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

I. Preliminaries

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

Virtual Energy (VE) constructions take place in imagination and are aimed towards a goal beyond the reach of this project: models of Shimmering Sensitivity, a physical principle of freedom that operates during movements of animal bodies. For a presentation, see Contests (sports and games), part B of the website.

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 further defined by other concepts or implicitly by means of practice and use.

Sometimes the style of construction of the VE model closely resembles the rigor of classical geometry, with its primitive concepts of points, lines, straight-edge and compass; sometimes a looser, rougher style of construction expedites development.

Overview of the formal VE model. The formal VE model is a set of concepts and methods to be used for construction of (VE devices)*. VE devices perform operations* that resemble elements in a command set in computer programming. VE designs resemble electronics circuit designs known as "schematic diagrams."

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 plus additional or modified features* and operations. Major kits of parts are projections*, pulsers*, (timing devices)*, bursters*, movers* and (force fiber devices)* that make up movers.

A module* – an assembly of device parts – performs useful functions. Larger constructions culminate in (engineered organisms)* with movements resembling those of animals. Devices, modules and larger constructions operate in bodies* governed by properties* that maintain and control operations and movements. Properties of bodies are foundational in (collective devices)*, e.g., (quadnet devices)*. Anticipated models of Shimmering Sensitivity use quadnet devices.

Models. Engineered organisms belong to a larger class of constructions called models*. Robots make up a different kind of model although there are resemblances between the two kinds. As an example of resemblances and differences, appearances of "computation" in VE designs are based on various combinations of forces, signals and operations in different kinds of bodies rather than on a single kind of calculation using binary digits.

A (physical model)* is built using technology; activities of a physical model are organized by means of a mathematical or (conceptual model)*. Coordinated physical and conceptual models are found in mechanical engineering, biology and computers and suggest future developments for VE models.

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 features of H_20, chemical bonds, electrical charges and Conserved Energy constructions.

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

I suggest that methods of specific models work better for investigations 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, such commitments tend to derogate 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 developed by George Stokes where a fluid is modeled as a mobile substance with idealized properties (e.g., linear relation between flow velocity and 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 two kinds of scientific models: (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."
>
> "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."
>
> "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."
>
> "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."
>
> "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."
>
> [References are included 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. Then, 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, twitches and stepwise arrays of stationary positions.

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

Summary of the VE substance. In models of H_2O, electrical charge and Conserved Energy, common features include: multiple forms*, e.g., forms with a static character or a fluid character; ranges of quantities*; and spatial locations*. Changes* in forms, quantities and locations are restricted by (conservation principles)*. VE incorporates these features subject to modification.

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

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

b. Initial conservation principles apply to changes between static forms.

c. Conservation principles are applied to changes in locations and flows.

d. A 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," reserving the word "water" for the liquid form. A (material substance)* is derived from stuff found in nature that has undergone processes of refinement and isolation to bring it into closer correspondence to products of human imagination. Bodies are made of materials found in nature and refined substances.

The (character)* of a substance is an expansive class 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., water vapor condensing to form snowflakes.

In this first step of construction, each body of H_2O has a single such form, which does not change. The body is static* when stationary; and the body 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. Like H_2O, charge has multiple forms, e.g., static charges in capacitors and storage batteries and fluid currents in wires. The charge substance is said to subsist in stuff found in nature like a material substance. It co-exists with mass (protons and electrons) and interacts with mass but with a character different from that of mass.

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 a static model of a standard chemical 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.

In the next step, "separated charges" and "canceled charges" serve as the first, static forms of electrical charge for paradigms of conversion and conservation.

In a primitive static model, each charge is assigned to a specific location or submicroscopic volume of space at any moment. Like H_2O, distributions of electrical charge in a static body are described by mathematical relations that assign a specific quantity of charge to each specific location. Methods of differential equations applied to H_2O are also applied to static electrical charges. Standard features of differential equations that describe liquid water 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 supply 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.
>
> …Though never found in a state of purity, but always more or less corpuscular (even in light), energy nowadays represents for science the most primitive form of universal stuff. 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. It is a mental invention based on concepts 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. A (formal substance)* is constructed from these features. Restricted models of H_2O, electrical charge and CE qualify as formal substances. Inside a body under investigation, the formal substance CE appears in static forms and fluid forms and is described by readily-changing quantities, locations and distributions organized by differential equations that have operators (gradient, laplacian) that also apply to H_2O and electrical charge.

Standard paradigms of ***diffusion*** manifest common features in the three substances. 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 driven by voltages and to model 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.

Virtual Energy. Virtual Energy starts with Conserved Energy (CE), including features of substance, character, form, quantity, location, distribution and mathematical representation. Other features are based on atomic models. An initial kind of VE is constructed from these features.

The (Virtual Energy Store)* (VES) in the body of a VE device serves functions like those of Internal Energy (U) invented by Rudolf Clausius as part of CE. Basic VE conversions and flows resemble those of H_2O, electrical charge and CE.

In further constructions, features of CE are modified. Dissipation principles become operational. New features are added based on physical principles imputed to bodies. These include principles used to control timing such as synchronized discharges of pulses in a collective VE device.

