE conservation is the result of device design. Looking at the device part "projection" as a leading example (Fig. 1, p. 23 below), a pulse of VE moving on a projection carries a certain quantity of VE called "one bang." One bang is discharged onto the projection from a discharging device in one location (the "origin") and one bang arrives at a receiving device in a different location (the "destination"). This operation appears to be conservative.

Similar to requirements of actual life, the projection is consuming VE while performing the operation of pulse transport. Consumption of VE continues during periods when no pulse passes. VE that is not used to transport a pulse ends up as waste heat. Such VE consumption and unquantified waste heat are disregarded in the conservative model of pulse transport.

Conservation of VE during transport is modeled by arithmetic operations. A quantity of VE is subtracted from one location and an identical quantity is added to another location. If the subtraction and addition occur at the same instant, the transport is instantaneous. Otherwise, the subtraction must occur before the addition.

Principles of energy conservation during transport are easily applied to massless and electrically neutral VE that is limited to a few defined changes. In this approach, VE conservation during transport is treated as axiomatic. VE devices and operations are presumed to produce movements of VE that appear to conform to the axiom.

c. VE conservation principles are extended and applied to changes between static forms (VES) and action forms (forceful twitches and VE sources, pulses and currents).

An arithmetic model of conservation can be extended to changes between forms of substance in a body. A quantity of the substance is subtracted from one form and an identical quantity is added to another form. The subtraction and addition occur at the same instant. Such quantity is said to have been "converted."

Arithmetic models apply to changes of form of H_2O, electrical charge and Conserved Energy. Ice melts to water and water boils to steam. Canceled charges in a storage battery separate and spread inside a capacitor. Steam flows through a turbine; heat energy is changed to electrical energy. In each case, a quantity of substance changes form and conservation principles are applied arithmetically.

The primal timing device provides an example of conservation during changes of form of VE (see Fig. 14, p. 36 below). One bang of VE in the form of a pulse arrives at the timing device via an input projection. That pulse is converted into a bang in the VES where it is stored. Then, VE in the VES is converted and discharged as a one-bang pulse. "One bang in, one bang out" conforms to the axiom of conservation. During operations, the timing device is consuming VE and producing unquantified waste heat; but this is disregarded in the conservative model.

Current VE designs involve a small number of conversions. Static stores of VE are converted into forceful twitches in one kit of device parts (movers) or into output pulses in other kits (pulsers, timing devices, bursters). Input pulses are converted into static VE stored in the VES of a device. Or an input pulse triggers the release from a reservoir of VE into the device. (Input pulses also perform other operational functions.) In background, VE sources provides VE flows needed for device operations. Conservation principles are incorporated in designs, which also incorporate dissipation principles and bodily properties. Arithmetic conservation rules are disregarded when expedient while de Chardin's principles remain as guides.

d. An energy potential is a capacity to produce changes.

A concept of potential energy starts with gravity. In a Conserved Energy model, potential energy is stored in a body raised to a height above the ground, e.g., an arrow shot vertically upward. Conserved Energy stored as potential energy changes into kinetic energy if the body then falls without constraint from that height to the ground.

The concept was easily extended to "electrical potentials" measured in "volts" and referenced to a "ground" that identifies the voltage of Earth. Other extensions led to "thermodynamic potentials" such as Gibbs Free Energy and Enthalpy that are involved in models of thermodynamic processes and chemical reactions.

VE potentials are investigated in constructions in §8(h) of this project.

3. Constructions occur in a VE domain that resembles those used for electrical and electronic devices. The VE domain features a plenum of sources of VE, deformable space and hierarchical time.

a. plenum of sources of VE

VE domains are imaginary environments for device constructions, including sources of VE for all VE devices.

Similar physical models using electrical and electronic devices are built on breadboards and printed circuit boards. "Schematic diagrams" provide conceptual parallels. Similar to an electronics domain, a VE domain has access to power at every location. Likewise, animals have circulatory systems that carry sugar, oxygen and other nutrients to every living cell. In VE systems, as in other such cases, a plenum* of energy sources is accessible through foundational functioning of the system.

An (energy economy)* is progressively constructed as part of VE models. A chief economic principle is minimization of energy expenditures while maintaining successful performance of functions. Guidance for development is suggested by minimal or variational principles in physics, e.g., principle of least action. Animal bodies also minimize net energy expenditures, e.g., "taking a shortcut." Acquisition of food and an energy economy appear as important purposes behind movements of animals.

b. deformable space

Parts in a VE design can be re-arranged by squeezing, stretching or bending of spatial dimensions. Such (deformable space)* is based on an operating feature of VE designs, namely, the (instantaneous transport)* of a pulse on a projection. Regardless of the length or shape of the projection, the "zero" time of transit is the same.

The instantaneous passage of a VE pulse on a projection resembles the (nearly) instantaneous passage of an electrical signal in a metal wire or the (nearly) instantaneous movement of water under pressure in a pipe when a valve is opened. The focal substance fills the inside of the body of the transport device; if a pervasive force is imposed, pushing and movement of the focal substance occurs everywhere all at once (nearly).

c. hierarchical time

VE devices operate in time structures defined by researchers for specific purposes. Here, the time structure starts with a (Master Clock)* linked to a national standard. The time structure has a hierarchical character shown in the following table. In anticipated later designs, multiple modules generate various independent time structures.

The table lists convenient values of time periods* used in current VE projects along with names and symbols. Values are subject to changes and variations as needed.

Table of time periods in VE projects

name	symbol	values	device designs
instantaneous*		0 sec.	transport via projections and channels
(fast switch)*	α	0.001 sec.	pulse width, minimum change period, junction transport
(slow switch)*	δ	0.01 sec.	pulsers, timing devices
tick*	t.	0.1 sec.	elemental time unit for movers (force devices) and bursters
beat*		0.4 sec.	4 ticks — used to synchronize and control movers and bursters

A principle of design is to include temporal (margins of silence)* sufficient to prevent successive changes from interfering with each other. One operation in a device is clearly finished before the next operation commences. For example, suppose that a pulse has a width in time of α; to maintain a margin of silence, a minimum period of 2α intervenes between the start times of two succeeding pulses on a projection. The projection restores its energy and condition during the intervening α.

4. Elements of initial constructions are VE devices that process flows of VE and produce pulse signals and muscle-like twitches. In later constructions, a body with whole-body properties contains an array of cells that hold modules made of VE devices and that operate collectively to perform repertoires of functions.

VE principles are defined for specific kinds of devices, which are elements of construction.

(a) Elemental VE conversion devices (pulsers, timing devices, movers, bursters) share uniform features: a body inside an envelope*, which isolates the body from its surroundings except for (1) quantified inflows* of source VE and input pulse signals and (2) quantified outflows* of pulses and twitches – along with dissipations* (waste heat), quantified or not.

(b) Elemental transport devices — projections, channels, receptors, junctions — are used for changes in locations and distributions of VE.

At any moment, a device maintains a specific condition*, e.g., a charging condition, a ready condition, a discharging condition. Changes in device condition are caused by internal processes and by external events.

Changes caused by internal processes occur in the primal pulser (Fig. 3). VE flows into the device, which is in a "charging condition," until a certain quantity of VE (one bang) is accumulated in the body; and then the body changes condition and discharges the bang of VE as a pulse on a projection. After which, the device begins charging again. The pulser repetitively "fills and spills," producing a "beep-beep-beep" signal.

Changes caused by an external event are shown in Figs. 14 and 15. A timing device stands in a "ready condition" and then discharges after a "trigger pulse" arrives from another device.

The action pattern or schema* of a device is defined as a sequence of conditions. First one condition, then the next condition. When a device has more than one schema, they are called (modes of operation)*. Changes of mode are caused by internal processes and external events. A device follows only one schema at a particular moment.

Collective devices are made of (arrays of cells)* in a body, where each cell contains modules made of devices. In various designs, cells are uniform or arranged in patterns of uniform cells, e.g., like a checkerboard.

Operations of such collective bodies often involve properties of the body, e.g., synchronized operations. Individual devices in a collective body may share envelopes and transfer VE through interconnecting junctions. Distributions of VE occur inside collective bodies.

Such definitions restrict VE designs to specified devices and operations. Uniform restrictions simplify and clarify constructions, serving many of the same functions as universal laws but with reduced burdens.

5. Methods of construction include kits of parts, provisional principles, presumptive bodily properties and idealizations.

    a. Kits of parts and provisional principles

In constructions below, each kit of parts starts with a primal device. Primal devices share common features: interconnectivity in a VE domain, device body and envelope, repetitive operations and one-bang pulse. Despite shared features, each primal device is defined independently of other devices. Each primal device initiates a course of development that is independent of those of other devices. Features may be adaptable between kits for purposes of smoother coordination. E.g., different kits produce pulse bursts that both drive muscle-like movers and also can be interconverted with signals from sensory devices.

VE principles and designs are provisional: there is an expectation that changes, extensions and modifications will be introduced. Designs are motivated by anticipations of and "readiness" for modification. Following a maxim of opportunism, shortcomings in present designs may suggest innovations and further development.

b. Presumptive bodily properties (synchronized, entrained, finality).

The VE model does not suggest a theory or "law of nature" for conversions of VE; rather, conversions are parts of mental constructions that are invented for particular purposes.

Further: the definition of a device may include properties of the device body that are invented, presumed or imputed. In this project, presumptive bodily properties include synchronization*, entrainment* and finality*.

Suppose that a large number of uniform VE pulsers are independently pulsing at the same rate; each device is isolated from all the other devices and there is no causal connection between devices. In such a situation, there is no basis for synchronization; there are no temporal relations or correlations between pulsers. Individual beeps turn into continuous noise.

Next, suppose that the same pulsers share a common body of material inside of which forces can move like sound waves. Perhaps devices are arranged on the surface of a wooden table — or perhaps devices are all suspended in a bowl of goo. Now the devices, as if of their own collective intent, gradually shift their activity patterns so that all devices pulse at the same instant. Throb-throb-throb. Thump-thump-thump. In this case, pulsations are synchronized.

Similar synchronized processes have been observed naturally in pendulum clocks, musical metronomes and neurons in brains. Similarities extend to synchronized movements in musical bands, choirs and dance troupes. Such natural phenomena provide justification for a bodily principle of synchronization in VE designs.

Next, the principle of synchronization is extended to state a more general principle of entrainment. Entrainment means that movements of different parts of a body occur in a fixed repetitive pattern, often at different times. Movements of distant water molecules in a wave are entrained, as are movements of parts of a beating heart. When a person drums their fingers on a table, entrained finger movements strike the table in a definite, repetitive pattern. Habits are formed from linkages of entrainments.

Examples of entrainment in music include repeated rhythmic series of tones, e.g., the opening theme of Beethoven's Fifth Symphony. The four tones in the theme are not synchronized but they are bound together in a specific memorable pattern.

In VE designs, entrainment means that classes of devices in a collective body can perform like a well-rehearsed choir, with voices in blocs of unified tones and with unified starting and ending of bloc voices. Multiple blocs of voices can be involved in many different patterns.

Ideal entrainment is further extended to state a principle of finality. Finality means that a device operation has a pre-determined specific instant of ending. The device "meets the deadline" by ending the operation on that instant with precision. Collective devices meet collective deadlines that are set by entrained operations.

Principles of finality in VE devices resemble "equifinality" in theories of human motor control based on work of Nikolai Alexandrovich Bernstein (1896-1966). Bernstein observed professional blacksmiths who aimed hammers at a piece of metal on an anvil. The head of a hammer followed a well-defined repetitive trajectory but movements of the blacksmith's arms and other body parts were more scattered. Many different intermediary movements led to "the same" final results. Aiming for a specific final position in space resembles aiming to meet a deadline in time.

c. Idealizations

Ancient Greek geometry was a chief source of mathematics; its influence extends into modern science. Geometry incorporates numerous idealizations, including a point that has no dimensions and a line that has only one dimension. Angles in geometry are exact, e.g., triangles with exact angles of 30°, 60° and 90°. Similar idealizations continue in modern scientific models based on perfectly empty space. Physical materials such as metals are modeled by idealized mathematical formulae.

The formal VE model adapts methods of idealization. In contrast to geometry, VE constructions occur in time rather than space. Like a dimensionless point, a VE pulse travels instantaneously from a discharging device to a receiving device. In definitions of operations of devices, periods of time are presumed to manifest mathematical precision. Repetitions are exact. Pulses produced by collective devices in bodies are perfectly synchronized and entrained. Transports and conversions are described by arithmetic. Operations are completed "on the dot."

Idealized constructions have advantages that outweigh their disregard of nature. Idealizations facilitate large-scale mental constructions such as geometry; and they support large-scale investigations into properties of materials such as metal alloys. Idealizations are features of mental disciplines that can be shared by a community. They suggest innovations that sometimes turn out to have practical value.

Idealizations can be modified to accommodate actual situations and to explore suggestive innovations. Exact repetitions can be avoided by introducing small wobbles. A single device can be replaced by a collective made of a variable population of elements.

If a fraction of energy in an actual device is lost during storage, conversion or transport, contrary to ideal designs, possible solutions are to provide a bigger VES or to provide more energy at the start of operations or higher rates of energy supply during operations. In the initial VE domain, sources of energy are ample for all such needs.

B. Device definitions, applications and extensions

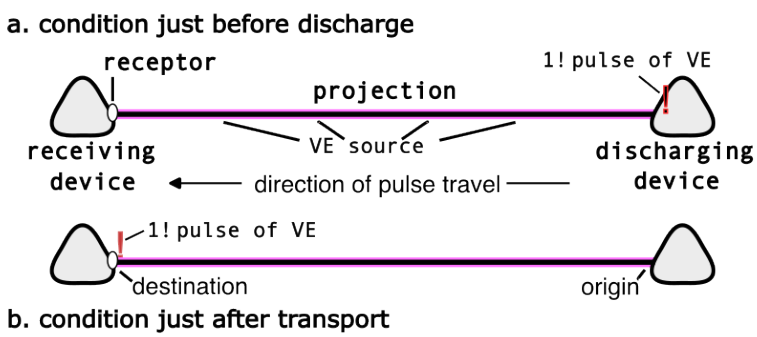
6. Projections, receptors, channels and junctions carry VE flows.

Fig. 1 shows the discharge of a pulse from a discharging device, transport of the pulse on a projection and arrival of the pulse at the receptor of a receiving device. Discharge and transport occur in a single instant.

Two figures are required to show an instant of discharge and transport. Fig 1(a) shows conditions just before discharge: the VES in the discharging device holds 1! of VE, ready for discharge. Fig 1(b) shows conditions just after the pulse carrying 1! of VE has traveled to the receptor of the receiving device.

All projections operate identically, each powered by a VE source shown as a colored covering. The device resembles a piece of wire or filament that can be cut to order and bent. A pulse appears at one end, the origin, and is instantaneously transported to the other end, the destination. [Fig. 1(b).]

Fig. 1: discharge and transport of a pulse on a projection



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In Fig. 1, the receptor of the receiving device directs input pulses from the projection to the VES. Different receptors connect to different devices, e.g., timing devices and bursters. A particular receptor may be a simple connection or it may have multiple modes and incorporate control features, e.g., active (open) in one mode and inactive (blocked) in another mode.

VE concepts discussed in §§ 1-5 apply to the design in Fig. 1. The underlying substance of VE is manifested as: a single quantity (one bang); two forms (first, storage inside a device and then a pulse on a projection arriving at a receptor); two locations (the two devices); and a schema or action-structure (first discharge, then transport; first Fig. 1.a, then Fig. 1.b).

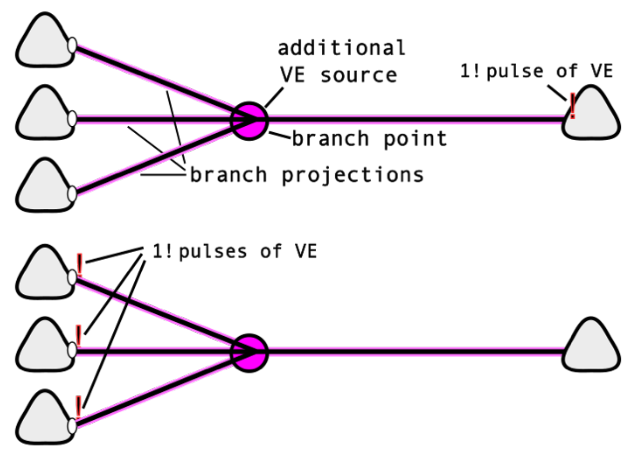
Notwithstanding dissipative operations, the VE substance in a pulse is apparently conserved during the transport process.

Fig. 2 shows an idealized (branch point)* and branch projections. At a branch point, an initial projection splits into two or more branch projections. Each branch projection carries a full signal. Similar to Fig. 1, Fig. 2 shows conditions "just before discharge" and "just after transport."

A single projection instantaneously transports a 1! pulse to the branch point; three branch projections each instantaneously transport a 1! pulse to the three destinations. The branch point has a source of VE for pulse multiplication that is accessed through the VE plenum. The VE source is shown as a colored circle in Fig. 2. Such symbols for VE sources are often omitted in later figures.

Fig. 2: branching projections, pulse multiplication

a. condition just before discharge



b. condition just after transport

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A model of a pulse on a projection can be extended to movements of VE inside bodies that hold collective cells. Transport of VE occurs in channels that resemble projections and in junctions that resemble receptors.

Channels have added features: (1) a channel can carry VE in quantities smaller than 1! pulses, e.g., in a stream; (2) channels can merge. During a merger, VE from many originating devices in a collective body can be channeled into a single receptive device.

A junction is used to connect neighboring VE cells in a body that share an envelope between them. Junctions also connect devices to channels and channels to projections. Varieties of junctions operate in one direction or in both directions. Like receptors, junctions can incorporate control features, e.g., open or closed.

7. Pulser devices

a. the primal pulser device

The primal pulser device shown in Fig. 3 is the "seed" or point of origin of devices that convert the form of VE.

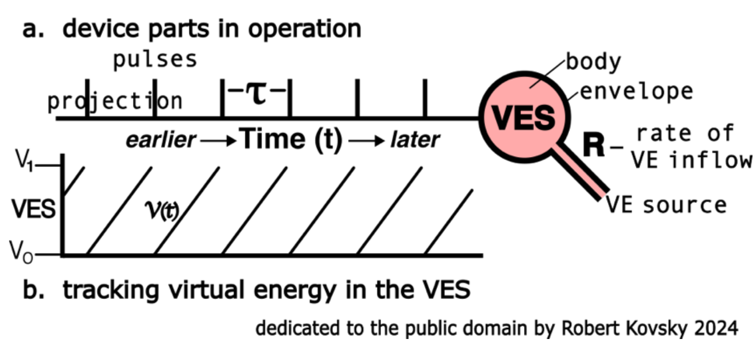
The chief parts of the primal pulser device [Fig. 3(a)] are the projection that carries pulses away from the pulser; the body that holds the VES; and the VE source that provides VE at a rate R. The envelope isolates the body from the environment except for a specific VE inflow (R) and a specific VE outflow (pulses on the projection).

As discussed above, VE devices operate in defined structures of time. Time (t) in Fig. 3 runs uniformly from "earlier" to "later." In addition to the function of transporting a pulse, the projection in Fig. 3(a) also incorporates a Time line in a graph-like depiction or chart* tracking the production of pulses. The pulse chart in Fig. 3(a) has the same time line as the graph in Fig. 3(b) that tracks the quantity of VE in the VES, denoted as $\mathcal{V}(t)$*.

In the Fig. 3 design, R is fixed. VE flows into the body at rate R and is changed into stored VE measured as $\mathcal{V}(t)$. $d[\mathcal{V}(t)]/dt = R$.

The lowest level of VE in the VES is $\mathcal{V}(t) = V_0$. Charged by R, $\mathcal{V}(t)$ increases until $\mathcal{V}(t) = V_1$, where $V_1 - V_0 = 1!$. Then 1! in the VES changes instantaneously into a pulse on the projection and $\mathcal{V}(t)$ falls to V_0.