Certain aspects of VE differ markedly from those of CE. There is no global energy law in VE but only a motley patchwork of 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 of CE, changing input streams of VE participate in processes where outputs are changing streams of VE. 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 selected* actual movements that exclude all others. Such a result can depend on tiny influences in forms of Sensitivity. Such a VE model of choice or selection is a chief aim of construction of this formal VE model.

In the first VE models, VE fits requirements of mathematical distributions; but I do not presume that VE is quantified or locatable in submicroscopic volumes of space under all circumstances. I anticipate that, during critical moments, VE is ***unquantified*** and ***unlocalized*** within a momentary action form that extends over multiple modules, each containing collections of devices. Such a ***shimmering 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 generates a flicker of an image*, e.g., a feeling*. (Thoughts* are also images.) I suggest that the feeling participates in the change; a different feeling accompanies a different change. A steady stream of feeling is generated when multiple uniform bodies climax in a cyclical sequence. In an assembly of bodies that pass through critical moments together, images in certain bodies control movements of other bodies.

b. Initial conservation principles apply to changes between static forms.

H_2O, electrical charge and CE share paradigms of (static conversion and conservation)*. During such a conversion, a quantity of a substance in one static form is changed into another static form of the same substance. The quantities of substance in the two forms add up to the same amount before and after the conversion, so the total summed quantity is constant or conserved.

A static conversion can be interrupted and resumed without changing the result. Accordingly, the results of a static conversion do not depend on the speed of the conversion. Ideal static conversions are said to be reversible*, able to return to the starting point with the same amount of substance change as the prior change, but in the opposite direction. Repeated reversible cycles produce the same results as an interruption that leaves things the same for an indefinite period.

I say that interruptible or reversible static conversions operate in (detached time)* to distinguish them from dynamic conversions that involve dissipation, momentum and changing forces occurring in the (actual time)* that is uninterrupted and that excludes static reversibility. Conservative static conversions are easier to model.

In H_2O, electrical charge and CE, applicable principles are called conservation of mass, conservation of charge and conservation of energy respectively.

H_2O. On a first level of investigation, forms of H_2O are solid, liquid and gas. A change in form occurs when a body of H_2O is confined in a closed chamber and heated or cooled. Liquid water boils to become gas or freezes to become solid ice. Ice melts to become liquid or sublimates to become gas. Gas condenses to become liquid water or solid ice or snow. The summed mass of the bodies (the number of molecules) in the closed chamber remains constant during each such a change.

Suppose that a body of ice floats in a body of water held in a pan inside a closed container, all under the control of a researcher. The amounts of H_2O in the two bodies can be modified in a gradual or (shifting conversion)* by slowly heating or cooling the pan. During a shift, a small quantity of one form of H_2O is converted into the other form and the sum of quantities in the two forms stays the same. Shifting can take place at various speeds but the relations between quantities of heat and quantities of material changed are independent of speed. Shifting can be interrupted and resumed without changing the result. Shifts occur in detached time and are easily reversed. The phrase "quasi-static process" is also used.

A deeper level of investigation of mass conservation includes chemical reactions where H_2O is not always conserved. New H_2O appears when a carbohydrate fuel (wood, gasoline, sugar) is burned in a process of combustion. Such a chemical reaction combines the carbohydrate with O_2 from the atmosphere and produces

H_2O and CO_2. Conversely, photosynthesis in plants combines H_2O acquired from the environment and atmospheric CO_2 and produces carbohydrate and O_2 — so H_2O is "lost." In a chemical reaction, the principle of mass conservation applies to the number of atoms of each kind, e.g., carbon, oxygen and hydrogen.

Electrical charge. In a first investigation of conserved charge, the model is applied to changes in form between canceled charges and separated charges in an electrical circuit where a capacitor is connected to an electrical storage battery. At the start, unconnected components are electrically neutral and all charges are canceled charges. When the capacitor is connected to the battery, negative charges flow from the cathode of the battery to one side of the capacitor and negative charges flow from the other side of the capacitor to the anode of the battery, leaving positive charges in the capacitor. Canceled charges in the battery become separated during a charging process.

During a charging process, the quantity of separated charges in the capacitor can be controlled by inserting a variable resistor that slows down the separation of charges and also a switch that can interrupt a transfer of charge. Regardless of slowdowns and interruptions, at the end of the charging process, the quantity of charge that is changed is the same.

Conversions between canceled charges and separated charges are described or measured by means of a standard "electron-volt" — defined as the quantity of energy released when an electron and equal positive charge separated by one volt are allowed to cancel. Such energy is subject to rules of arithmetic. The role of the electron-volt in charge conversions resembles those of the calorie and the erg in conversions involving H_2O and chemical reactants.

Conserved Energy. Conserved Energy (CE) includes electron-volts, ergs and calories, which are all inter-convertible. CE comes in multiple static forms, e.g., energy stored in water in a high-altitude lake; energy stored in electrical charges; energy stored in chemical bonds. Energy in one static form can be converted into energy in another form through processes maintained by means of pipes, turbines, boilers, electroplating tanks, etc. In any actual conversion, some energy is lost as (waste heat)*. (This is the "payment" described in de Chardin's second principle.) If waste heat is defined as a form of "energy," the conservation principle becomes infallible by definition.

Many thermodynamic processes operate in detached time with interruptible processes that do not depend on speed. The Carnot Engine is an exemplary detached time paradigm; it does not involve a conversion between static forms but an inventive extension serves as an exemplar of static conversion. (*Feynman Lectures* at pages 45–6 to 45–7.)

Virtual Energy.

In domains of chemical reactions, electrical devices and CE, a conservation principle is an axiom and any specific use is an application of the general principle.

The VE approach is different: there is no general conservation principle. Principles in VE constructions are tethered to specific paradigms. Specific applications are constrained by a variety of principles: some are conservative and others have dissipative aspects. With ample operational inflows and multiple dissipations, the quantity of VE in many a VES is changing or readily changeable.

Primitive elements of VE constructions are muscle-like twitches* and instantaneous transmissions of pulses*. These elements are actions rather than states. They are not interruptible or reversible. Neither detached time nor actual time is applicable to their operations; they operate in (controlled time)* in the VE domain as defined by a researcher or generated in device systems. Another similar kind of controlled time is the beat generated by an orchestra conductor.

In this project, certain VE devices have a conservative VES with a static capacity and certain other devices maintain a balance between VE inflows and outflows in quasi-static forms. There is, however, no simple conversion from one static form to another static form. So, at the first step, there is a possible class of applications of static conservation principles to VE but the class is empty.

In models of H_2O, charge and CE, conservation during conversions is axiomatic and exact. Primal VE control devices (pulsers, timing devices and bursters) incorporate exact conversions, e.g., conversions from the VE in the VES to pulses. Initially, a device has ample VE sources and exact operations can be maintained, e.g., through adjustment of VE flows. Initially, VE is exactly measured by a foundational unit called a bang* and symbolized by "!". In primal applications, a VE device discharges a pulse and 1 bang of VE in the VES of the device is converted into a 1-bang pulse traveling on a projection.

c. Conservation principles are applied to changes in locations and flows.

It is apparent in common experience that, during certain changes in location, that is, during transport*, the quantity of material in a body remains constant, e.g., liquid water in a jug, earth in a wheelbarrow or a container of foodstuff. No new material appears without a source. Perhaps a small quantity of material is lost in transit, but during ideal movements, the loss is reduced to zero.

Scientific models of substances include concepts of transport that are based on common experience. At p. 108, 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."

Concepts of conservation based on static conversions are readily extended to some flows* of mass, electrical charges and CE. Conservation of mass is applied to water flowing from a tank through a tube into a drain. All the molecules that flow out of the tank go down the drain. Conservation of atoms in standard chemical reactions is expressed in stoichiometric equations. If a storage battery is connected to an incandescent lamp, eventually all the electrons that flow out of the anode into one wire will return to the cathode through the other wire. During the journey, CE stored in the electrochemistry of the battery will be converted into heat and light in the filament of the lamp. Taking into account heat produced in the battery and wires during the process, conservation means that all the electrochemical CE consumed will be converted into light and heat.

New, more complicated results appear during some other processes of flow. Changing flows of mass involve mechanical aspects of acceleration, force and kinetic energy. As speed increases, smoothly-flowing water becomes turbulent. Chemical reactions become explosive. Changing flows of charge generate electromagnetic fields that cause movements of distant charges in radio antennas.

Energy conservation during transport is readily extended to massless VE that is provided by ample sources and that is restricted to defined conversions. Accordingly, VE conservation during transport is axiomatic.

d. A potential is a capacity to produce changes.

The concept of potential energy started with gravity; such potential energy is Conserved Energy that 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 from that height to the ground.

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

In a context of Conserved Energy, an initial definition of potential* involves:

(1) a permanent range of values as to any particular body; (2) an energy variable that has a single value in the range at any moment; and (3) a body or assembly of bodies in which changes depend on such values in general and, more specifically, changes depend on the differences between the value of an energy variable at the start of a change and the value at the end of that change.

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

3. Constructions occur in a VE domain that resembles a domain for electronic circuits. 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.

In electrical engineering, comparable domains for physical models are breadboards and printed circuit boards. Similar to an electronics domain, a VE domain has power access at every point. Likewise, animals have circulatory systems that carry fuel, oxygen and other nutrients to every living cell. In VE systems as in such cases, a plenum* of energy sources is accessible through foundational functioning of the system.

An (energy economy)* is progressively constructed as part of the project. 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" that is suddenly noticed on a familiar path. Acquisition of food and an energy economy appear to be chief driving motivations 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 of the projection, the "zero" time of transit is the same.

The instantaneous passage of a pulse on a projection resembles the (nearly) instantaneous passage of an electrical signal in a 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; when a pervasive force is imposed, pushing and movement of the focal substance occurs everywhere all at once.