Fig. 3: primal pulser device



Activity of the primal pulser continues cyclically as in "beep-beep-beep." One aim is to mimic activity of a rudimentary neuron.

Pulses are produced at a fixed rate with a period τ between any two successive pulses. In ideal operations, $R \times \tau = !$.

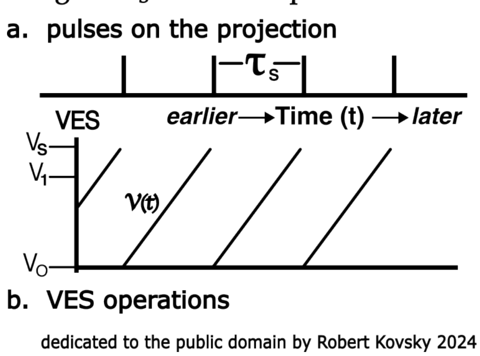
For the primal pulser, the suggested maximum or standard value of R is 100!/sec. and the suggested minimum value of τ is .01 sec.

VE concepts discussed in §§ 1-5 apply to the primal pulser. An underlying substance of Virtual Energy has three forms: an incoming stream R; a quantity of VE stored in the VES denoted as $\mathcal{V}(t)$; and one-bang pulses on the projection. Changes in form are constrained by conservation principles.

The pulser schema can be extended to describe repetitive pulsations of a body that holds collective devices, e.g., during generation of synchronized pulsations. In the final Gazer design, "Timing functions are relocated to the sensorial body, which generates an ongoing beat that entrains active devices." Designs below include presumptions that synchronized and entrained beats are based in pulser-like properties of sensorial bodies.

b. dissipative pulsers and the Virtual Energy functional

Fig. 4: V_S-controlled pulser device



Operations of a V_s-controlled pulser device are shown in Fig. 4. The modified VES holds more than 1! of VE; and the quantity of VE in the VES, $\mathcal{V}(t)$, reaches a higher level than V_1 before the device discharges a pulse. The higher level, denoted by V_s, is called the (discharge point)*

$V_s - V_0 > 1!$.

More time is required between two successive pulses: τ_s is longer than the τ of the primal pulser.

The quantity of VE in a pulse is still one bang. During each cycle, a quantity of VE, namely $V_s - V_1$, is dissipated or converted into waste heat inside the VES. In order to deal with this waste heat, an additional feature is added to the envelope of the device, namely, a capacity for passing waste heat into the environment.

Next, operations shown in Fig. 4 are developed into a new device that uses a (VES functional)*. This functional is adapted for timing devices, bursters and movers. In mathematics, a functional is a general form that leads to classes of functions. Here, a VES functional leads to classes of devices.

The construction of a VES-functional pulser has two steps. The first step (Fig. 5) constructs a VES with a varying dissipation. Next, in Fig. 6, the second step adds a V_s and other features to define an operating device.

In this design, while VE is flowing into the device and is being stored in the VES, VE that is in storage in the VES is being partially converted into waste heat and passed into the environment (dissipation). The rate of dissipation is proportional to the difference between $\mathcal{V}(t)$ and V_0. In symbols:

The rate of dissipation = $D \times [\mathcal{V}(t) - V_0]$, where D is a constant. This is a familiar form, originating with Newton's law of cooling.

In Fig. 5, $\mathcal{V}(t)$ tracks the VE level after t_0, the instant of the most recent pulsation.

$d[\mathcal{V}(t)]/dt = R - \{D \times [\mathcal{V}(t) - V_0]\}$.

Inflow R increases the quantity of VE in the VES; dissipation decreases that quantity. Solving the differential equation:

$\mathcal{V}(t) = V_0 + [(R/D) \times (1 - \exp(-D(t - t_0)))]$, as shown in Fig. 5.

Observe the VES functional at its extremes. Close to $t = t_0$, $d[\mathcal{V}(t)]/dt$ is close to R, as in the primal pulser. At the other end, $\mathcal{V}(t)$ approaches an asymptote, namely, $V_m = V_0 + R/D$.

Fig. 5: VES functional in dissipative VES (no discharge)

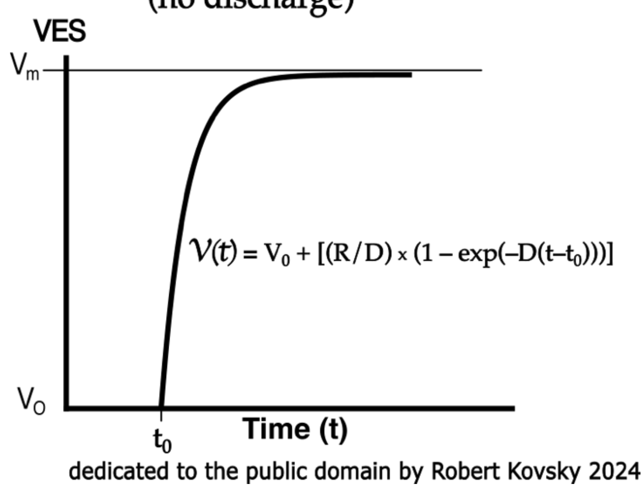
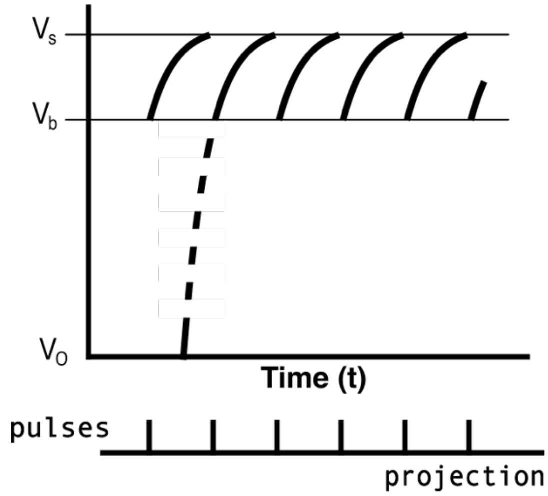


Fig 6 shows an operating VES-functional pulser device. The discharge point is set at $V_s < V_m$. When discharge occurs, $\mathcal{V}(t)$ falls to V_b (rather than to V_0 as in the primal pulser). The dashed line shows the omitted segment of the VES functional.

It is required that $V_s - V_b > 1$!. Any excess VE passes as waste heat into the environment.

Fig. 6: VES functional in operating pulser



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The device operates cyclically, producing a pulse in each cycle. The period between pulses is determined by device specifications R and D and by device settings V_s and V_b.

c. pulsers with extended discharge periods

Fig. 7 shows VES operations of pulsers with extended discharge periods. In Fig. 7(a), pulser operations produce a steady stream of single pulses. In Fig. 7(b), a similar device produces a steady stream of pulse bursts.

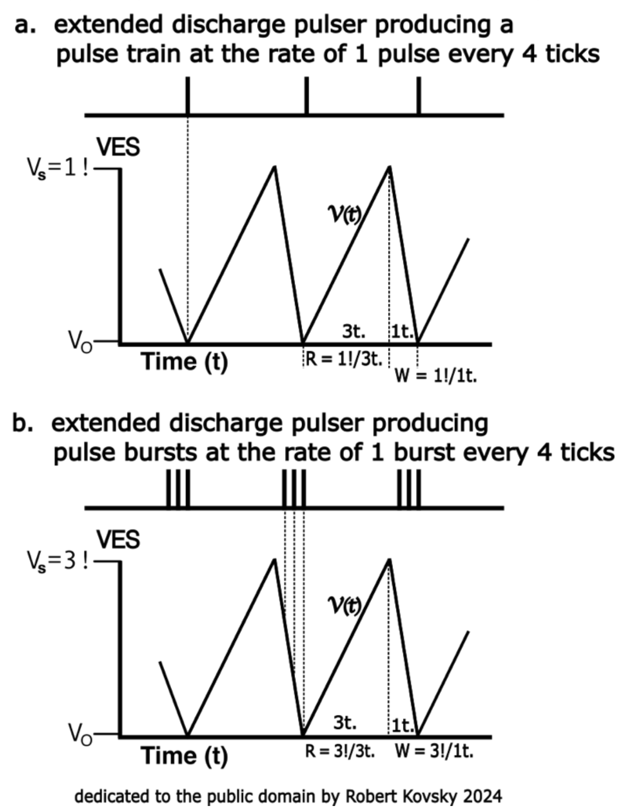
In both designs, the rate of positive change of VE in the VES is a constant R during the (charging period)* and the rate of negative change is a constant W during the (discharging period)*. Through an internal process, a charging condition changes to a discharging condition when $\mathcal{V}(t) = V_s$. Similarly, a discharging condition changes to a charging condition when $\mathcal{V}(t) = V_0$. Each VES is conservative and converts VE without loss. A principle of finality applies so that conditions of charging and discharging fit exactly into their assigned time periods.

The unit-bang definition of a pulse imposes a requirement on devices that discharge onto projections: a full bang of VE must be ready for discharge before discharge can occur. The device body has a presumptive capacity of holding VE ready for pulsation until a full bang is accumulated.

In Fig. 7(a), the period of R is 3 ticks and the period of W is 1 tick. R is set at R = 1!/3t. The discharge process starts when $\mathcal{V}(t)$ reaches V_s. Then, W = 1!/1t. Pulse discharge is delayed until $\mathcal{V}(t) = V_0$. A finality principle states that pulse discharge starts exactly at that instant.

In Fig. 7(b), the scale of VE operations is multiplied by 3. $V_s - V_0 = 3!$. In this device, R = 3!/3t. and W = 3!/1t. Discharge of the first pulse in a burst occurs 1/3 tick after the discharge process starts, at the first instant that $V_s - \mathcal{V}(t) = 1!$ The last pulse is on the tick (finality principle) and the middle pulse fits into place.

Fig. 7: pulsers with extended discharge



d. ideal pulse patterns

Pulse patterns produced by pulsers with extended discharge periods (Fig. 7) serve as exemplars for ideal pulse patterns (Fig. 8). The ideal exemplars introduce a non-zero pulse width denoted by α and assigned a convenient value of .001 sec. in §3(c) above. A pulse abruptly starts at a sharply-defined instant and abruptly ends after α. The pulse width refers to time required for the device to produce the pulse.

In initial designs in this project, no change in function occurs if pulse width 0 interchanges with pulse width α. Device specifications and constraints limit the maximum rate of pulses on a projection to 50 per sec. with a minimum period between pulses of .02 sec. Designs with zero-width pulses are simpler to construct and understand. A sharper analysis is required in faster designs in §8(g) below,

The pulse pattern in Fig. 8(a), called a (pulse train)* is a succession of pulses with a fixed time period τ between any two pulses. Timing intervals of length τ partition the time line exactly. It is convenient to define the cycle as starting at the instant that a pulse starts.

Fig. 8: ideal pulse patterns

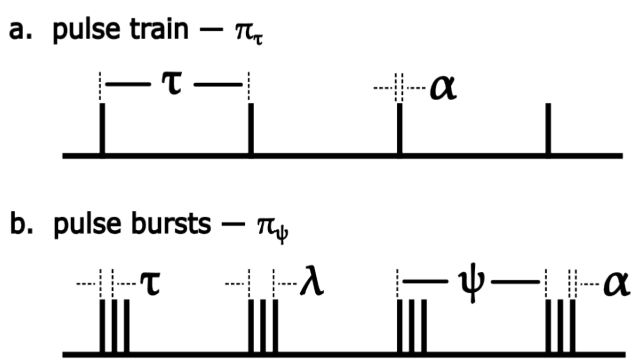


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Fig. 8(b) shows a steady stream of (pulse bursts)*. A uniform time period ψ denotes the interval between bursts. Each ψ starts at the instant the device starts discharging the first pulse in a burst and ends at the instant the device starts discharging the first pulse in the next burst. Time required to discharge a pulse (α) is the same as in Fig. 8(a). Interval τ is re-defined as the period between starting instants of successive pulses in a burst. The defined width of the pulse burst – λ – is not used in this project.

e. sensory pulsers and modules

In final designs in this section, variable-rate pulse signals are produced by a sensory module and the rate of pulses measures an environmental influence, e.g., temperature or pressure of an object on the skin.

Steps in the construction of the sensory module are:

i. pulser with controlled R

ii. pulser with stable self-control

iii. pulser with dissipative sensor

iv. sensory pulser

v. sensory module with direct readout

---

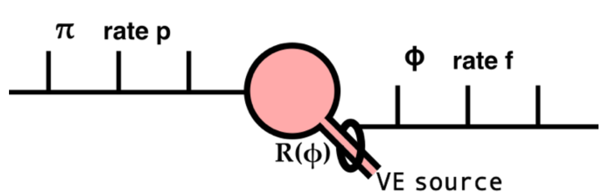
i. pulser with controlled R

An ideal pulse train π is specified by its period τ. The inverse of τ is the (rate)* of pulse production, a number of pulses per specific time period, also called a frequency. Rates and frequencies can be used when signals are ideal pulse trains but not necessarily for other signals. Rates are suitable for this construction.

The defining time period in this construction is 3 ticks or 3t.. The rate of pulse production, "p" in Fig. 9, is defined as p pulses in 3t. The rate of VE inflow, R, is also defined for a 3 tick period. In this device, R = p × ! and p is a real number between 1 and 15.

In the Fig. 9 design, the value of R in the primal pulser is controlled by an input pulse train φ specified by rate f, also a real number between 1 and 15. A (control function)* R(φ) defines the relation between rate f and R.

Fig. 9: pulser with controlled R



Suppose that, as shown in Fig. 9, pulse train φ controls a sphincter* around the VE inflow tube, constricting the flow as f increases. When f increases, R and p decrease. Here, let R(φ)/! = 16 – f` and thus f + p = 16.

Rates f, R/! and p are real numbers in the interval [1, 15]. In other words, the maximum R is 15!/3t., equal to 50!/sec.

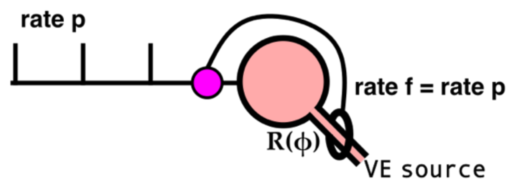
f	5	6	7	8	9	10
p	11	10	9	8	7	6
R/!	11	10	9	8	7	6

The adjacent table shows results of operations for some integral values of f, p and R/!.

ii. pulser with stable self-control

In Fig. 10, a new projection branches from the output projection and controls the sphincter function adapted from Fig. 9. As a direct result, f = p and both rates are 8 according to the table above.

Fig. 10: pulser with stable self-control



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Suppose that a researcher interferes with the branching projection so that f is reduced below 8. Then p will increase by a corresponding amount. Next suppose that the interference ceases. Faster p and f will tighten the sphincter constriction and thus reduce p.

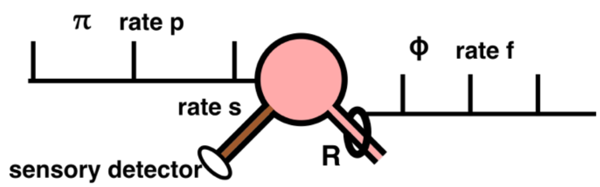
Ensuing movements depend on how the sphincter responds to the change in f. If the sphincter were to respond instantaneously, the pulse rate would bounce up and down. A sufficiently slow response of the sphincter will result in a smooth return to p = 8. This stabilizing response resembles that of a sufficiently damped harmonic oscillator in mechanics. An insufficiently damped oscillator will vibrate back and forth before settling into the final position. A sufficiently damped oscillator will slide smoothly into the final position without moving past it.

iii. pulser with dissipative sensor

The pulser with dissipative sensor (Fig. 11) is another modification of the Fig. 9 design. The device has an added outflow of VE from the VES and this VE is dissipated in a sensory detector at a rate s.

The sensory detector dissipates energy as a measure of an environmental influence, e.g., heat, pressure on the skin. As the influence strengthens, dissipation grows larger and s, the outflow of VE from the VES, also grows larger.

Fig. 11: pulser with dissipative sensor



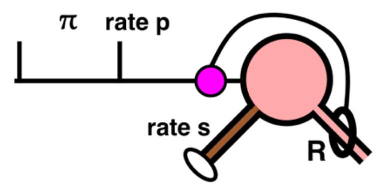
R/! is no longer equal to p; rather a conservation principle requires that: R/! = p + s. Recall that R/! = 16 – f. Hence, f + p + s = 16.

f	5	6	7	8	9	10
p	9	8	7	6	5	4
s	2	2	2	2	2	2
R/!	11	10	9	8	7	6

The adjacent table shows operations of the pulser with dissipative sensor for some integral values of f, p and R/! when s=2.

iv. sensory pulser

Fig. 12: sensory pulser



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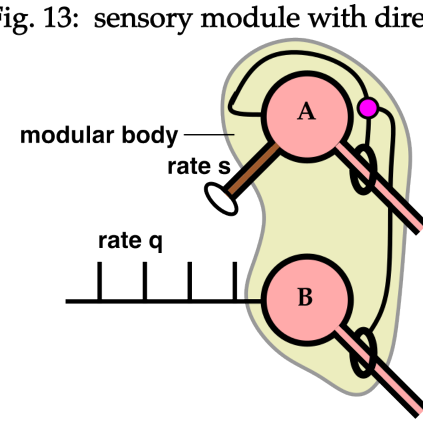
The sensory pulser in Fig. 12 combines dissipation and self-control. Rate f is set equal to rate p. Referring to the previous table for the case s=2, when f equals p, both are equal to 7. Rate p has dropped by 1 as a result of sensory dissipation. Generally, p = (8 – s/2). An increase in s is measured as a decrease in p.

v. sensory module with direct readout

A simple principle of coordination suggests that a stronger sensation should result in a faster rate of pulses in the output of the sensor, leading to a faster and stronger movement. The Fig. 12 design produces a contrary result. To correct this, the sensory module with direct readout in Fig. 13 produces the desired result.

In Fig. 13, a (modular body)* contains two pulsers and has its own envelope, specified inputs (source VE for each pulser) and specified outputs (sensory dissipation at rate s and pulses on a projection at rate q). In this first step of development, the modular body is only a package.

Fig. 13: sensory module with direct readout



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Device A in Fig. 13 operates like that in Fig. 12. The p = f projection that drives R(φ) in device A also drives an identical R(φ) in device B. But device B has no dissipation and rate q = R/! = 16 – p, as in Fig. 9. And p = 8 – s/2 as shown above.

The result: q = 8 + s/2. When there is no sensation, q = 8. An increase in sensation produces an increase in q.

8. Timing devices, linear arrays and extensions

Development of timing device designs began in 2007 and culminated in 2011 with "An Ear for Pythagorean Harmonics," a .pdf publication, and with "Brain Models Built from Timing Devices," a web project.

This construction is narrower in scope than prior projects but it includes new devices and modules that apply to the Gazer project. Culminating designs perform functions of "VE centering devices" used in that project.

The concept of Virtual Energy starts as a pulse on a projection and develops into a VE distribution in a linear array of entrained devices operating inside a sensorial body. In final versions of "VE centering devices," VE potentials resemble voltages in electronic designs.

Steps in this construction are:

a. primal timing device

b. signal generators

c. pulse waves in linear arrays of timing devices

d. pulse bursts produced during extended discharge periods

e. mode changes in gated devices and two-pulse devices

f. centering modules for Gazer designs are built from timing devices

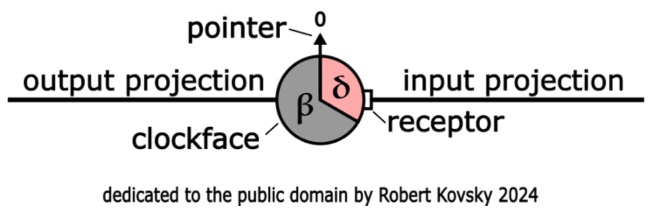
g. centering module designs are extended to distributive processes

h. further extension to potential-driven processes

a. primal timing device

A functional design for the primal timing device is shown in Fig. 14. The device starts in a condition that is ready and waiting. An input pulse arrives over the input projection, triggers the receptor and starts the internal clock of the device. The action resembles that of a stopwatch in sports, with a pointer moving over a clock face. An exact period of time denoted by "δ" intervenes between the arrival of the input pulse and the start of discharge of a pulse on the output projection. Discharge and restoration of the VES occur during a subsequent exact period of time denoted by "β." Then the device is ready for another response.