In contrast to instantaneous transport of a pulse on a projection, passage of a remote nerve signal inside a large animal body requires a substantial period of time. Modifications may be required to adapt VE designs with instantaneous signals so that they function usefully when some signals have long travel times. It is presumed at this stage of development that needed modifications can be invented and that concerns about long travel times can be deferred.

c. hierarchical time

VE devices operate in time structures defined by a researcher 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 independent time structures.

The table lists time periods* used in current VE projects along with names and symbols. Examples are tethered to convenient values used in device designs.

Table of time periods in VE projects

name	symbol	values	device designs
instantaneous*		0 sec.	projections, channels
(fast switch)*	α	0.001 sec.	pulse width, minimum change period, junctions
(slow switch)*	δ	0.01 sec.	timing devices
tick*	t.	0.1 sec.	movers (force devices), bursters that drive movers
beat*		0.4 sec.	4 ticks — used to synchronize movers and bursters operating collectively in a body
schema*		various; e.g., 0.8 sec.	action form defined in terms of operational ticks, e.g., 8 ticks in a mover schema `NPqQQQqR` that controls each twitch of a force fiber device.

A principle of design is to include temporal (margins of silence)* sufficient to prevent successive operations 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. The device restores its energy and condition during the intervening α. Based on the convenient value in the time hierarchy ($\alpha = 1/1000^{th}$ of a second), the maximum rate of pulsation in this approach is 500 pulses per second.

In VE designs, energy and pulse rates are closely connected. VE constructions use (low-level methods)* and (high-level methods)*. Low-level movers operate at low rates and economize on energy while high-level timing device operate at high rates and need relatively large energy supplies to achieve fast responses to stimuli.

4. Elements of initial constructions are VE devices and modules 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 a function.

VE principles are defined for specific kinds of devices, which are elements of construction. Individual VE conversion devices (pulsers, timing devices, movers, bursters) share uniform features: a body is defined inside an envelope*, which isolates the body from its surroundings except for quantified inflows* of source VE and pulse signals and quantified outflows* of pulses and twitches, along with dissipations* (waste heat), quantified or not. Changes in form of VE take place in the VES os such a body.

Simple transport devices — projections, channels, receptors, junctions — carry flows of VE that are involved in changes in locations and distributions of VE.

At any moment, a device body maintains a specific condition*, e.g., a charging condition, a holding condition, a discharging condition. Changes in condition are caused by internal processes and external events. An example of changes caused by an internal process: VE flows into a primal pulser that is in a "charging condition" until a certain quantity of VE (a "bang") is accumulated in the body and then the body changes condition and discharges the bang of VE as a pulse on a projection. The pulser repetitively "fills and spills;" it goes "beep-beep-beep." As an example of an external event: a timing device is in a "ready condition" and discharges after a "trigger pulse" arrives from another device.

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

Collective devices are made of (arrays of cells)*, where each cell contains operational modules made of devices which are performing functions and sharing a modular body or a sensorial body. Operations of such collective bodies may involve physical 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 to specific devices and operations. Uniform definitions simplify and clarify constructions, serving many of the same functions as universal laws but with reduced burdens of theory and justification.

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

a. Idealizations

Ancient Greek geometry was a chief source of mathematics and science; 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 astrophysics where huge stars and planets are modeled by geometrical points. Many scientific models presume an environment of perfectly empty space. Physical materials like metals are modeled by ideal mathematical formulae.

The formal VE model adapts methods of idealizations. 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 exactitude. Repetitions are exact. Pulses produced by collective devices in bodies are perfectly synchronized.

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.

Energy conservation is another idealization borrowed from scientific traditions. Ideal energy conservation in VE constructions includes conservation during VE storage, during changes in form and during changes in location. In the primal pulser design, a certain quantum of VE (a "bang") is stored in the Virtual Energy Store (VES) of the device; this VE is converted into the same-sized pulse of VE that travels instantaneously and without loss on a projection to another device.

Such idealizations can be adapted to accommodate actual devices. 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. Presumptive bodily properties (synchronized, entrained, finality).

The VE model does not suggest a "theory" or "explanation" for conversions of VE, such as explanatory theories of "information" or "quantum mechanics." Rather, VE conversions are components of construction that are invented for particular purposes and that are often later adapted to new uses. The definition of a device include properties of bodies that are invented or presumed or imputed.

In this project, presumptive bodily properties include synchronization*, entrainment* and finality*.

First, 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.

Next, suppose that the same pulsers share a common body of material inside of which forces can move. 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. Such pulsations are synchronized.

Such 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.

In VE designs, synchronized operations of devices in a body provide useful ideals that simplify some designs and suggest innovations in others. Synchronized operations presumptively arise from a physical property of bodies that is shared by the individual devices and the common larger material of the body.

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 water molecules in a wave are entrained. Movements of a beating heart are entrained. When a person drums their fingers on a table, entrained finger movements strike the table in a definite, repetitive pattern.

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. 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 a 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 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 the hammer followed a well-defined repetitive trajectory but movements of blacksmiths' 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. Primal devices, kits of parts and provisional principles

Methods discussed above are combined in primal devices. Primal devices in this project include: projection, primal pulser, primal timing device, primal repeating burster and the force fiber device used in constructions of muscle-like steady movers. Primal devices are idealized mental constructions restricted to a device body that produces twitches or pulses during exactly (repetitive cycles)*.

The foregoing primal devices share common features based on VE, e.g., the VE concept, the VE domain and the definitional one-bang pulse. Notwithstanding shared features, each primal device is defined independently of other devices. Each primal device starts a course of development that is independent of those of other devices. Features may be adaptable from one course of device development to another course for purposes of smoother coordination. E.g., different signals share common time elements; and pulse bursts that drive muscle-like movers can be interconverted with pulse trains produced by sensory devices.

A kit of parts is the result of a line of development from a primal device, e.g., kits of parts of pulsers, timing devices, movers and bursters. Kits of VE parts resemble kits of electrical signal generators, switches, resistors and relays.

VE principles and designs are provisional: there is an expectation that changes, extensions and modifications will be introduced. Following a maxim of opportunism, shortcomings in present constructions may suggest innovations and further development.

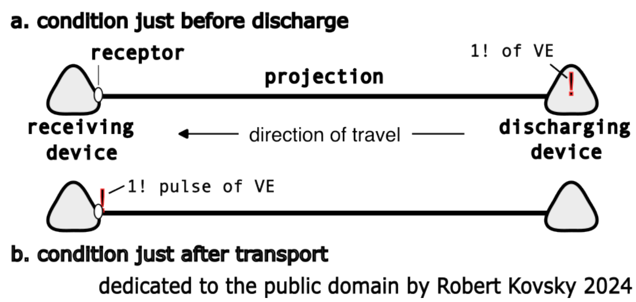
II. Device definitions, applications and extensions

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

Fig. 1 shows the first construction in the VE domain: 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)*. Each pulse contains one unit of VE called a "bang" and symbolized by "!". Discharge and transport all occur in an instant. An "instant" is the shortest period of time in VE constructions, idealized as 0 and resembling a point in geometry. As a practical definition, doubling or tripling the duration of an instant would not change anything.

I am not able to show an instant of discharge and transport in a single figure, so Fig. 1 does so indirectly with two figures. Fig 1(a) shows conditions of devices at the last instant prior to discharge: the VES in the discharging device holds 1! of VE, ready for discharge. Fig 1(b) shows conditions of devices just after a pulse carrying 1! of VE has traveled to the receptor of the receiving device.

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



The projection is the primal device for transport of VE. Such transport is one-directional. All projections operate identically; a transport operation carries one pulse of VE from an origin device to a destination device. The design is intended to mimic the movement of an action potential on a nerve.

The transport of a pulse on a projection is a conservative process, meaning that one bang of VE is discharged and one bang of VE arrives at the receptor. It is presumed that the projection requires a VE source to operate and that an unidentified quantity of VE from this source is dissipated during transport.

In Fig. 1, an abstract version of a receptor conveys incoming VE pulses from the projection to the receiving device. Different receptors connect projections 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., the receptor is active (working) in one mode and inactive (blocked) in another mode. The time required for operation of a receptor is included in the operating time of the receiving device.

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

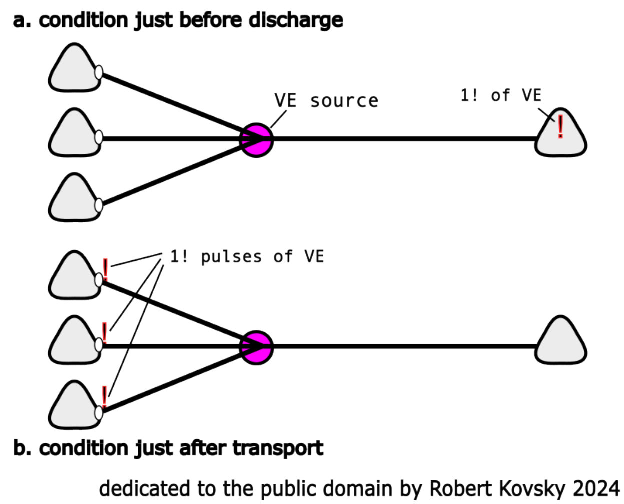
Considering the two kinds of models described in § 1, thermodynamic features include changes in form and conversions. Atomic simplicity appears in distinct devices and identical one-bang units in transport and processing operations.

Chief idealizations are instantaneous pulse discharge and instantaneous pulse transport. In more advanced models, instantaneous pulse discharge is replaced by a specified discharge period and pulse width, namely, α. Instantaneous pulse transport stands throughout as the 0 endpoint in the hierarchy of time.

Idealized (branch points)* and projections are shown in Fig. 2. At a branch point, an incoming projection splits into two or more outgoing branch projections. Each outgoing projection carries a full signal. Similar to Fig. 1, Fig. 2 shows conditions "just before discharge" and "just after transport"

A single projection carries a 1! pulse into the branch point and three outgoing projections each carry a 1! pulse. The whole transport occurs instantaneously. The branch point has a VE source, accessed through the VE plenum, preserving the principle that "no new VE appears" during such pulse multiplication. The VE source is shown as a fuchsia circle in Fig. 2. Such VE sources are often omitted in later designs.