Fig. 14: functional design of the primal timing device



A more formal definition begins with the timing device in the (ready condition)*. The arrival of a trigger pulse at the receptor at time t_0 switches the device to the (responding condition)*. At time (t_0 + δ), the device starts to discharge a pulse. Time period δ is called the (responding period)*. At the start of discharge, the device condition changes to the (restoring condition)* and the cycle continues for an additional time period β, called the (restoring period)*. Pulse-width α (if non-zero) is included in β in this definition. After β, the device returns to the ready condition.

As part of the cycle of operations, the receptor is inactive* (blocked) during the (δ + β) period and cannot process an arriving pulse. When time reaches (t_0 + δ + β), the receptor becomes active* and the device returns to the ready condition.

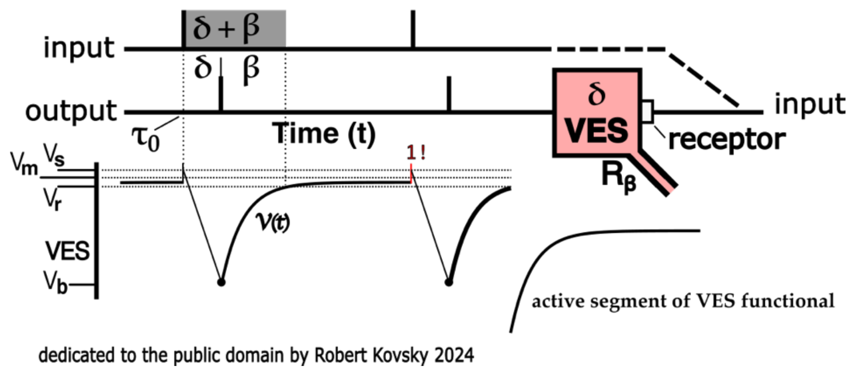
A form or schema of the cycle is:
ready – responding – (discharging/restoring) – ready.

The corresponding timing cycle is: γ – δ – β – γ
where δ and β are timing device specifications and γ denotes the period that the device is in a ready condition, which may be of indefinite length.

Fig. 15 shows VES operations of the primal timing device. The "active segment of VES functional" in Fig. 15 is taken from Fig. 5. V_s, V_m and V_b are defined in Figs. 5 and 6. V_r is the minimal operational value of $\mathcal{V}(t)$; while $\mathcal{V}(t) < V_r$, the input receptor is blocked.

The "active segment" is exaggerated for purposes of presentation. For fastest operations, V_b would be a tiny bit less than V_r; V_s a tiny bit more than V_m; and $V_s – V_r$ a tiny bit more than 1 !. The range of operations would be a tiny bit more than 1!.

Fig. 15: VES operations of the primal timing device



$\mathcal{V}(t)$ approaches V_m from below but does not reach V_m on its own. An input pulse arriving at time τ_0 is converted and added to the VE in the VES, momentarily pushing $\mathcal{V}(t)$ above V_s and starting the discharge process.

The responding period δ starts when a trigger pulse arrives at the receptor and ends when the device starts discharging. Applying a finality principle, the timing is exact. Other timings are adjusted to meet this requirement.

In the primal timing device, δ is set at 1/10 of a tick, e.g., 0.01 sec. In later designs, timing devices have responding periods of 1 tick or 4 ticks. The restoring period β depends on the application.

The receptor in the primal timing device is inactive or blocked during the (δ + β) part of the cycle as denoted in gray in the input line of Fig. 15. At the end of the restoring period, $\mathcal{V}(t) = V_r$; the receptor is then unblocked and the device becomes ready to respond if a new input pulse arrives.

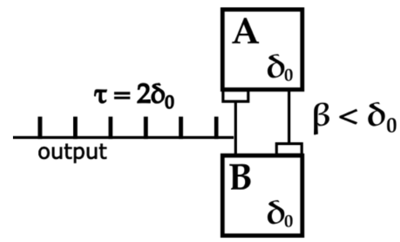
In a cycle of idealized operations, 1! is added to the VES via the trigger pulse and a 1! pulse is discharged from the VES. Operations are thus apparently conservative despite dissipations.

b. signal generators

The signal generator in Fig. 16 is built from two identical primal timing devices A and B; the devices are interconnected and discharge onto each other in reciprocating operations, generating an ideal pulse train with a repetitive period $\tau = 2\delta_0$, where δ_0 is the responding period of each device.

Suppose that device A discharges a pulse at time $t = t_0$; this pulse triggers device B. After the responding period δ_0, device B discharges a pulse that triggers device A at time $t = (t_0 + \delta_0)$. A duplicate pulse appears on the branching output projection. After another δ_0 passes, device A discharges a pulse at time $t = (t_0 + 2\delta_0)$, completing one cycle of signal generation. Successive output pulses will be produced in identical operations during ongoing cycles.

Fig. 16: signal generator built from 2 primal timing devices



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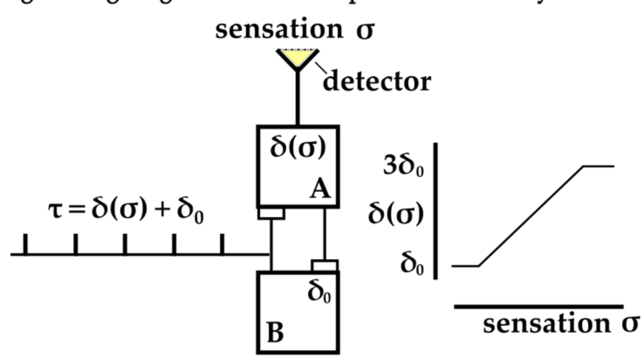
One constraint on operations of this design is that β must be less than δ_0. The VES of a timing device that has just discharged must be restored and ready when the other timing device discharges.

The signal generator in Fig. 17, an extension of that in Fig. 16, responds to a variable sensation σ. A stronger sensation lengthens the responding period of device A, which is denoted by $\delta(\sigma)$. An example is shown in the accompanying graph, with a maximum increase to $\delta(\sigma) = 3\delta_0$.

Suppose that $\delta_0 = 0.01$ sec. and that $\delta(\sigma)$ varies between 0.01 sec and 0.03 sec. The frequency of pulses on the output projection will vary from 50 per sec. when there is no sensation or detection to 25 per sec at maximum detection of sensation.

Fig. 17: signal generator that responds to a sensory variation



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c. pulse waves in linear arrays of timing devices

In Fig. 18, nine identical primal timing devices are connected in a (linear array)*. Triggered in succession with a time step of δ, the array produces a wave of pulses.

At time $t = t_0$, timing device A discharges.

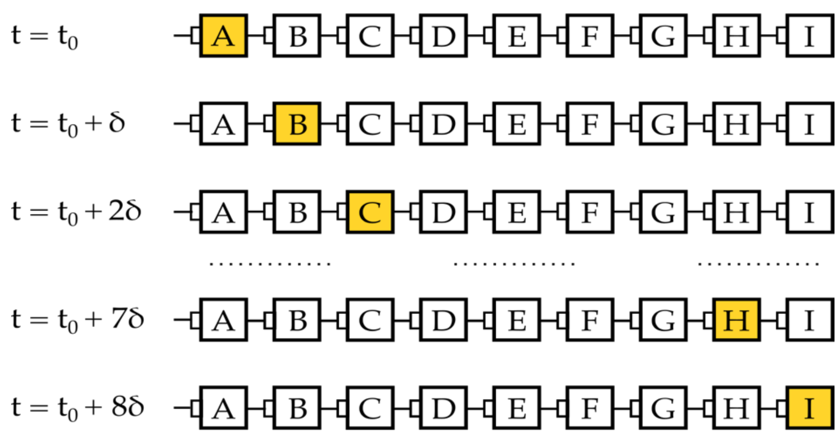
At time $t = t_0 + \delta$, timing device B discharges.

At time $t = t_0 + 2\delta$, device C discharges.

…continuing down the line, and so forth…

… until the end.

Fig. 18: a wave of pulsations in a linear array of primal timing devices



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The array in Fig. 19 performs a function of pulse cancellation. Devices are modified from the primal design with two projections, two receptors and bi-directional operations. When a device discharges, it produces two pulses, one on each output projection. If a device is ready, it can be triggered through either input projection. The constraint $\beta > \delta$ means that when device A discharges onto device B, device A is not ready when device B discharges. A reciprocating pattern like that in Fig. 16 is excluded.

Operations start the same as in Fig. 18. At the $t = t_0 + \delta$ step, a pulse wave starts at the other end of the array. When the two waves meet, further triggering cannot occur because receptors are blocked and because of the constraint $\beta > \delta$. The two waves cancel.

Fig. 19: pulse cancellation in a bi-directional array of timing devices, $\beta > \delta$

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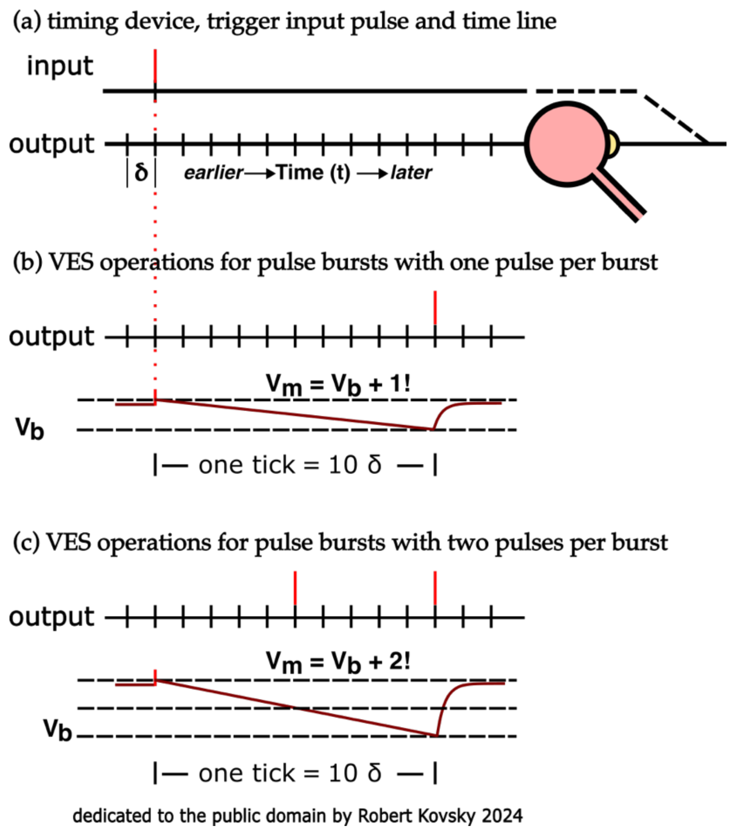
d. pulse bursts produced during extended discharge periods

In Gazer designs, certain timing devices represented by numbered triangles operate at the edges of sensorial bodies and send signals to burster modules. That function is performed by timing device modules constructed in Figs. 20-22, which produce pulse burst signals used in the Gazer project, as shown in Fig. 23.

These device modules produce bursts that fill one tick, including both end points. In other words, one "enlarged tick" lasts for $10\delta + \alpha$ where δ is the responding period of the timing device and α is the duration of a pulse. The enlarged tick makes it easier to coordinate various devices. Because of margins of silence, the enlargement does not affect operations.

Outputs of these modules are the same as those of pulsers with extended discharge periods. (Fig. 7.) Fig. 20 shows a timing device with extended discharge periods and the two simplest cases.

Fig. 20: timing devices that discharge pulse bursts



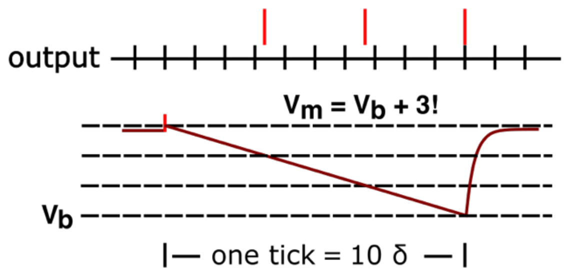
A representative device is shown in Fig. 20(a) with input and output projections and a time line. An input pulse starts operations.

The Fig. 20(b) device has a 1-bang VES range and a 1-pulse output burst. The discharge process starts at $\mathcal{V}(t) = V_m$. Pulse discharge at the end of the tick applies a principle of finality.

The Fig. 20(c) device produces the first output pulse 5δ after arrival of the input pulse – at the first instant that 1! is ready for discharge. A finality principle applies to produce exact discharge of the second pulse at the end of the tick.

Fig. 21: more timing devices that discharge pulse bursts

(d) VES operations for pulse bursts with three pulses per burst



(e) VES operations for pulse bursts with four pulses per burst

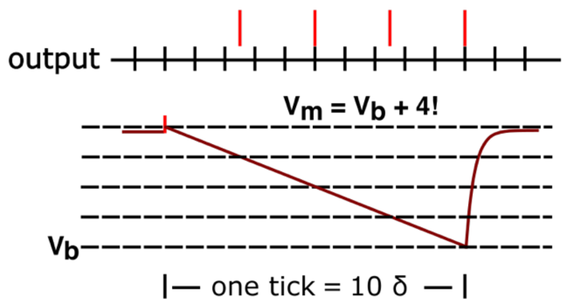


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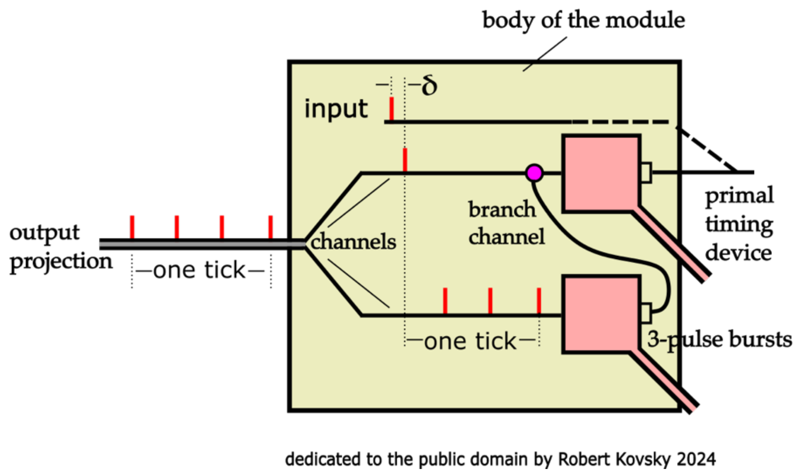
Fig. 21 rounds out the class: a 3-pulse device is shown in Fig. 21(d) and a 4-pulse device is shown in Fig. 21(e). A finality principle is applied in each case.

The discharge period is divided into n sub-periods, where n is the number of pulses in a burst. Each sub-period concludes with the discharge of a pulse.

In the timing device module in Fig. 22, two timing devices operate in a modular body. The primal timing device and the 3-pulse burst device both discharge VE into internal channels that carry VE instantaneously just like projections. The channels merge and transport VE into the output projection. A branch channel from the primal device output channel carries a pulse signal to the 3-pulse burst device.

An input pulse triggers the primal timing device, which discharges a pulse after a period δ. This pulse appears on the output projection and also starts operations of the 3-pulse burst device. Pulses are combined to form a 4-pulse output signal with equal periods that add up to a full tick.

Fig. 22: timing device module that discharges full-tick 4-pulse bursts



Operations of the module produce a unified output signal in two ways:
(1) by means of the branch channel that connects devices; and
(2) bodily entrainment of operations. Entrainment in Fig. 22 resembles drumming one's fingers on a table.

Fig. 23: pulse burst signals

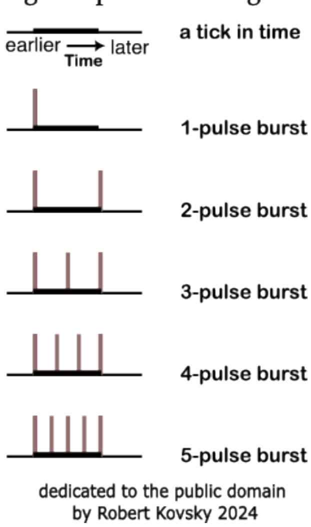


Fig. 23 shows the repertoire of pulse burst signals that are produced by timing device modules based on the Fig. 22 design. This is also the repertoire of signals set forth in § 2 of the Gazer project.

e. mode changes in gated devices and two-pulse devices

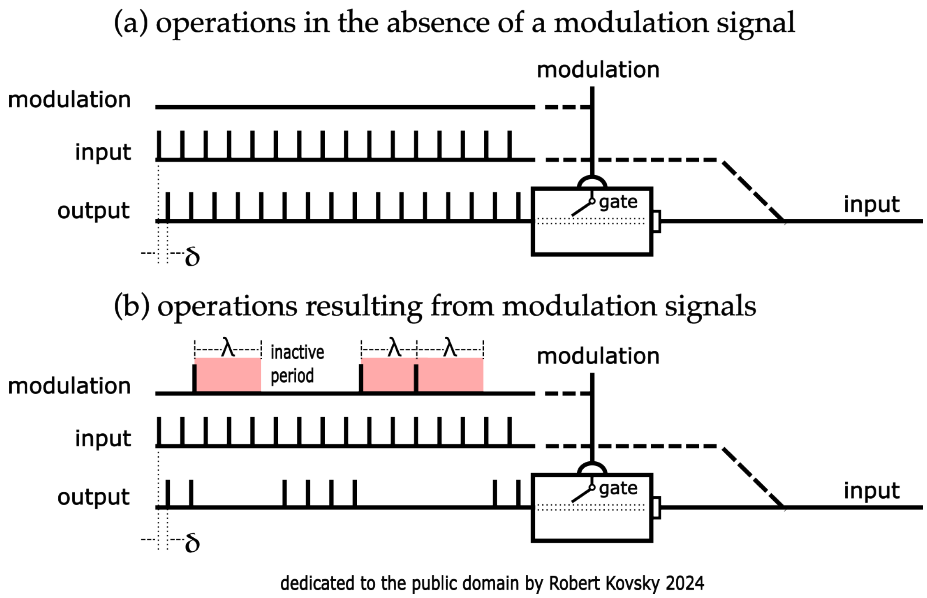
As discussed above in §5, a schema is a sequence of conditions that organizes operations of a VE device. Several classes of devices have two or more schemata and are switched between schemata by pulse signals or internal processes. E.g., a pulse through one input changes the effects of pulses through another input.

i. gated timing devices

Operations of gated timing devices resemble those of electrical relays, original transistors and vacuum-tube triodes: a signal passes or does not pass from input to output depending on the presence or absence of a modulation* signal.

Fig. 24(a) shows operations of a "normally-active gated timing device" in the absence of modulation signals — the results are the same as those of a primal timing device, reproducing a pulse stream with a delay δ.