Fig. 2: branching projections, pulse multiplication



In collective devices that operate inside bodies, transport of VE occurs in channels* that resemble projections and in junctions* that resemble receptors. A channel has added features: (1) a channel can carry VE in quantities other than 1! pulses, e.g., in a continuous stream; (2) channels can merge. VE from many originating devices in a collective body is channeled into a single receptive device. A junction connects neigboring VE devices or connects devices to channels. Junctions can 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 below in Fig. 3 is the "seed" or point of origin of devices that convert the form of VE. In the primal pulser device, source VE changes into VE stored in the device body; then stored VE changes into pulses. One aim is to mimic activity of a very simple pulsing neuron.

As discussed above, VE devices operate in structures of time. Such a (Time (t))* is shown in Fig. 3, running from "earlier" to "later." Such time applies to operations of device parts (shown in Fig. 3(a)) and to the momentary quantity of Virtual Energy [$\mathcal{V}(t)$]* in the Virtual Energy Store (VES) (Fig. 3(b)).

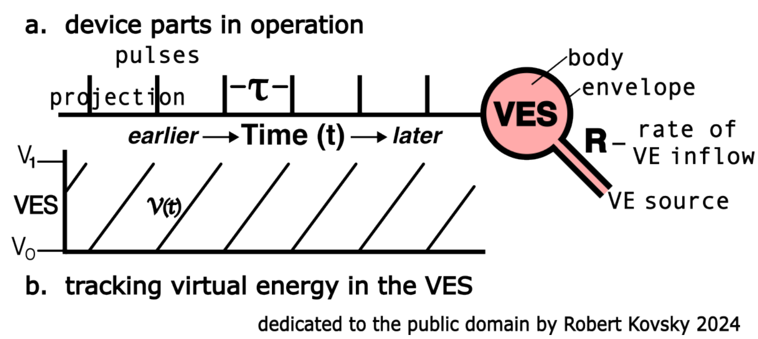
The chief parts of the primal pulser device are the projection that carries pulses away from the pulser, the body that holds the VES and the VE source that provides VE at a rate R. An envelope isolates the body from its environment except for a specific VE inflow (R) and a specific VE outflow (pulses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

In addition to the function of transporting a pulse, the projection in Fig. 3(a) also serves as 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 by $\mathcal{V}(t)$.

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

The lowest level of VE in the VES is $\mathcal{V}(t) = V_0$. As changed by R, $\mathcal{V}(t)$ increases until $\mathcal{V}(t) = V_1$, where $V_1 - V_0 = 1!$. Then 1! in the VES changes without loss 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." Pulses are produced at a constant 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.

The primal pulser resembles the Carnot heat engine, an imaginary device used in thermodynamics to model a steam engine. A body of steam in a steam engine acts like a VES, storing energy. Heat energy from a fire under a boiler is converted into latent heat in steam, then latent heat in steam is converted into work. The function of VE in the VES resembles that of latent heat in steam engines.

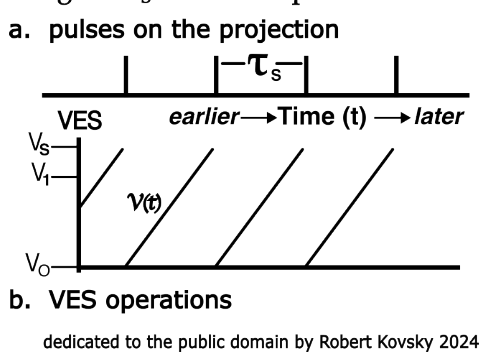
VE concepts discussed in §§ 1-5 apply to the primal pulser. An underlying substance of Virtual Energy has three forms: an incoming stream R; a quantity stored in the VES, $\mathcal{V}(t)$; and one-bang pulses on the projection. Changes in form are constrained by a conservation principle.

The pulser schema can also be applied to repetitive pulsations of bodies, e.g., in generation of synchronized or entrained pulsations. In the final design of the Gazer project, "Timing functions are relocated to the sensorial body, which generates an ongoing beat that entrains active devices."

b. dissipative pulsers and the Virtual Energy functional

Pulsers are the first kit of parts. Steps in the development of pulsers are precursors for development of more complex kits of parts.

Fig. 4: V_S-controlled pulser device



Operations of the **V_s-controlled pulser device** are shown in Fig. 2. A modified VES holds more than one bang 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 is denoted by V_s, called the (discharge point)*. $V_s - V_0 > 1!$.

More time is required for each pulse: 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. Waste heat has no other significance in current VE constructions.

Next, operations in Fig. 4 develop into the **VES-controlled pulser device** based on the (VES functional)*. Similar "functionals" also operate in timing devices, bursters and movers. In mathematics, a "functional" is a general form that leads to classes of functions. Here, the VES functional leads to classes of devices.

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

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

The rate of dissipation = $D \times [\mathcal{V}(t) - V_0]$, where D is a constant of proportionality. 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 pulse discharge.