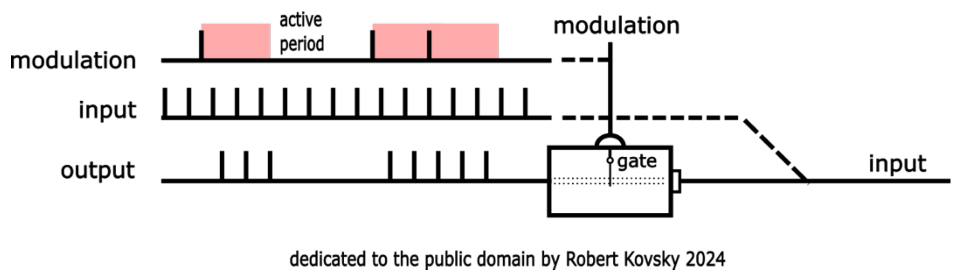
Fig. 24: operations of a normally-active gated timing device



As shown in Fig. 24(b), when a pulse arrives over the modulation projection, the input receptor immediately switches to an inactive condition that lasts for an "inactive period λ". It is as if a gate has closed, blocking processing of pulses. When the inactive period ends, the gate opens and the receptor returns to the normally-active condition. If modulation pulses arrive in a steady stream at a rate greater than 1/λ, the receptor stays closed.

A similar device is shown in Fig. 25, except that the condition of the receptor is "normally inactive." The receptor becomes active for a period λ after arrival of a pulse over the modulation projection. Repeated modulation pulses at a sufficiently high rate keep the receptor in an active condition.

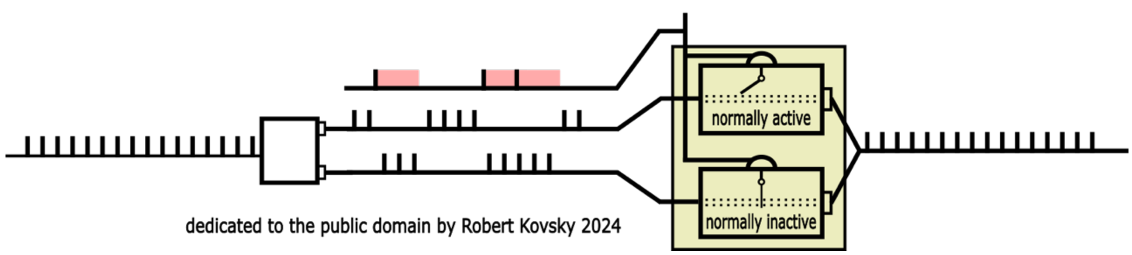
Fig. 25: operations of a normally-inactive gated timing device



In Fig. 26, a single depiction shows three stages in the processing of a pulse train. The module has two gated timing devices that operate synchronously — one gated device is normally active and the other normally inactive.

An input stream of pulses arrives at both timing devices identically. A modulation pulse switches both devices simultaneously. Then the two outputs drive a single timing device. The result is splitting and recombining a pulse train.

Fig. 26: timing devices splitting and recombining a pulse train



ii. two-pulse devices

The two-pulse timing device shown in Fig. 27 has two uniform input projections. It produces an output pulse when separate pulses on input 1 and input 2 arrive within a modulation period λ of each other, Thus, the device detects (approximately) coincident pulses.

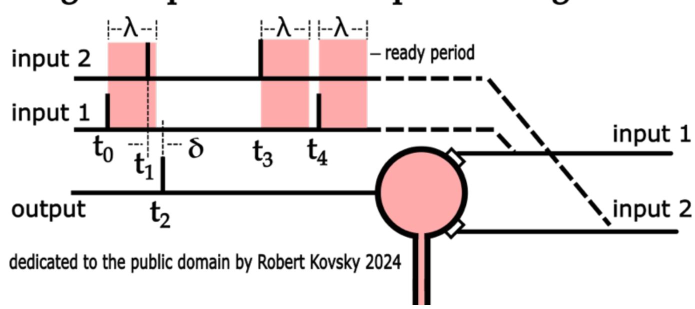
Schemata of the 2-pulse device are developed from the schema of the primal timing device, namely: ready – responding – restoring – ready

2-pulse device schemata: unready – ready – unready (mode 1)
unready – ready – responding – restoring – unready (mode 2)

The device is in the unready* condition until an input pulse arrives over one of the input projections; the device then switches to the ready condition and can respond like a primal timing device to a pulse on the other projection. The input receptor that carried the first pulse is blocked during λ.

Arrival of both pulses during the modulation period triggers the response process and mode 2. After restoration, the device returns to the unready condition. If a second pulse does not arrive during the modulation period, the device returns to the unready condition without discharging (mode 1).

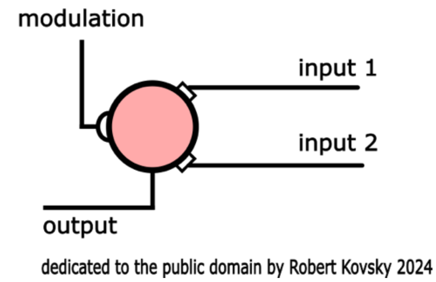
Fig. 27: operations of a 2-pulse timing device



Examples are shown in Fig. 27. The pulse arriving on input 1 at time t_0 changes the condition of the device from unready to ready. The device remains in the ready condition (as shown on the time chart) until a pulse arrives on input 2 at time $t_1 < t_0 + \lambda$, triggering a timing device response and discharge of an output pulse at time $t_2 = (t_1 + \delta)$. Alternatively, while the device is in the ready condition after a first pulse on input 2 at time t_3, a period of time λ passes without any pulse arriving on input 1, at which point the device returns to the unready condition at time $(t_3 + \lambda)$. Then, the next pulse at t_4 over input 1 starts a new readiness period.

Fig. 28 shows a further development in which a modulation control is added to the 2-pulse timing device. Modulation control in the 2-pulse device is like that in the normally-inactive gated device. Input receptors in a normally-inactive device are blocked except for an active period after the arrival of a modulation pulse.

Fig. 28: a normally-inactive 2-pulse timing device



The following list sets forth the schemata of the normally-inactive 2-pulse timing device. Listed schemata serve as "atom-like" elements in "molecular" structures of combination. "responding" includes "discharge."

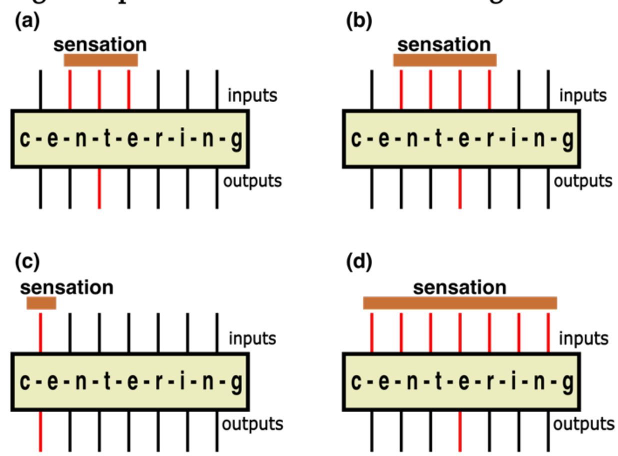
1. inactive
2. inactive – M – unready – P – inactive
3. inactive – M – unready – I_1 – ready – P – unready – P – inactive
4. inactive – M – unready – I_1 – ready – I_2 – responding – P – unready – P – inactive

Schemata in the list include linkages* between successive conditions of the device, namely: M denotes the arrival of a modulation pulse; I_1 denotes the arrival of a first input pulse; I_2 denotes the arrival of a second input pulse; and P denotes a change resulting from internal processing of the device.

f. centering modules for Gazer designs are built from timing devices

In Fig. 29, the centering module is based on the seven-location primal model from §2 of the Gazer project. During operations of the module, a "sensation" arrives as a bloc of active input projections. Other input projections are silent. After processing, a single pulse appears on one output projection at or near the center of the bloc.

Fig. 29: operations of a 7-location centering module



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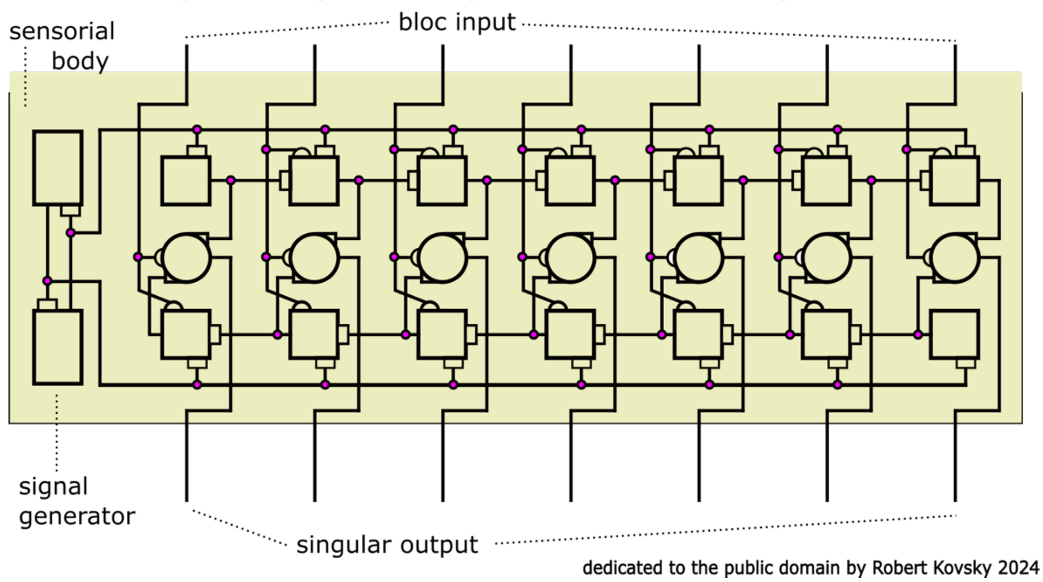
The simplest example (Fig. 29(a)) shows one active output projection at the center of the bloc of three active input projections. When an even number of input projections are active (Fig. 29(b)), the active output projection is just off center to one side or the other.

As examples of extreme operations, the module produces appropriate results for a single stimulus at an edge of the module (Fig. 29(c)) and for a stimulus that covers the whole module (Fig. 29(d)).

In Fig. 30, the timing device design for the centering module shows a bloc input and a singular output. The signal generator on the left discharges pulses ("clicks") in an alternating pattern onto the long horizontal top and bottom projections. The seven operating columns are identical except for a variation at the edges (with simpler inputs). Each column has a top and bottom two-mode timing device and a two-pulse device in the middle. The sensorial body incorporates all the devices in the module, synchronizes their operations and may extend to neighboring modules.

Fig. 30: timing device design for a 7-location centering module

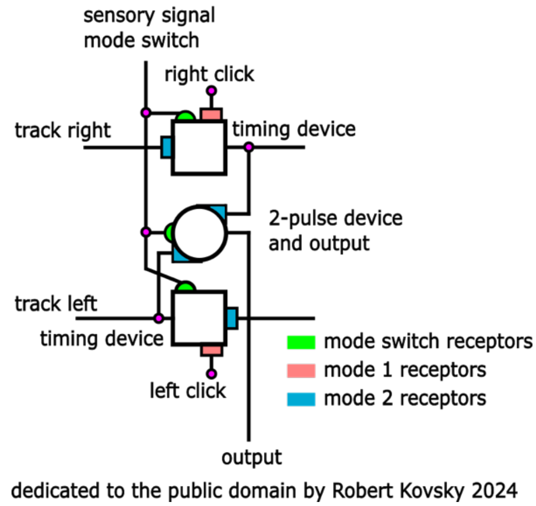


In a summary of operations, the module starts with all timing devices in mode 1. A bloc of input pulses switches a bloc of columns from mode 1 to mode 2. Inside the switched columns, timing devices along the tops are connected to form a linear array (the "right track") that carries a wave of pulses to the right like the wave in Fig. 18. The linear array along the bottoms of the switched columns (the "left track") carries a pulse-wave to the left. When the two pulse waves meet at a central column, a discharge is triggered from that central two-pulse device.

Fig. 31 shows a representative column. It has two-mode timing devices at the top and bottom of the column and a normally-inactive 2-pulse device in the middle. At any moment, the column is either in mode 1 or mode 2. In either mode, one set of receptors is active and the other set is blocked.

In mode 1, the column connects to click pulses from the signal generator. In mode 2, the column participates in waves along tracks. Arrival of a sensory signal switches modes in the timing devices from mode 1 to mode 2 and activates the 2-pulse device.

Fig. 31: column in centering module



Devices in the module have the following specifications for periods of timing controls. This application uses the convenient δ = 0.01 sec.

signal generator devices:	responding period = δ	restoring period = 0.5δ
2-mode timing devices:	responding period = 2δ	restoring period = 2.5δ
2-pulse device:	ready period = 1.5δ	responding period = δ

Starting conditions of the centering module are shown in Fig. 32.

Fig. 32: activating the centering module

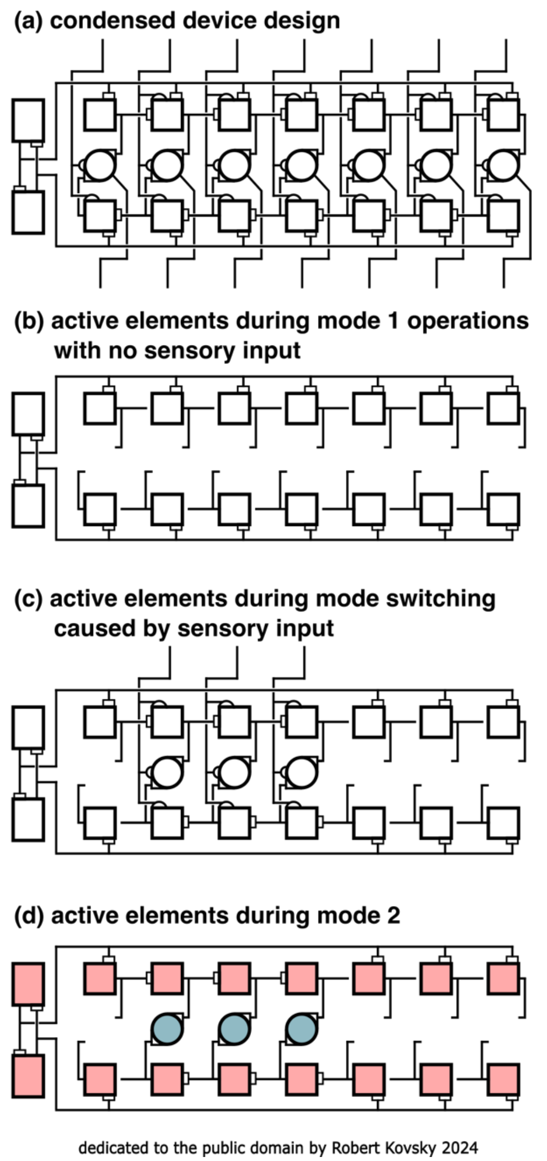


Fig. 32(a) shows a condensed version of the centering module.

Fig. 32(b) shows devices and receptors that are active during mode 1 operations when there is no sensory input. The timing devices respond to alternating click pulses but their output projections are not connected to active receptors and their discharges have no effect.

Fig. 32(c) shows mode switching, using the example in Fig. 29(a). As to devices in the switched columns, mode 2 receptors are activated and mode 1 receptors are blocked (and removed from the figure). Inside the switched bloc, columns are connected along the tracks. The 2-pulse devices are activated in switched columns.

Fig. 32(d) shows activated elements at the outset of mode 2 but prior to operations. The activated 2-pulse devices are in the unready condition and all the timing devices are in the ready condition.

Fig. 33: operations of the centering module

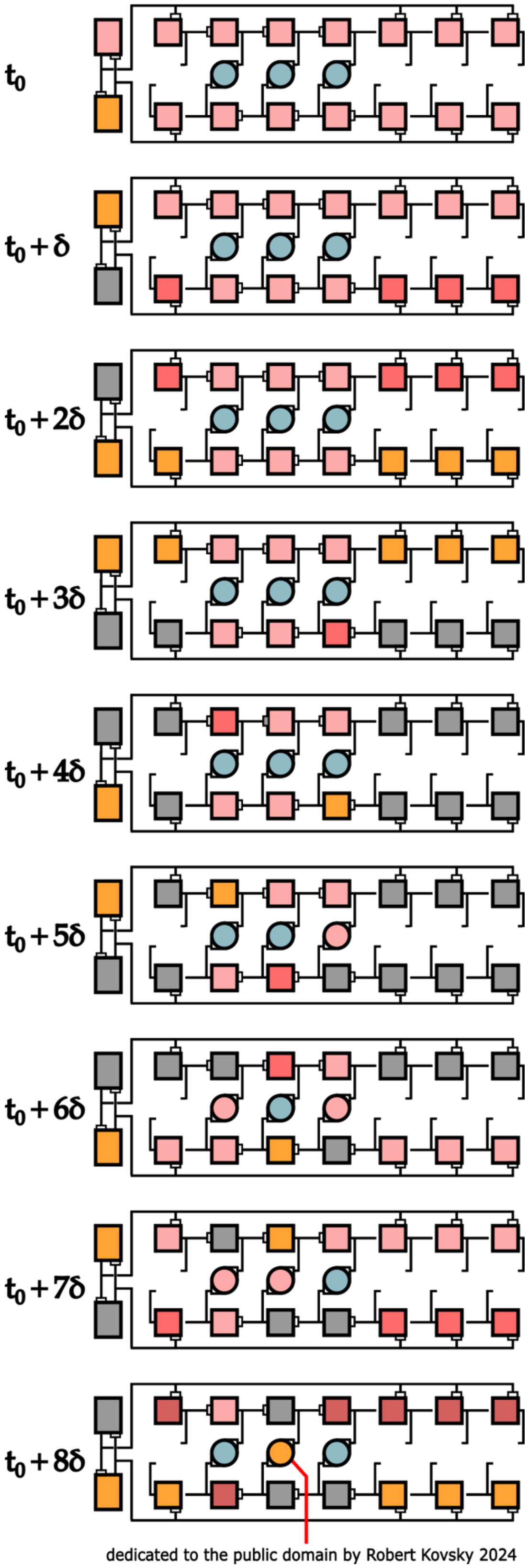
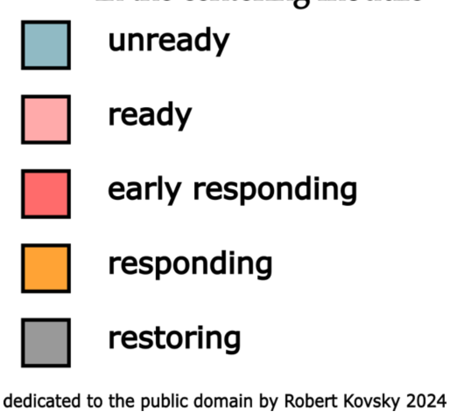


Fig. 33 shows operations of the centering module for the ongoing example. Operations start with the triggering of a timing device in the signal generator. Conditions of devices are shown at time t_0 "just after" that first trigger.

Operations occur with successive steps of δ. At $t_0 + \delta$, the first click pulse has just arrived at the 4 left track timing devices that are in mode 1, starting their responses.

Fig. 34 lists color codes for conditions of devices. The track timing devices have a responding period of 2δ and two different color codes are used, an early responding code and the general responding code.

Fig. 34: conditions of devices in the centering module



At $t_0 + 3\delta$ and $t_0 + 4\delta$, mode 2 timing devices at the inside edges of the switched bloc have just received pulses from mode 1 columns just outside the bloc and have started to respond. During successive steps, pulses advance towards the center of the bloc from each side, first stepping on one track, then on the other. After pulses on the two tracks reach the same column, the 2-pulse device in that column receives two pulses that trigger its discharge. This column is at or near the center of the switched bloc and will discharge just after $t_0 + 9\delta$, completing and terminating the centering process.

g. centering module designs are extended to distributive processes

The centering module constructed from timing devices has features that suggest further development. This step introduces VE distributions in collective devices that are interconnected by junctions, which perform centering functions by new means.

i. slow speed of the centering module built from timing devices

Speed is a measure of merit in VE device systems and such a measure is readily constructed for centering modules. The time required for performance is denoted "T" and given the value $T = 9\delta$ for operations of Fig. 33. This T measure is crude and omits preparatory steps but is sufficient for purposes here.

If the bloc of switched devices is enlarged to 5 input projections, operations require two more steps and $T = 11\delta$. If all 7 input projections carry switch signals, $T = 13\delta$. From another perspective, if an operational period $T > 13\delta$ is always provided for centering performance of the Fig. 30 design, performance will be completed during that time for any size of input bloc.

Analysis for the 7-input centering module can be extended to the full 31-input centering module used in later Gazer designs. The longest time required for performance is that needed to center an image that covers the whole linear dimension of 31 inputs, namely, $T = 37\delta$.

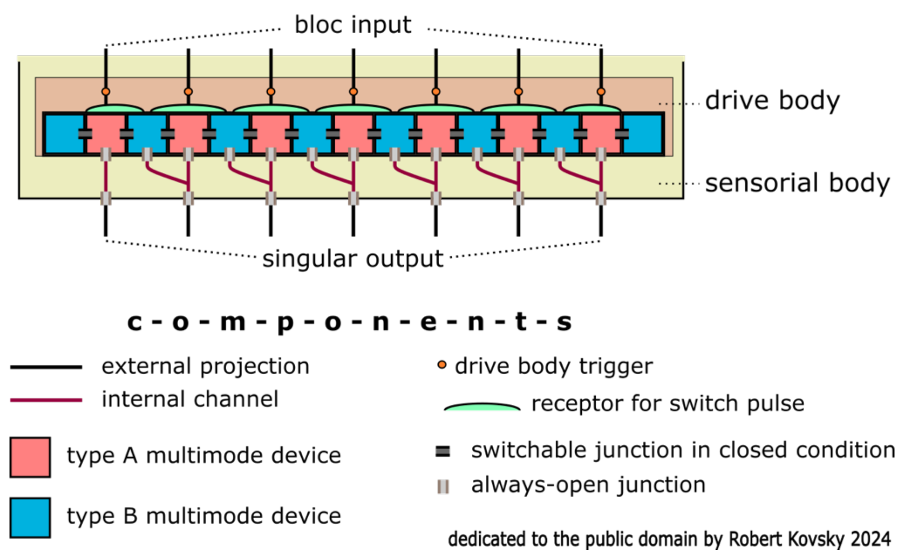
Gazer operations are controlled by a repeating cycle of eight ticks or 80δ. Suppose that an amount of time Δ is assigned to the centering function. Performance time for a 31-input centering module appears to fit into a structure where $\Delta = 40\delta$. In this time period, the module will always complete performance and become ready for a new stimulus. A similar $\Delta = 40\delta$ is also the effective performance time of an elemental twitch of a force fiber device. In such a context, a performance time for centering of $\Delta = 40\delta$ is just feasible. The system can work; but a lot of time is required for centering and time requirements limit any increase in the size of the sensorial field.

ii. faster speed through use of junctions

The hierarchical time structure in §3(c) includes junctions that transport VE "about 10 times faster" than timing devices that use projections. Operations of the junction-based centering module shown in Fig. 35 resemble those of the Fig. 30 design but there are numerous differences.

Looking first at shared features, both designs have a linear array of columns. In both, a bloc of active inputs produces a single active output at or near the center of the bloc. Operations of elemental devices are organized in collective cycles. Devices have multiple modes; input signals cause devices to switch from one mode to another. Unswitched devices feed signals into both sides of a bloc of switched devices; signals step towards each other; they meet at the center and trigger an output pulse.

Fig. 35: 7-location centering module with junctions



The Fig. 35 design includes new components. The timing device module (Fig. 30) has seven columns with three devices in each column; the junction module has 15 multimode devices. Internal channels transport discharge pulses from timing devices inside the sensorial body and two output channels merge into one output projection.

Another new component in Fig. 35 is the (drive body)* that replaces the signal generator shown in Fig. 30. At the start of operations, the drive body is ready and waiting for triggering by any input pulse. After a trigger and a delay for mode switches of devices, the drive body produces a repetitive series of squeezes* that continue until operations are terminated. As shown below, a squeeze transfers VE from one multimode device to an adjacent multimode device.

A (multimode device)* has pulse operations and transfer operations. All operations are based in the VES. The VES of the multimode device is conservative: it holds a quantity of VE for an indefinite period; changes in quantity are arithmetic. In the Fig. 35 module, the $\mathcal{V}$(t) of a multimode device is limited to values 0, 1! and 2!. In an activated device, $\mathcal{V}$(t) starts at 0 and increases in two steps.

As to pulse operations, a device has a pulser-style V_s with a convenient value V_s = 1.5!. If, during operations of a particular device, $\mathcal{V}$(t) = 2!, the device discharges a pulse onto its output channel; the pulse travels through the always-open junction that connects the channel to its output projection. Such pulsation and discharge complete performance of the centering function; immediately after discharge, the module terminates operations and enters into a restoration period.

As to transfer operations, a type A multimode device has two (switchable junctions)* that connect the device to the two adjacent type B multimode devices. Junctions in the Fig. 36 design are switched between closed and open conditions; an open junction can transfer VE in either direction.

During the restoration period, multimode devices are loaded* with VE. In the Fig. 35 module, each multimode device is loaded with 1! of VE. A colored box in the figure denotes 1! in the corresponding VES. The initial quantity can be transferred or dissipated; then the VES is cleared*. The VES condition of a device that has been cleared is denoted as $\mathcal{V}(t) = \varphi$ (nil).

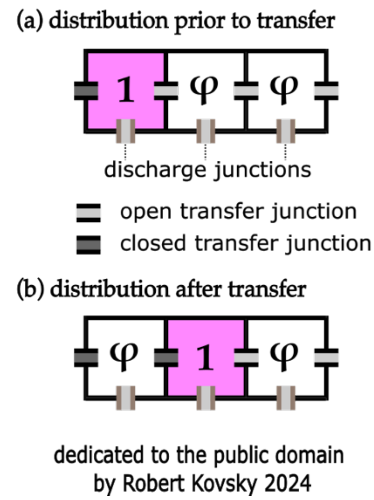
Transfer* is a result of a squeeze from the drive body. Transfer in the Fig. 35 module is restricted to operations where a loaded device has a single open junction that is shared with a cleared device. An example of transfer is shown in Fig 36.

Prior to transfer, the VE distribution in Fig. 36(a) is denoted as 1φφ. As required for a transfer, the loaded device has one open junction connecting it to a cleared device.

After transfer, the VE distribution is φ1φ. (Fig. 36(b).) The previously-loaded device has been cleared through transfer and the VE now resides in the previously-cleared adjacent device.

Also, the junction that carried the transfer has been closed. Closing a junction after pulse transfer through it is required for further transfer in the array. This function resembles that performed by the β > δ constraint in Fig. 18.

Fig. 36: VE transfer through a junction



In a linear array, quantities of VE in the device VES's can be summed like arithmetic numbers to define a (collective VE)* that is equal to all the VE in the array. The transfer operation in Fig. 36 changes the distribution of VE in the array while conserving the quantity of collective VE.

Fig. 37 continues the ongoing example started in Fig. 29(a) and Fig. 32(c). Before switching (Fig. 37(a)), multimode devices in the module are all in the ready condition, each with 1! of VE. All switchable junctions are in the closed position.

In addition to triggering the drive body, input pulses cause mode changes in multimode devices, which switch from mode 1 to mode 2. A single input pulse changes the mode in a (red) type A multimode device. Pulses from two inputs are required to change the mode in a (blue) type B multimode device. (The two inputs must be adjacent in the bloc of input pulses.) As a result, the bloc of switched multimode devices has an odd number of devices and type A devices are at the edges of the bloc.

Fig. 37(b) shows switching of multimode devices on the arrival of input signals. In a switched device, the 1! of stored VE is dissipated, leaving the VES in a cleared condition denoted by φ. Each switchable junction is controlled by a type A device and is changed to the open condition when that type A device is switched.

Fig. 37: switching operations in the junction module

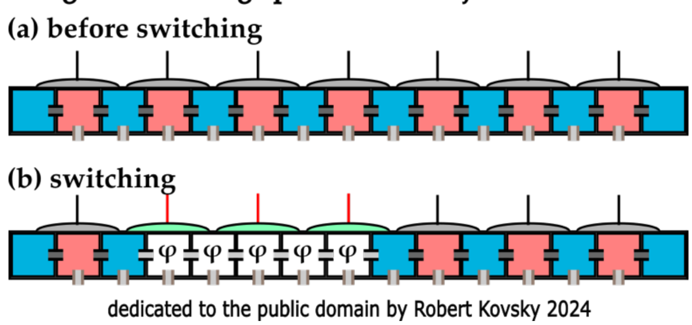
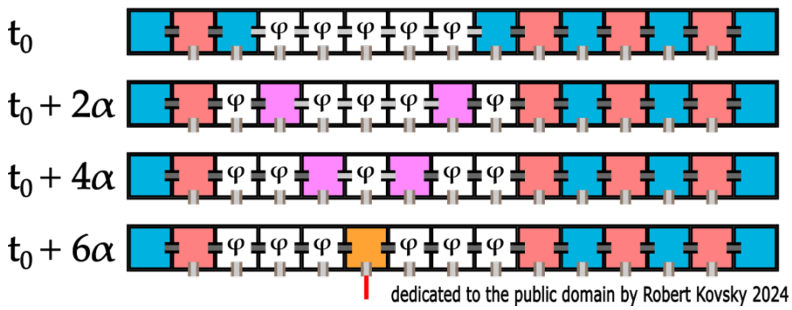


Fig. 38 shows operations of the junction module. Operations start just after switching of multimode devices caused by inputs. Initial conditions at time t_0 are shown just before the first squeeze from the drive body.

Fig. 38: internal flow operations in the junction module



Suppose that a squeeze occurs every 2α where α is the time required for the transfer. Conveniently, α = 0.001 sec. This is the fastest speed within the hierarchy of time while maintaining a margin of silence. The figure at time $t_0 + 2\alpha$ shows conditions after the first squeeze and before the second squeeze. The first squeeze transfers VE from individual devices outside the switched bloc into devices inside the switched bloc.

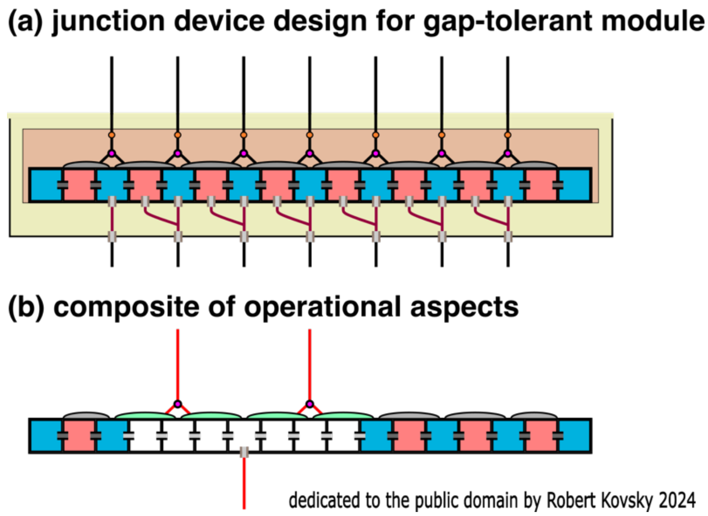
Successive squeezes transfer VE inside the switched bloc of devices from both ends towards the center. The last squeeze transfers VE from two adjacent devices into both junctions of a central device. The VES of the central device operates in a conservative fashion and $\mathcal{V}$(t) reaches 2!. This quantity exceeds the V_s of pulse operations; the device discharges a pulse, thus completing performance.

Compare the performance time of the two centering modules using convenient values for δ and α. A Fig. 30 step requires .02 sec. A Fig. 35 step requires .002 sec. Disregarding preliminary operations, the performance time for the Fig. 30 example is 9δ. A corresponding performance time for the Fig. 35 example is 6α. Although the two examples are not quite comparable, the junction module operates in the range of "10 times faster" than the timing device module.

iii. centering module that tolerates gaps

In the Gazer project, it is said that certain centering devices tolerate a gap in the input bloc no larger than a single input projection. The design in Fig. 39 incorporates a gap-tolerant feature. The chief change from the Fig. 35 design is use of branching input projections; each input pulse activates two receptors. Also, two more timing devices are added to the whole array — and to each bloc of switched devices.

Fig. 39: centering module that tolerates gaps



Operations of the gap-tolerant centering module are shown in Fig. 39(b) in a composite figure that superimposes separate steps in the centering process: (1) activation of input projections, with a gap in the bloc of inputs; (2) initial clearances of multimode devices; and (3) final discharge of the multimode device that is located at the center of the switched bloc.

h. further extension to potential-driven processes

A course of construction leads to a faster method for finding the center of a bloc of signals in VE devices. Whole-body quadnet device operations overcome a shortcoming of prior centering designs: the time-consuming step-by-step march of pulses inwards from both edges of the switched bloc — until pulse waves meet at the center.

i. Mathematical models of natural diffusion.

ii. A design for diffusion of potential VE in a linear array of cells in a module resembles Fourier's paradigm of heat diffusion in an iron bar.

iii. An advanced VE diffusion model uses potential VE detectors that convert potential VE differences between adjacent cells into signals; and such signals control VE inflows into cells from sources and VE outflows from cells by way of dissipations.

iv. VE device versions of mathematical operators (difference devices, balancing units) provide more efficient controls for VE management.

v. VE devices control potential VE distributions in blocs of devices that function like gradients of voltages in electrical devices.

vi. Functions of a centering module are performed by two mirrored gradient distributions of potential VE that cross at the center of the stimulated bloc of inputs, leading to a central output signal.

vii. Comparative performance of three kinds of centering modules.

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i. Mathematical models of natural diffusion.

The leading mathematical model of diffusion was published in 1822 in *The Analytic Theory of Heat* by Jean-Baptiste Joseph Fourier. Fourier's theory applies to movements of heat in solid material bodies such as iron bars.

George Ohm applied similar methods to movements of electrical charges in metal conductors; Thomas Graham and Adolf Fick applied them to movements of salt dissolved in water.

In such models, a substance in a body is distributed with variable concentrations (quantities) in different locations. When adjacent locations contain different concentrations of the substance, some substance will move from the location with the higher concentration to the location with the lower concentration, thus tending to equalize the two concentrations. Models of movements are constructed by means of conservation principles and Newton's Law of cooling mentioned above in §7(b).

ii. A design for diffusion of (potential VE)* in a linear array of cells in a module resembles Fourier's paradigm of heat diffusion in an iron bar.

The VE diffusion module in this design adapts common features of diffusion models for chemicals in water, electrical charge and heat.

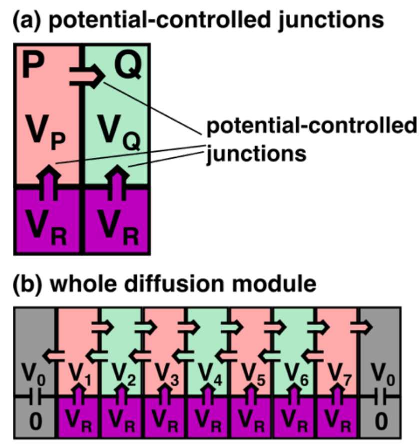
As an initial definition, the (potential VE)* in a device is a specific quantity of VE in the VES, denoted V_k, that is available for conversion into pulses. E.g., n bangs of potential VE in a VES can change into n pulses on a projection. Similar potential energy is held in water in a high-altitude lake that drives a hydroelectric turbine; or as "latent heat" in steam in a steam engine; or as electrical charge in a storage battery; or in chemical bonds of fuel. "Free energy" is a thermodynamic potential. In some designs, the potential VE in a device is equal to $\mathcal{V}(t)$, the quantity of VE in the VES; but this is not always the case, e.g., when discharge is limited by V_b.

In the VE diffusion model, an interconnected linear array of uniform VE devices has a collective form of cells in a body. During diffusion, VE moves from one cell with a higher potential VE to an adjacent cell with a lower potential VE in an amount (or at a rate) that is proportional to the difference in potentials. Applying a conservation principle, the sum of amounts of VE in the cells is the same before and after any movement of VE between cells.

Diffusion operations can be defined either by iterations* (repetitions of step-by-step cycles) or by multiple co-existing streams* of flow. VE diffusion designs in this project use interchangeable iterations and streams.

The first diffusion model is shown in Fig. 40. In Fig. 40(a), a pink device P and a green device Q are independently connected to VE sources with high potential V_R by means of a one-way (potential-controlled junction)* that a researcher opens and closes. The process starts with closed junctions and uncharged cells P and Q. Then V_R junctions are opened: allowing the transfer of VE from P's V_R into P to set V_P – and from Q's V_R to set V_Q. $V_R > V_P$ and $V_R > V_Q$.

Fig. 40: diffusion design



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A similar potential-controlled junction connects P to Q. To transfer VE between cells, the P-Q junction is opened. If V_P is greater than V_Q, VE flows from P to Q in an amount (iteration) or at a rate (streaming) that is proportional to $V_P – V_Q$. If V_P is less than V_Q, there is no flow.

In a streaming version, the flow rate of VE through the P-Q junction is: $f_{PQ} = F_0 \times (V_P – V_Q)$ where $V_P – V_Q \geq 0$ and F_0 is a constant of proportionality.

Fig. 40(b) shows a whole diffusion module. The cells at either end are maintained at $V_0 = 0$; these serve as foci of dissipation. In this array, seven pink and green cells are connected via potential-controlled junctions.

An iterative approach is convenient. There are two alternating steps. During the first step, potential VE differences between adjacent cells are calculated: $\Delta V = (V_{n+1} – V_n) \geq 0$ or $\Delta V = (V_n – V_{n+1}) \geq 0$. The index n is within the set {0, 1, 2, 3, 4, 5, 6, 7). In this application, $V_{7+1} = V_0$ and $V_0 = 0$.

In the second alternating step, energy transfers ΔVE occur through all junctions according to the formula $\Delta VE = G_0 \times \Delta V$ where G_0 is a constant of proportionality. Applying a conservation principle, the quantity of VE in each VES changes like an arithmetic number subject to addition and subtraction. VE subtracted from one VES is added to the other VES.

Below, such rules are applied to a diffusion process. Activated cells in a bloc or segment are selected by stimulus inputs; cells that are not selected are held at V = 0. A "PE_k" row shows potential VE levels in each cell at step k. In alternating steps, VE transport occurs during transfers.

Suppose that the stimulus triggers a bloc containing cells 1 through 5 and that the initial potential VE for V_1 through V_5 is set at 27! In an iterative process, let G_0 = (1/3). The following table calculates several steps in the process. If a calculation of a transfer results in a fractional amount, the actual transfer is rounded down to the next lower integer.

cell	0	V_1	V_2	V_3	V_4	V_5	V_6	V_7	0
PE_1 just after stimulus	0	27	27	27	27	27	0	0	0
$transfers_1$	←9	0	0	0	0	9→	0	0	
PE_2	0	18	27	27	27	18	0	0	0
$transfers_2$	←6	←3	0	0	3→	6→	0	0	
PE_3	0	15	24	27	24	15	0	0	0
$transfers_3$	←5	←3	←1	1→	3→	5→	0	0	
PE_4	0	13	22	25	22	13	0	0	0
$transfers_4$	←4	←3	←1	1→	3→	4→	0	0	
PE_5	0	12	20	23	20	12	0	0	0
$transfers_5$	←4	←2	←1	1→	2→	4→	0	0	
PE_6	0	10	19	21	19	10	0	0	0
$transfers_6$	←3	←3	0	0	3→	3→	0	0	
PE_7	0	10	16	21	16	10	0	0	0

In the table, later PE distributions have a peak at the center of the bloc and symmetrical, moderate declines on the sides, resembling standard models of natural diffusion.

iii. An advanced VE diffusion model uses potential VE detectors that convert potential VE differences between adjacent cells into signals; and such signals control VE inflows into cells from sources and VE outflows from cells by way of dissipations.

In the Fig. 41(c) design, new VE operations mimic those of Fig. 40(b). The Fig. 41(c) design uses VE streaming.