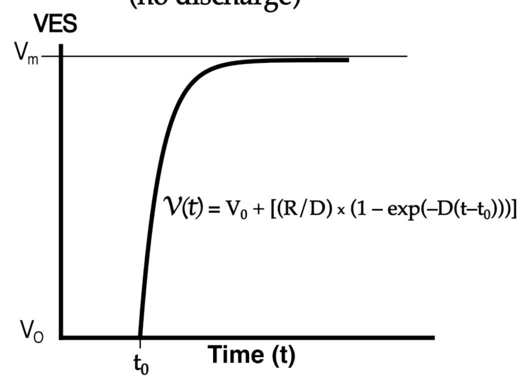
$d[\mathcal{V}(t)]/dt = R - \{D \times [\mathcal{V}(t) - V_0]\}$.

Inflow R increases the quantity of VE in the VES; dissipation decreases that quantity.

Solving the differential equation:

$\mathcal{V}(t) = V_0 + [(R/D) \times (1 - \exp(-D(t - t_0)))]$.
This is the VES functional shown in Fig. 5.

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



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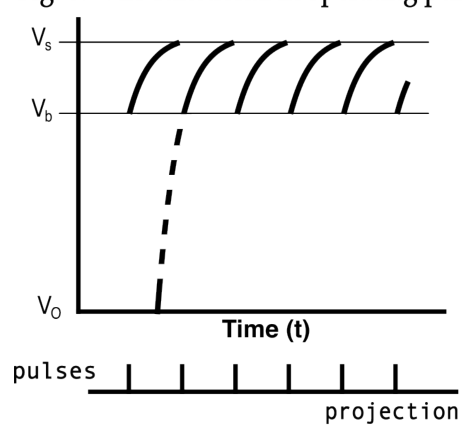
Observe the VES functional at its extremes. Close to $t = t_0$, $d[\mathcal{V}(t)]/dt$ is close to R, as in the primal pulser. At the other end, $\mathcal{V}(t)$ approaches a constant; $V_m = V_0 + R/D$.

Fig 6 shows the VES functional in an operating VES-controlled 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.

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

Fig. 6: VES functional in operating pulser



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A different functional is useful for analysis of operations in an energy economy. In an idealized "minimal time," form, source inflow is R and dissipation is zero while $\mathcal{V}(t) < V_m$; when $\mathcal{V}(t)$ reaches V_m, dissipation jumps to equal R. In sum, $\mathcal{V}(t)$ increases at the linear rate R until it reaches V_m and then remains at that level.

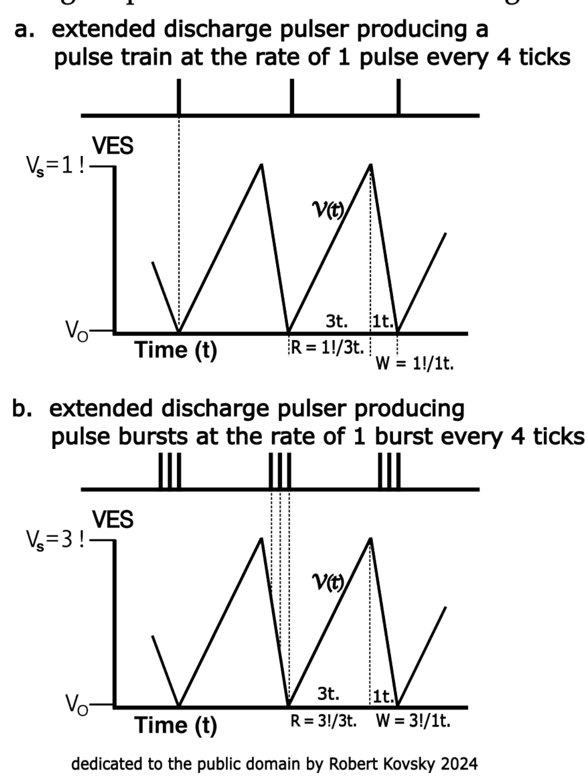
c. pulsers with extended discharge periods

VES operations of pulsers with extended discharge periods are shown in Fig. 7. Fig. 7(a) shows operations and VES of a pulser producing a steady stream of single pulses; Fig. 7(b) shows a similar device producing a steady stream of pulse bursts. Steady* operations maintain controlling quantities at fixed levels for sufficient time for changes to cease. When a change occurs, affected controls maintain the new levels while other operations adjust.

In Fig. 7 devices, the rate of positive change of VE in the VES is a constant R during the (charging period)* and the rate of negative change of VE in the VES is a constant W during the (discharging period)*. Through an internal process, the charging condition changes to the discharging condition when $\mathcal{V}(t) = V_s$. Similarly, a discharging condition changes to a charging condition when $\mathcal{V}(t) = V_0$. Principles of finality state that conditions of charging and discharging fit exactly into their assigned time periods. Charging periods and discharging periods alternate; together, they fill the time line.