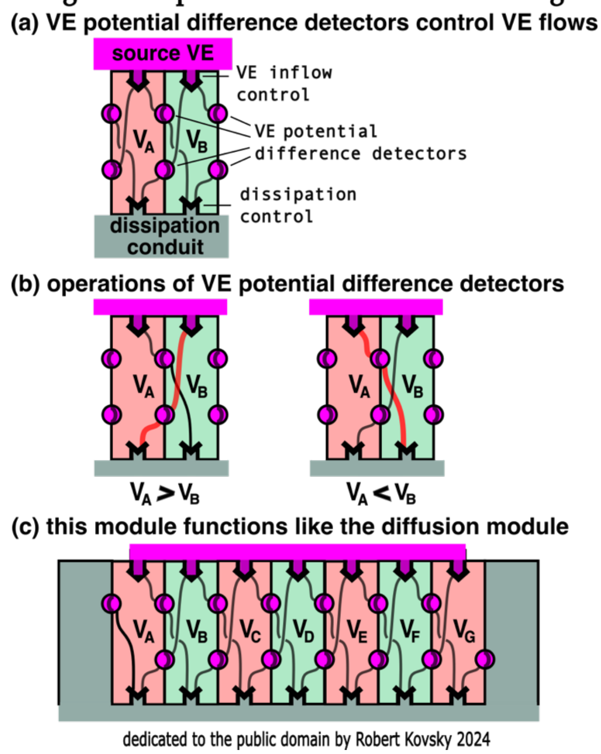
(VE potential difference detectors)* are new VE parts. Such a detector is embedded in a wall between two adjacent cells in a module, detecting a VE potential difference between the two cells and producing twin flows of pulses through two channels (one in each cell) at a rate that is proportional to the potential difference. Each potential difference detector measures the difference in one direction only. Each has its own independent source of VE. Operations of VE difference detectors resemble certain phenomena of piezoelectricity in the domain of natural materials.

Fig. 41(a) shows potential difference detectors. Each potential difference detector sends signals to a VE source inflow control in one cell and to a dissipation control in the adjacent cell.

Fig. 41(b) shows elemental operations. If $V_A > V_B$, one detector responds; if $V_A < V_B$, the other detector responds. A response is a twin flow of pulses on two projections.

During operations, an elemental signal from a potential difference detector causes 1! of inflow VE to be released from the VE source in one cell; and, in the adjacent cell, 1! of VE is dissipated. Treating VE as an arithmetic quantity, it is "the same" as if 1! was transferred between cells.

Fig. 41: VE potential difference detector design



iv. VE device versions of mathematical operators (difference devices, balancing units) provide more efficient controls for VE management.

The Fig. 41 design wastes energy when VE both comes from a source into a cell because of a potential difference on one side and also leaves the cell via dissipation because of a potential difference on the other side. It's like running both an apartment heater and air conditioner at the same time.

As shown below, waste VE is reduced in designs using (1) difference devices and (2) balancing units constructed from difference devices.

Difference devices. Fig. 42 shows operations of a difference device. In the schematic form in Fig. 42(a), input signals are pulse trains. One signal with pulse rate μ travels over the "minuend" projection and arrives at the "+" receptor of the difference device. Another signal with a pulse rate σ travels over the "subtrahend" projection and arrives at the "–" receptor.

In Fig. 42(b), V(t) denotes the momentary level of VE in the VES during device operations. A pulse arriving on μ raises V(t) by 1! in a conservative operation. A pulse arriving on σ lowers V(t) by a 1! dissipation.

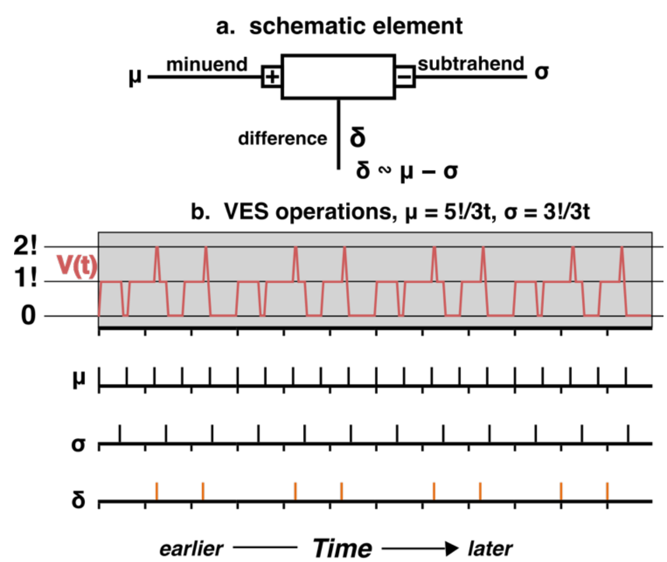
The device produces an output "difference signal" δ over the difference projection with an approximate pulse rate of δ ~ (μ – σ). The device produces output only if μ > σ. The difference signal is irregular and "gappy," but such irregularities are inconsequential in this project.

Fig. 42(b) shows operations for a particular case. Frequencies are: μ = 5!/3t.; σ = 3!/3t.; and δ ~ 2!/3t.

The chart of VES operations shows momentary changes in V(t) — the level of VE in the VES. V(t) ranges between 0 and 2!. When V(t) reaches 2!, the device discharges a pulse over the δ projection and V(t) drops from 2! to 1!.

If two opposing pulses on μ and σ happen to arrive close together, processes cancel; V(t) stays (or ends up) where it started.

Fig. 42 difference device



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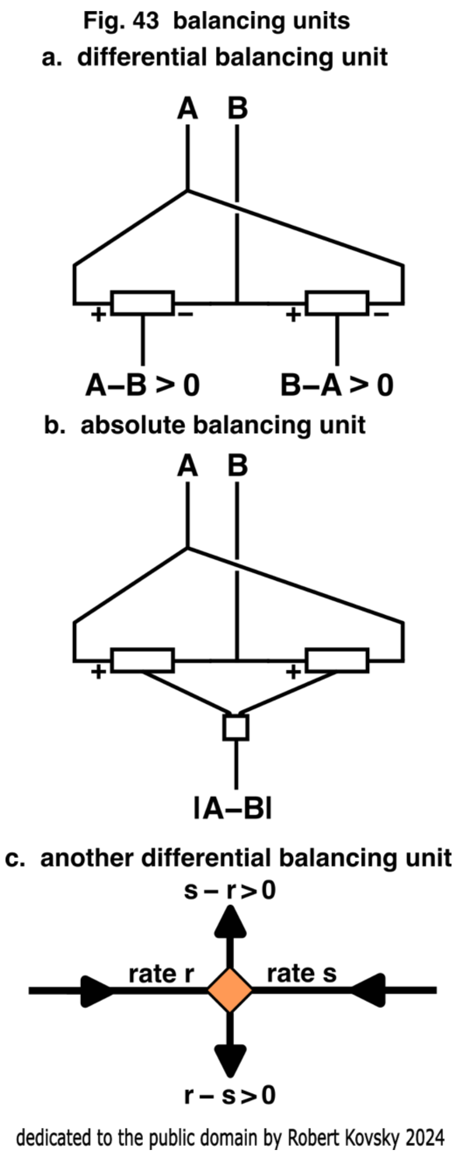
The result of operations is that the difference signal δ is constructed from the minuend signal μ by removing or canceling certain pulses from μ and allowing the other pulses in μ to produce output pulses. A subtrahend pulse cancels the next μ pulse. It may be that a subtrahend pulse arrives close to the same time as a minuend pulse and there is a question of which minuend pulse is canceled. The difference between the two outcomes is slight, shifting a gap in the difference signal one space forward or back.

Balancing units. Fig. 43 shows designs for balancing units.



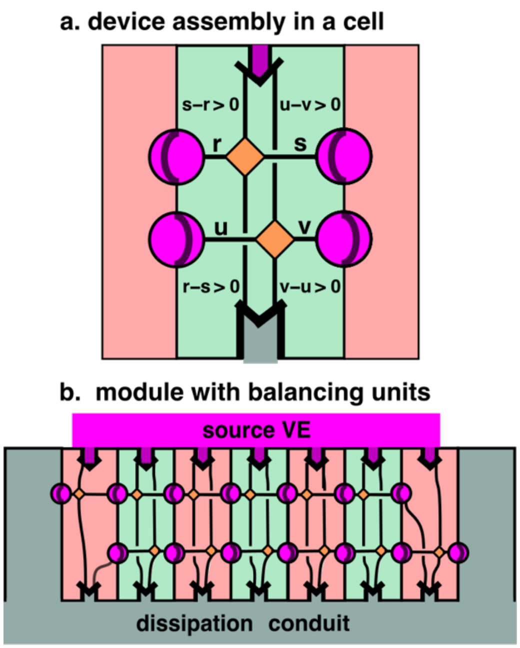
The "differential balancing unit" in Fig 43(a) is made of two difference devices. A pulse train, A, arrives at the minuend receptor (+) of the first device and the subtrahend receptor (–) of the second device. A second pulse train, B, arrives at the subtrahend receptor (–) of the first device and the minuend receptor (+) of the second device. If A ≠ B, one difference device will produce an output. A larger imbalance produces a higher difference rate. In later developments, balancing units can provide functions of "left and right" and "up and down."

In Fig. 43(b), the "absolute balancing unit," outputs of both difference devices are connected to a primal timing device that produces pulses at a rate equal to the absolute value of A – B.

Fig. 43(c) shows an iconic symbol for a differential balancing unit. Two input signals r and s arrive at the balancing unit, which then produces one of two possible resulting signals, depending on which input signal has a faster rate. In either case, the pulse rate in the active output signal tracks the difference between rates in the two input signals.

In an arrangement spanning three cells, operations of balancing units in Fig. 44 are driven by signals from potential difference detectors. The balancing units have output lines, s–r>0, u–v>0, r–s>0 and v–u>0. Output signals from balancing units control VE sources and dissipations. VE distributions and changes in the improved-efficiency module in Fig. 44 appear identical to those in Fig. 41.

Fig. 44: diffusion module with balancing units



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In mathematical models of mechanics, a gradient is defined as a first spatial derivative of an energy function. Operations of the VE potential difference detector resemble taking such a first derivative of a potential energy function.

Operations of a balancing unit resemble taking a second derivative. In the Fig. 44(b) design, signals from operations involving VE potential extend across three cells and drive the change in time of the VE potential in the central cell by means of release of VE from the source and dissipation of VE in a conduit.

These device operations resemble mathematical operators (gradient, laplacian) used in equations of standard diffusion paradigms, e.g.:

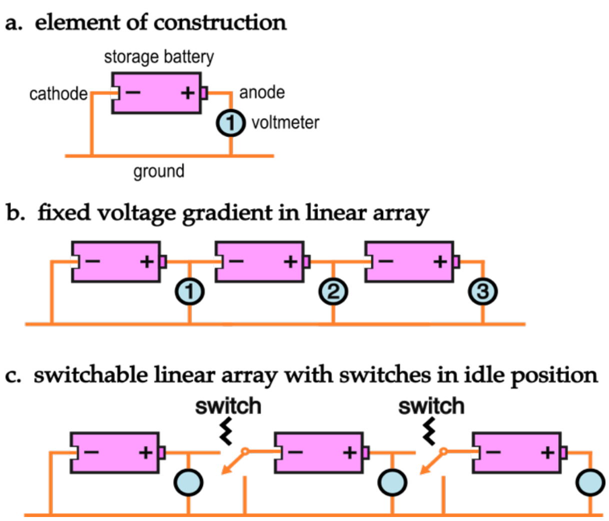
$\partial^2 v(x, t)/\partial x^2 = K \times \partial v(x, t)/\partial t$.

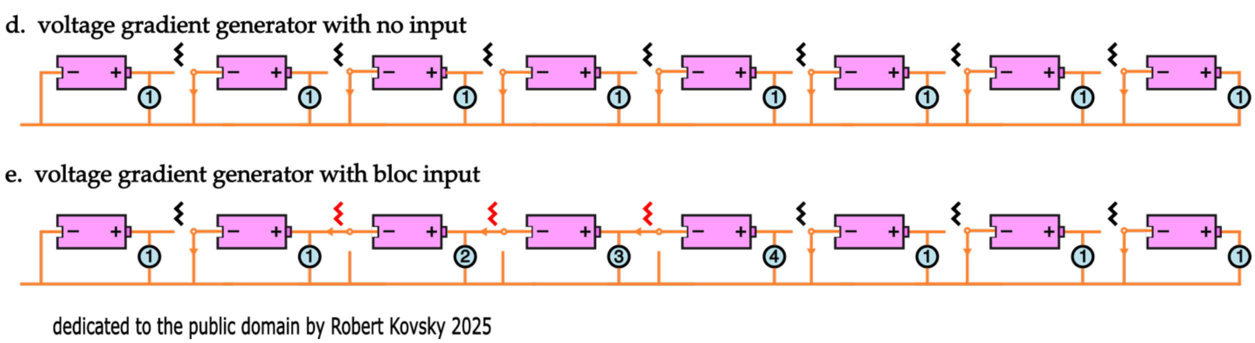
(See Paul J. Nahin, *Oliver Heaviside* (2002) at 30, in a discussion of early applications of diffusion principles by William Thomson (later Lord Kelvin) to electrical signals in original 19th-century trans-Atlantic cables.)

v. VE devices control potential VE distributions in blocs of devices that function like gradients of voltages in electrical devices.

Electrical voltages are familiar examples of potentials. Fig. 45 shows the construction of an array of voltage sources (batteries) and switches. The final design generates a variety of voltage gradients.

Fig. 45. variable generation of voltage gradients





In the element of construction shown in Fig. 45(a), the voltmeter shows 1 volt potential between the battery anode and the ground that is connected to the cathode. (Current flow through the voltmeter is 0.)

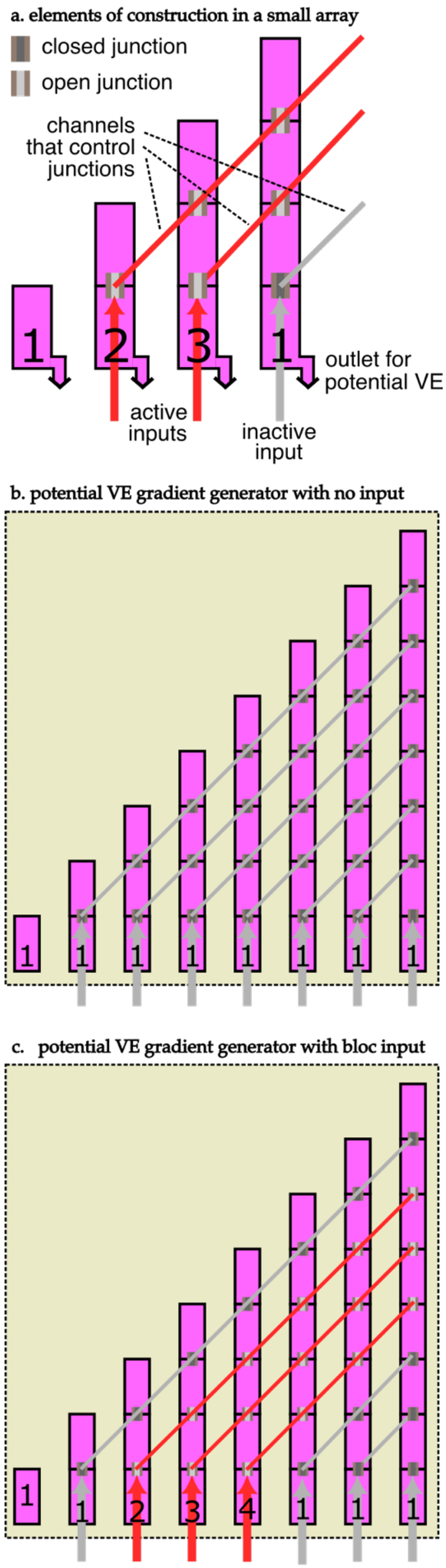
When three batteries are connected in a linear array in Fig. 45(b), a voltage gradient is generated.

In Fig. 45(c), "switches" are attached to cathodes of batteries and are shown in idle position, disconnected from contacts. Voltmeters are off.

Figs. 45 (d) and (e) show a generator of a variety of voltage gradients. Recalling a centering module, seven switches respond to inputs from an external control; seven corresponding voltmeters provide output.

During operations, a switch is either active or inactive. When the switch is inactive, the cathode of the battery is connected to ground. When the switch is active, the cathode is connected to the anode of the neighboring battery. In the example in Fig. 45(e), three switches are activated in a bloc and the voltage gradient extends over four batteries.

Fig. 46. generation of potential VE gradients



In Fig. 46(a), each device holds 1! of VE. Devices are arranged in a column; potential VE in a column is defined as VE that is ready for discharge from the outlet for potential VE. Potential VE in a column is indicated by a number (of bangs) at the bottom.

VE in the lowest device in a column is always ready. Whether VE is ready in devices at higher levels in a column depends on the junctions. Higher level devices hold ready VE when they are connected to the lowest level device by a path of open junctions.

Junctions start off closed and inactive, shown in gray in figures. Active inputs produce red signals on channels. Signals open junctions.

The potential VE gradient generator shown in Fig. 46(b) has a condition of "no input." All junctions are inactive and closed. The potential VE in each column is 1!.

Fig. 46(c) shows the results of operations when a bloc of inputs is activated. The resulting signals are shown in red in activated channels. An active stimulus opens the lowest junction in its column and triggers signals in channels that open sets of junctions, resulting in higher levels of potential VE. A bloc of inputs results in a gradient of potentials.

If the switchable junction of the bottom device in a column remains inactive, the potential VE in the column remains at 1! even when there are open junctions higher in the column.

vi. Functions of a centering module are performed by two mirrored gradient distributions of potential VE that cross at the center of the stimulated bloc of inputs, leading to a signal on a central output.

The final design in this section, a "gradient centering module," has an input end and an output end. The arrival of a stimulus bloc triggers the start of operations of devices in both ends.

In the output end of the module (Fig. 47), final output projections are driven by primal pulser devices where $V_s = 10!$. At the start of operations, $V(t) = 0$ in each pulser.

Fig. 47. VE gradient centering module, output end

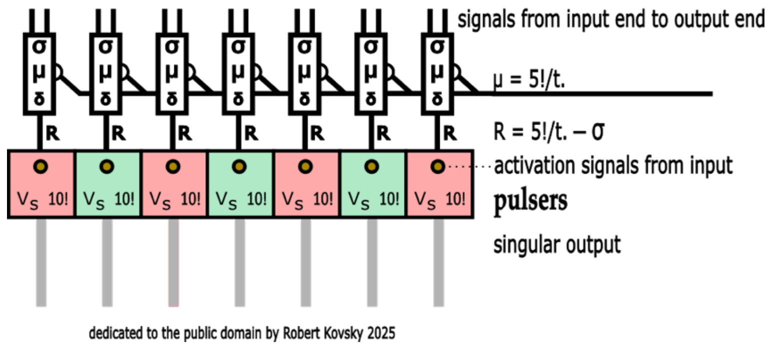


Fig. 47 pulsers start charging from VE sources only if they have received activation signals from corresponding inputs, which arrive at brown dots on the pulsers. Pulsers with inactive inputs do not start charging.

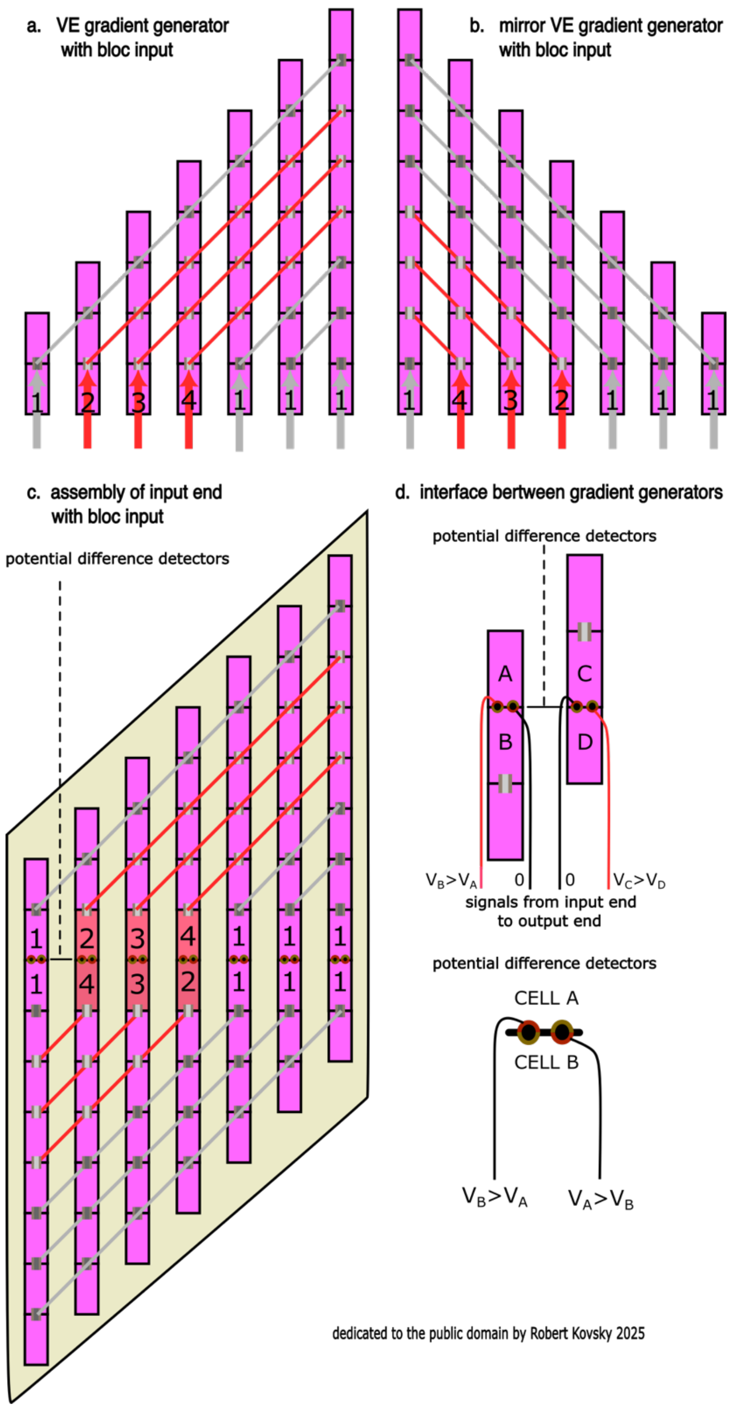
There is a difference between pink and green pulsers. The discharge of a green pulser is delayed by 2δ and will not occur if a pink pulser discharges first and terminates the process. This feature "breaks the tie" when two adjacent pulsers reach $V(t) = 10!$ at the same instant, as applied below.

Pulsers start charging only after processing in the input end. VE sources for the pulsers (denoted R) arrive on difference projections from difference devices. Minuend signals into the difference devices have a rate $\mu = 5!/t$. Subtrahend signals are the result of operations of devices in the input end.

In sum, an input signal on the subtrahend line into a difference device slows down the corresponding output pulser. The result is a contest or race between output pulsers. The first pulser to discharge identifies the center of the bloc and terminates the process.

The activated pulser with the smallest input signal wins the race. Any tie between adjacent pulsers is broken by an additional delay in the green cell.

Fig. 48. construction of input end of VE gradient centering module



Construction of the input end starts with the VE gradient generator from Fig. 46(c), reproduced in Fig. 48(a). The exemplary trio in the input bloc is carried forward.

In the "mirror version" in Fig. 48(b), a gradient runs in the opposite direction from the original.

For assembly in Fig. 48(c), the horizontal mirror version is further mirrored vertically. Then the two gradients are joined with an interface that consists of VE potential difference detectors between corresponding bottom devices in the two gradients.

The difference detector produces pulses at the rate 1!/t. for each ! of potential difference across the detector, with a maximum rate of 5!/t. Said production rate limits the speed of operations of the module.

The smallest signals from the input end will be produced by detectors at the center of the bloc, where gradients cross.

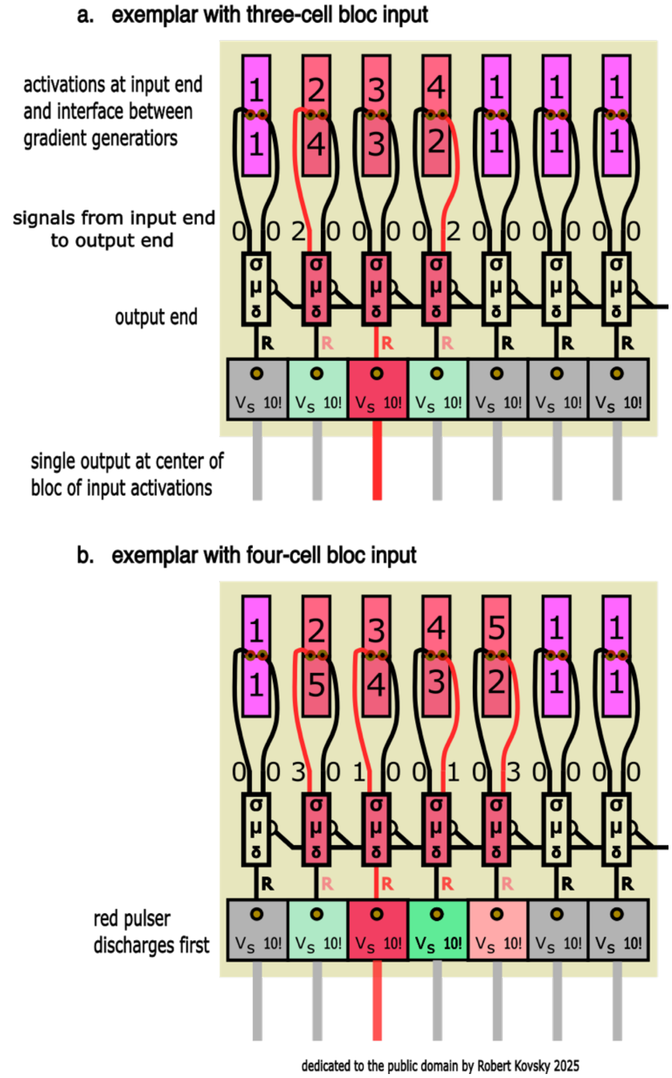
In Fig. 49, the input end of the VE gradient centering module is connected to the output end. Operations are restricted to the bloc of devices defined by inputs.

Inside the active input bloc, two mirrored gradients run in opposite directions, crossing at the center.

When, as in Fig. 49(a), the number of stimulus inputs is odd, there is a single central pulser that receives the maximal VE inflow R = 5!/t. Neighboring pulsers receive only R = 3!/t. and fall behind the central pulser in the race to V(t) = 10!.

When the number of stimulus inputs is even, as in Fig. 49(b), two pulsers at the center both receive the highest VE inflow R = 4!/t. Neighboring pulsers receive R = 2!/t. and fall behind the central pulsers.

Fig. 49. operations of VE gradient centering module



Two neighboring pulsers are "one pink, one green." When a pink pulser and green pulser both reach the V(t) = 10! level at the same instant, the delay in discharge of the green cell will result in sole discharge from the pink pulser and termination of the process.

vii. Comparative performance of centering modules

Three centering modules have been constructed based on:
(1) timing devices (Fig. 30); (2) linear-array junctions (Fig. 35); and
(3) VE gradients (Fig. 49).

In comparing performance times, chief interest is directed at the centering function rather than preparatory or final operations. For 31 inputs, performance time for centering by the timing device design fits within 4t. Performance time for the junction design fits within 1t.

Performance time for the input end of the gradient design is shorter than in other designs: gradient junctions open immediately, starting signals from detector devices; a performance time of 1t. is excessive. Performance time of the output end is slower, requiring as much as 3t. (Faster designs for the output end are readily conceivable. The limit in this design is the slow rate of pulses from potential difference detectors.)

In timing device and linear junction modules, the performance time for step-by-step operations increases linearly as the number of inputs increases. For the potential gradient module, in contrast, performance time remains the same no matter how large the number of inputs.

The number of devices needed for a module, denoted by N, depends on the number of inputs, denoted by J. For the timing device module, $N = (3 \times J) + 2$ (thus including the signal generator). For the junction module in Fig. 35, $N = (2 \times J) + 1$, plus the drive body.

For the input of the VE gradient module, $N = J^2 + 3J$ (including two VE potential difference detectors for each input). For the output, $N = (2 \times J)$.

Energy requirements are much higher in the gradient module than in the others. During operations, each device requires a continual supply even when resting. Many devices and high rates of VE consumption are prices paid for the fine structures and quick responses of the gradient module.

In animals, energy requirements for the nervous system are small when compared to requirements for muscles. A small improvement in speed or maneuvering capacities justifies a lot of nervous activity.

9. Movers and bursters

Muscle-like force devices or "movers" and bursting devices or "bursters" were first defined in Bursters I: Elemental Constructions in Virtual Energy Domains" (2015). Definitions and applications were developed in Wriggler projects (2020-2022).

The following construction of mover-burster designs starts with the original definitions for steady movers and incorporates Wriggler developments. Steps in the construction parallel those in the Gazer project. The Gazer project focuses on movements and functions of devices; this construction focuses on VE operations of devices.

<u>Steps in the construction</u>

a. primal force fiber device that produces twitches

b. steady mover (duet) made of two force fibers and two bursters

c. steady mover with a fixed tonic force and a variable phasic force

d. augmented bursters that combine leading pulses and content pulses

e. a module with coupled bursters that drives opposing movers

f. a module with bundled bursters that drives opposing bundled movers

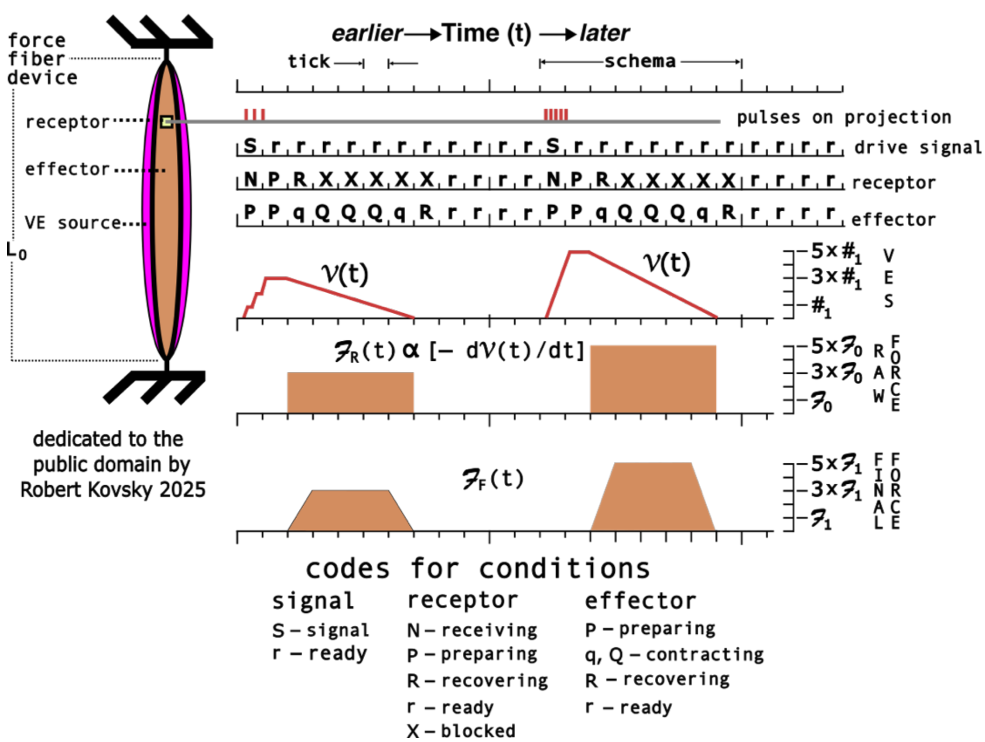
a. primal force fiber device that produces twitches

Fig. 50 shows operations of the primal force fiber device. The left side of the figure shows the device's receptor, effector* and VE source. In this initial definition, the device is attached to fixtures; its variable length L(t) is maintained at the maximum, $L(t) = L_0$.

The function of the force fiber device is to produce a twitch by the effector after arrival of a pulse burst at the receptor. All twitches have the same duration and shape in time. The strength or force size of a twitch is proportional to n, the number of pulses in the stimulating burst.

Initially, ticking is controlled by the Master Clock. Device operations are organized by an 8-tick schema: NPqQQQqR. The schema is charted in Fig. 50: after traveling over the projection, a pulse burst (S), arrives at the receptor, which starts operations during the first tick (N) of the schema. The effector performs preparation (P) during the first and second ticks, incorporating the pulses, followed by effector contraction for the next five ticks (q, Q). Recovery (R) occurs during the final tick in the schema. The device is then ready for a fresh stimulus. Preparation time P includes a margin of silence, which can be used for modifications and adjustments.

Fig. 50: operations of a primal force fiber device



Production of (final force)* $\mathcal{F}_F(t)$ requires two processes that occur simultaneously. The first process produces a (raw force)* $\mathcal{F}_R(t)$ that has a simple mathematical relationship with VES operations and a rectangular shape $\mathcal{F}_0$. The second process produces the final force with the same force as $\mathcal{F}_R$ for most of the contraction but based on a different trapezoidal shape, $\mathcal{F}_1$ that has ramped sides. Dissipation during q ticks causes loss of VE and force during the second process. Dissipation slows the rise of force at the start of the twitch and cuts into the force at the end.

VES operations of the force fiber device are controlled by the schema and the Master Clock. Arrival of an input pulse at the receptor releases into the VES a specific quantity of VE, denoted by "#" and called "a pound of VE," which suffices to produce a twitch of final force strength $\mathcal{F}_1$ during discharge. VE flows into the VES at the rate 5#/t.

In Fig. 50, the first burst has 3 pulses and the rising VE level, $\mathcal{V}(t)$, has a step-wise shape. The second burst has 5 pulses and $\mathcal{V}(t)$ rises smoothly.

During 5 ticks of contraction, n# of VE in the VES are converted and $\mathcal{V}(t)$ falls at a constant rate. In response to bursts with {1, 2, 3, 4, 5} pulses, the device produces twitches with a raw force $\{1, 2, 3, 4, 5\} \times \mathcal{F}_0$ and a final force of $\{1, 2, 3, 4, 5\} \times \mathcal{F}_1$. Presumptively, and applying a principle of finality, internal VE flows can be adjusted to perform this function exactly.

A correspondence relation can be summarized as:

$\mathcal{F}_R(t) \propto [- d\mathcal{V}(t)/dt]$, a differential form of $\mathcal{F}_R(t) \propto \{1, 2, 3, 4, 5\} \times \#/5t$.

Definitions of force relations are developed for purposes of project goals and are not directly aimed at describing nature. Project goals motivate the "trimming" of the force shape from a rectangle ($\mathcal{F}_0$) to a trapezoid ($\mathcal{F}_1$) and the variation in mover force with length discussed in the next step. Desired features of force production are imputed to the body of the device.

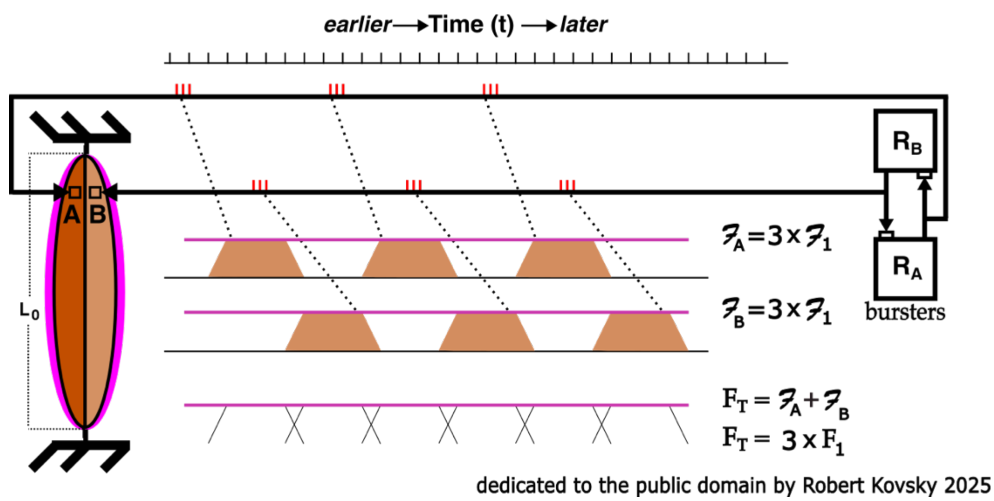
b. steady mover (duet) made of two force fibers and two bursters

In Fig. 51, two force fiber devices (A and B) share a fixed arrangement and are maintained at maximum length. The force fiber devices produce alternating twitches that combine to exert a steady force. Alternating pulse bursts drive the force fiber devices; and alternating and reciprocating burster operations produce the burst signals.

A burster and a force fiber make up a "unit," working together like a musician and an instrument. Two coupled units of bursters and force fiber devices make up a "duet."

Burster R_A generates a stream of pulse bursts with 3 pulses in each burst; it drives force fiber A and produces force $\mathcal{F}_A$. Burster R_B drives fiber B with a 3-pulse stream and produces force $\mathcal{F}_B$. The two forces combine in the mover arrangement like numbers so that steady force F_T is the sum of alternating twitches. The strength F_T has the same size as that of an active force fiber device during the QQQ ticks.

Fig. 51: operations of full-length primal steady mover — a "duet"



The foregoing construction applies to a mover fixed at full length and defines the first part of the mover force relation, namely, $F = n \times F_1$.

Next, a variable length of the mover is related to a variable strength of force produced by the mover. ΔL is defined as the shortening* of the mover or $\Delta L(t) = [L_0 - L(t)]$. The definition of the force relation for the variable length steady mover is: $F = [n \times F_1 - (j \times \Delta L)]$ where j is the (dissipation factor)*, which denotes a loss of converted VE (force) when the mover shortens. This is called Formula 1 in the Gazer project, §4.

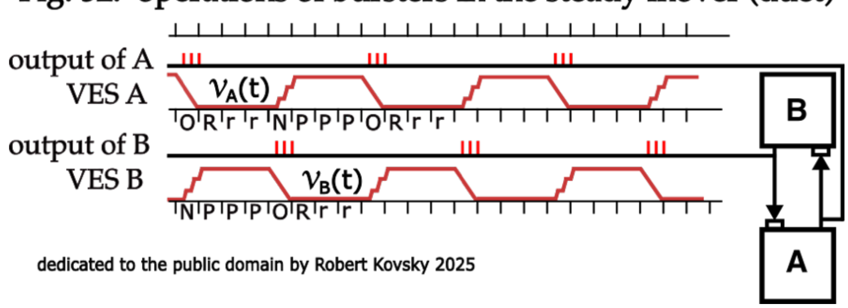
VE operations of bursters in Figs. 51 and 52 resemble those of force fibers. Differences include schemata of operations, with NPPPORrr rather than NPqQQQqR. The long preparation anticipates future developments. A burster produces a single pulse burst during the "O" tick and uses much smaller quantities of VE than a force fiber device.

Operations of (repeating bursters)* A and B are shown in Fig. 52, where each performs a function "n pulses in, n pulses out" after a processing time of four ticks. The pulse number n is selected from a set of integers, e.g., {1, 2, 3, 4}. In a duet, repeating bursters discharge alternating pulse bursts onto each other and generate a steady stream of bursts. Reciprocating operations resemble those of the timing device signal generator in § 8(b).

VE operations shown in Fig. 52 start with production of a pulse burst on the output of burster A through conversion of VE in VES A. Burst production closely resembles that shown for other devices (§§ 7(c), 8(d)). The body of the device retains converted VE until one bang is accumulated; then that bang is discharged as a pulse. The last pulse in the burst is discharged at the start of the next tick.

Pulses discharged by burster A arrive at B's receptor and each pulse is converted into 1! in VES B. VE flows into VES B at the rate 5!/t.; hence the VE level in VES B, $\mathcal{V}_B(t)$, has a step-wise appearance during B's N tick. On the fifth tick of B's schema, $\mathcal{V}_B(t)$ starts to fall, converting VE into pulses on B's output, leading to reception and processing by burster A.

Fig. 52: operations of bursters in the steady mover (duet)



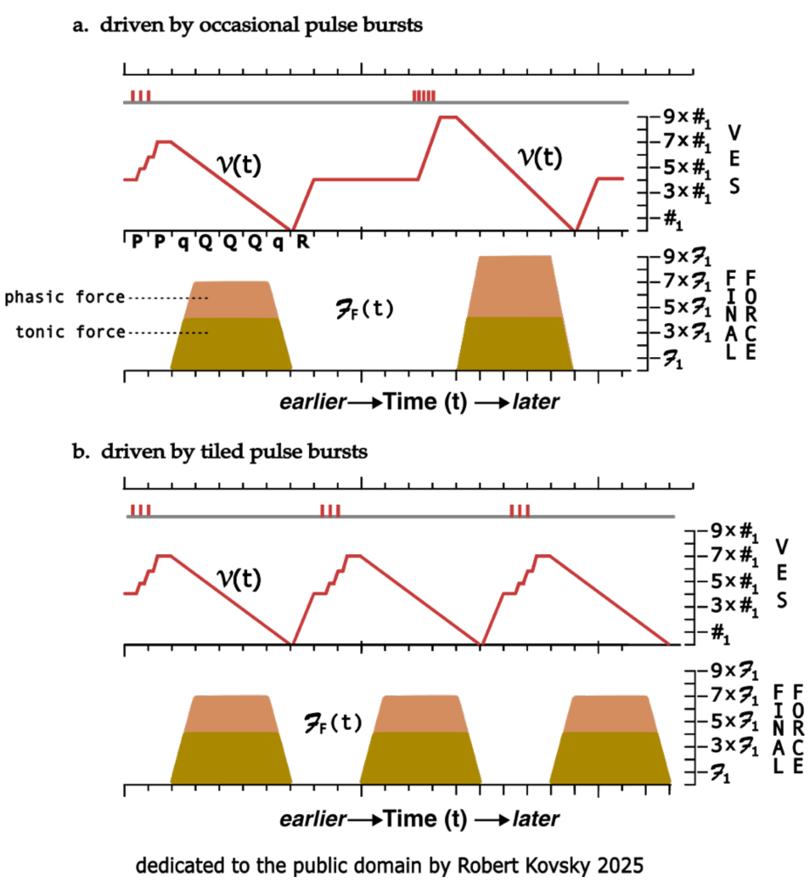
c. steady mover with a fixed tonic force and a variable phasic force

In §4 of the Gazer project, the initial steady mover is developed into a somewhat different steady mover used in the primal stimulus-response model (Gazer §2) and in final designs (Gazer §§ 5-7). Parallel development here involves two steps, introducing tonic/phasic forces in this step and augmented pulse bursts in the next.

Tonic and phasic forces are shown in Fig. 53(a). The tonic force is the same for every twitch; the phasic force is variable. In response to a 3-pulse burst, the final force $\mathcal{F}_F$ combines a tonic force (4 × $\mathcal{F}_1$) and a phasic force (3 × $\mathcal{F}_1$). In response to a 5-pulse burst, operations combine a tonic force (4 × $\mathcal{F}_1$) and a phasic force (5 × $\mathcal{F}_1$).

More precisely, the combination occurs in the VES. During the schema, VE arrives at the VES in two steps. The VES receives 4! during the R tick (at the rate of 4!/t.) and (1–5)! during P ticks as in the original design.

Fig. 53: VES operations of a force fiber device with combined tonic and phasic forces



At least 8 ticks must intervene between two successive pulse bursts to a force fiber device. In the special case where bursts arrive every 8 ticks, successive schemata connect with each other immediately, as shown in Fig. 53(b); this condition is tiled*.

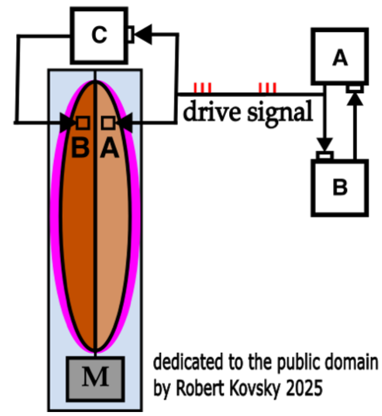
Tiled schemata are used in steady mover designs. Signals arrive continually and movers are always tense. Steady positions correspond to steady signals. When signals change, new signals stay steady while movers shift into new steady positions.

The two projection lines in a duet are reduced to a single drive signal line.

In an example (Fig. 54), a projection from burster A is branched and carries signals both to force fiber A and also to nearby burster C, which discharges 4t. later onto force fiber B. Otherwise, operations are the same as in Fig. 51.

Such single drive lines are used in the Gazer project.

Fig. 54. duet with single drive projection



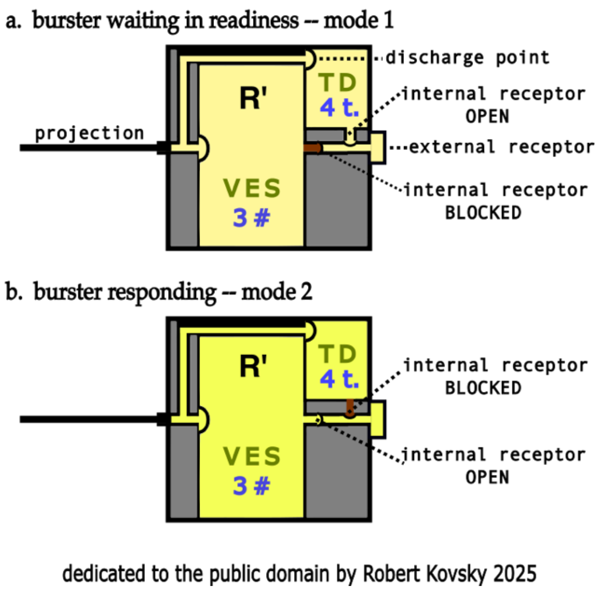
d. augmented bursters produce pulse burst signals that combine leading pulses and content pulses

Pulse bursts with leading pulses are defined above as to timing devices in §8(d) and Figs. 20-23. In the extension for bursting devices in Fig. 55, output bursts can have either 1, 2, 3 or 4 pulses. Variable operations of bursters expand on the timing device design in Fig. 22, where all output bursts have 3 pulses.

By means of leading pulses, timing control is relocated from the Master Clock, first to a modular device — timing device TD in Fig. 55 — and then to modular and sensorial bodies. Collective operations in such bodies acquire temporal independence.

Internal receptors in the Fig. 55 design switch between OPEN and BLOCKED conditions, resembling switchable junctions in Fig. 46. In mode 1 (device is ready), the receptor to TD is OPEN and the receptor to VES is BLOCKED.

Fig. 55. Self-timing burster for bursts with leading pulses



The arrival of a leading pulse triggers the timing device, thus blocking its receptor. The leading pulse also opens the VES receptor.

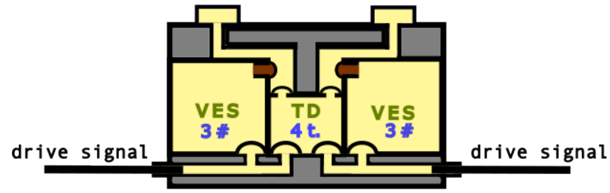
Following pulses in the burst pass through the VES receptor and trigger releases of VE into the VES.

Four ticks after arrival of the leading pulse, the timing device discharges through the discharge point.* VE is transported from the timing device through a channel to the output projection. Discharge of the timing device triggers synchronous discharge of the VES through its discharge point. The leading timing device pulse and any content pulses combine to fill a tick like signals in Figs. 20-22.

e. a module of coupled bursters drives opposing movers

Fig. 56 shows a burster module that drives opposing movers. Two sensor bursts arrive every 8t. and the module repeats those bursts in drive signals.

Fig. 56. Module that drives opposing movers



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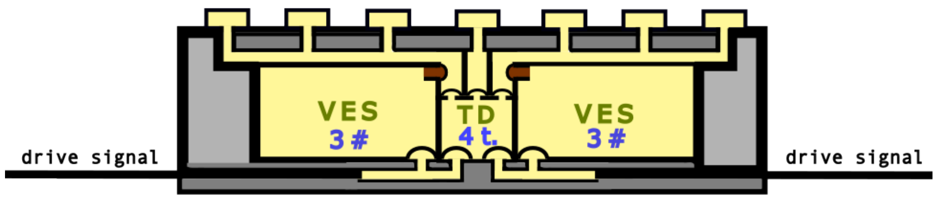
To simplify operations and accommodate the slow speed of movers, the pulse number n in successive bursts changes only occasionally.

The Fig. 56 design is extended to the 7-input design in Fig. 57, which is used in the final Gazer model.

Fig. 57. Opposing movers module with 7 inputs, as used in Gazer



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Signals are continually streaming in the Fig. 56 design . In other words, sensory detections occur every 8t. and the results are passed through the associative networks and centering module in regular order to produce fresh drive signals every 8t. There is no memory.

Another design performs functions of the primal model in §2 of the Gazer project, holding a position steady in the absence of a drive signal. A new signal substitutes for the existing signal.

In a hold/substitute version, each burster drives a repeater burster and two reciprocating bursters maintain signal values as a rudimentary memory until new drive signals are substituted to produce new positions. A hold/substitute version can handle streaming input but there is a delay in production. A hold/substitute burster system was constructed in the Wriggler I project.

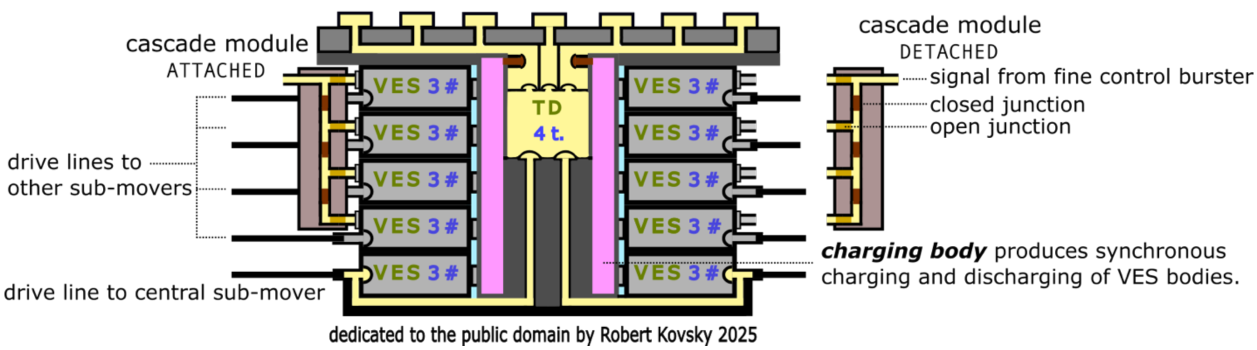
f. a module with bundled bursters drives opposing bundled movers

In the Fig. 58 module, enlarged from that in Fig. 57, five bursters drive five sub-movers in each of two opposing bundled movers. Operations involving the central timing device and leading pulses are the same in the two designs. On discharge of the Fig. 58 timing device, two leading pulses start the drive signals for the two central sub-movers. Contraction of the central sub-mover in a bundle triggers synchronous contractions of the other sub-movers. Discharge of the timing device also triggers synchronous discharge of all the bursters.

Two sources of VE add in each VES: (1) the coarse amount from the central charging body (0 to 3 #); and (2) the fine amount (0 or 1 #) triggered by pulses arriving through the cascade module from the fine control burster.

The chief source of VE to VES's is through the charging body that is filled with VE during the restoration period. Each pulse that arrives at the charging body triggers the release of 1# of VE into each VES.

Fig. 58. bundled bursters for bundled movers

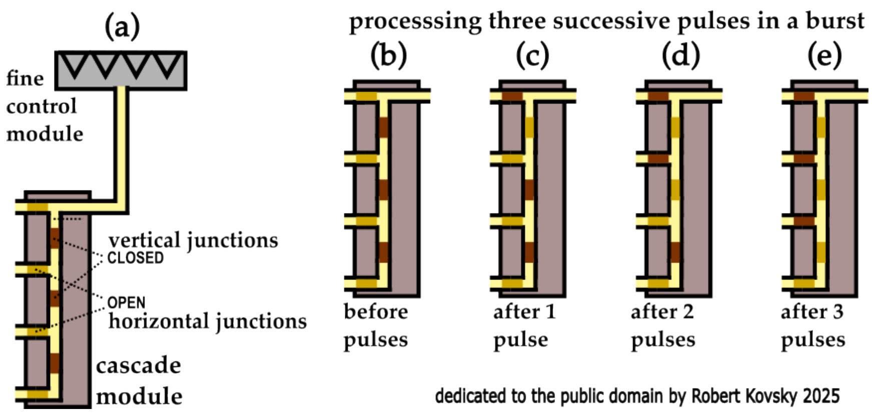


Fine control adjustments to individual bursters involve cascade modules, which process pulse burst signals produced by fine control bursters. Such burst signals have no leading pulse and 0-4 content pulses.

The fine control burster has a short schema: NPOR. Hence the output burst from the fine control burster arrives at the cascade module 2 ticks after the corresponding coarse control burst and within the preparation time of the schema of the bundled burster module. The preparation tick P of the fine control burster can be shortened by several δ to increase margins of silence in operations.

A fine control module and cascade module are shown in Fig. 59(a). During operations, a pulse discharged from the fine control module passes through the cascade module and arrives at an individual burster, triggering the release of 1# of VE into that burster's VES. The cascade module distributes pulses in a burst to individual drive bursters, using junctions that switch between open and closed.

Fig. 59. operations of fine control module and cascade module



Details of cascade processing are shown in Figs. 59(b – e). Before any pulses are received, horizontal junctions that lead to bursters are open. Vertical junctions that direct pulses between bursters are closed. The initial arrangement of closed and open junctions channels the first pulse in a fine control burst to the top burster. Fig. 59(b).

After the arrival of a pulse at a burster, the horizontal junction to that burster is closed for the rest of the cycle. Also, a pulse that arrives at a closed vertical junction changes the junction's condition from closed to open for the rest of the cycle. Thus, the first pulse in the Fig. 59 burst changes junctions in the module so as to direct the second pulse in the burst to the second burster. Fig. 59(c).

Arrival of the second pulse repeats the events of the first pulse at the second burster. Fig. 59(d). The third pulse receives a corresponding reception, leading to the final condition where the module is ready to receive a fourth pulse, which, however, does not arrive. Fig. 59(e).

C. Retrospective views and prospective development

The foregoing project sets forth VE definitions, operations and constructions for designs in the Gazer project. I suggest that these projects provide a solid foundation for further developments.

From a retrospective view of projects on the website, investigations of predation and its cousins started on the first page of the first project, citing a scientist's observations of decisional tactics of hawks: "they may feint and then follow through if the prey betrays some uncertainty or physical weakness." ("The Crucible: Structural Foundations of Consciousness and Freedom" (1992) and Errington, *Of Predation and Life* (Ames, Ia; 1967).)

The earliest designs for "[e]ngineered organisms that move and sense from a condition of balance" incorporated balancing units discussed above in § 8(h)(iv). The organisms "follow a light" in an aqueous environment.

> When there is balance, the output of the balancing unit is a null signal, a condition called “internal silence.” Then, the organism is “heading for the light,” assuming there is a light. If a light is moving from one side to the other, the organism will “follow the light.” The organism acts so that any light becomes “centered” between the sensors. There is a centerpoint of operations around a balanced condition, called “centerpoint balancing.” (¶) “Centerpoint balancing,” “internal silence” (null signals) and “following an external object” make up a fundamental unit in the operations of the engineered organism.
>
> ["An Ear for Pythagorean Harmonics: Brain Models Built from Timing Devices" (2011 rev.) at 36-40)].

Now, combinations of Wriggler locomotion and Gazer object-location appear to offer opportunities for further development of engineered organisms that "follow a light."

Speed of performance is of high importance in predation — and in VE designs. The capacity of an animal to catch a prey or evade a predator depends on its top speed in moving through the environment. The top speed depends, in turn, on physical structure and muscle strength, stamina, etc., which are outside the scope of these investigations. However, VE designs can investigate other aspects of predation, such as maneuvering (sudden, evasive changes of direction of movement) and quick opportunistic use of favorable features of the environment.

Suppose that a VE domain is occupied by various mobile engineered organisms with a uniform physical constitution and a variety of control systems, all designed to navigate mazes and solve other practical puzzles. A measure of success is the capacity of an organism to "compete and win" a speed contest in completing a particular maze.

Evaluating current VE designs against these standards leads to the conclusion that steady mover designs in Wriggler and Gazer projects are very slow, especially as movers approach final positions. Such slow, simple movements are suitable for early development. "Final position" is a useful feature of steady mover operations that will be carried forward. Steady mover designs provide guidance for faster developments.

To start, the force fiber device is developed into a multi-part fiber with both a steady part that is unchanged from the prior design and also a new saccadic part. With certain exceptions, operations of saccadic force fiber devices are the same as those of steady parts. The exceptions result from a force form that is different from the trapezoidal $\mathcal{F}_1$ previously used. Instead, the saccadic force form is denoted as $\mathcal{G}_1$ and represented mathematically with a term $\exp\{-(t - t_0)/\lambda\}$ for t greater than t_0 and where λ=1t. is a convenient value. Using this form and value, the first tick contains almost 2/3 of the total force production. $\mathcal{G}(t) = [n \times \mathcal{G}_1 - (j \times \Delta L)]$.

Saccadic twitches do not connect smoothly like steady twitches. The duet with two units (each with a burster and force fiber device) is developed into an octet with eight units. In a standard mode of production, each unit is receptive to an input for one tick out of every eight ticks; receptive periods of devices link up in a cycle to provide continuous receptivity.

Twitching in an octet is organized by an action pattern (schema). One unit starts each tick in a cycling sequence. Summed saccadic forces are irregular or "trembling." Trembling can be reduced by multiple octets with staggered cycles If the sum of forces imparts momentum to body parts or to the whole organism, "flywheel effects" smooth the trembling.

In another modification for speedier movements, a module might start the movement in "overdrive" with a force greater than that needed to achieve the final position and then reduce the signal as the mover approaches the final position. Another possibility is starting with a reduced force from the antagonist mover, which is increased at the end of the movement.

A further level of complexity might involve banks of replicated modules of movers that can be activated in different patterns (like different gaits of horses) and that could provide large repertoires of speeds and strengths.

Another development might involve the hierarchy of time. Guiding values in current designs (α, δ and t.) can be reduced in size and combined.

Developments in mover complexity would require corresponding developments in controls, e.g., larger modules of bursters and timing devices in collective bodies in an intricate network. The development of centering modules in §8 shows that synchronous operations in large collective bodies can achieve high speed performance. Each device operation requires a specific period of time; series of operations go slower as the number of operations grows larger. Designs where multiple large collectives function simultaneously should produce the fastest responses.

Development of multiple bodies of collective devices that operate synchronously and that coordinate selections from large repertoires of movements — these steps appear to lead towards Shimmering Sensitivity.

Images prepared with Inkscape 1.2
December 2025