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

Fig. 7: pulsers with extended discharge



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. 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 instant $V_s - \mathcal{V}(t) = 1!$ The last pulse is on the tick (finality principle) and the middle pulse fits into place.

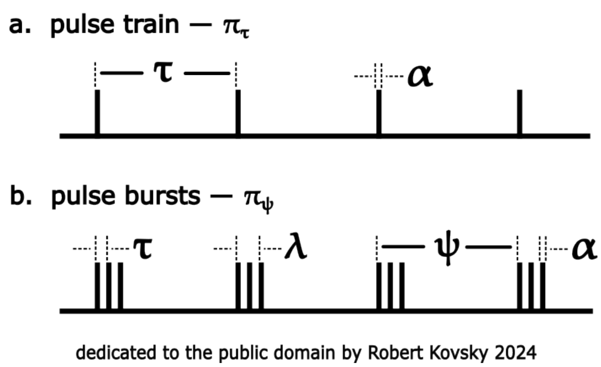
d. ideal pulse patterns

Pulse patterns produced by pulsers with extended discharge periods (Fig. 7) serve as exemplars for ideal pulse patterns shown in Fig. 8.

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

Each pulse in the ideal pulse train extends over a non-zero period of time denoted by α. A convenient value for α is .001 second. An ideal pulse abruptly starts at a sharply-defined instant and abruptly ends after α.

Fig. 8: ideal pulse patterns



A stream of (pulse bursts)* – denoted by π_ψ – is shown in Fig. 8(b). Time period ψ denotes the periodic interval of time between bursts. Each ψ period 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). Time period τ is re-defined as the period between starting instants of successive pulses in a burst. Following the guidance on a maximum pulse rate (5! per tick), τ has a minimum value of 0.02 sec.

Time period λ approximately defines the width of the pulse burst. In Fig. 7(b), λ equals 2/3 tick. The λ period starts at the first instant of discharge of the first pulse and ends at the first instant of discharge of the last pulse. The period of the last pulse – α – is not included in this λ. These definitions facilitate interconversions between sensorial pulse trains and pulse bursts that are used to drive movers. In such operations, higher pulse rates in trains result in stronger twitches in movers.

e. sensory pulsers and modules

In the final design in this course of construction, variable-rate pulse trains are produced by **sensory modules** and the rate of pulses serves to measure an environmental influence, e.g., pressure on the skin or temperature.

Operations in these designs are stable. That is, if the researcher introduces a slight temporary disturbance in operations, they return smoothly to the prior values after the disturbance ends, with no change other than a shift in time. It is also possible to modify operations progressively, by small changes.

Steps in the construction of the sensory module are:

i. primal pulser with controlled R

ii. pulser with stable self-control

iii. pulser with dissipative sensor

iv. sensory pulser

v. sensory module with direct readout

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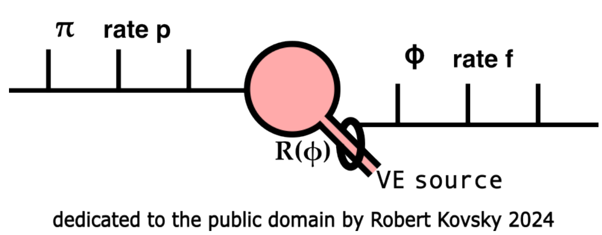
i. primal pulser with controlled R

An ideal pulse train π is specified by its period τ. The inverse of τ is the (rate)* of pulse production, namely, a number of pulses per standard time period. Rates can be used when signals are ideal pulse trains but not necessarily for other signals.

In this construction, the defining time period for operations is 3 ticks or 3t.*. The rate of pulse production, "rate 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, p = R.

In Fig. 9, the value of R in the primal pulser is controlled by an input pulse train φ specified by rate f. A (control function)* R(φ) defines the relation between rate f and R. A simple control function states that arrival of a φ pulse at the device causes the release of a π pulse as output. In other words, p = R = f.

Fig. 9: pulser with controlled R



For purposes of development, let pulse train φ control a sphincter* around the VE inflow tube, constricting the flow as f increases. The value of f is [1, 15]. When f increases, R and p decrease. Here, let R(φ) = 16!/3t. – f and thus f + p = 16!/3t.

Rates R and p are real numbers in the interval [1, 15]. This means that the maximum R is 15!/3t., equal to 50!/sec., the suggested maximum rate.

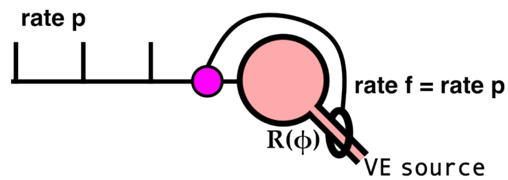
f	5	6	7	8	9	10
p	11	10	9	8	7	6
R	11	10	9	8	7	6

The adjacent table shows results of operations for some integral values of f, p and R. Dimensions for the values are !/3t.

ii. pulser with stable self-control

In the Fig. 10 design, a new projection branches from the output projection and drives the sphincter control function introduced in Fig. 9. Referring to the table above, this means that f = p and that both rates are 8!/3t.

Fig. 10: pulser with stable self-control



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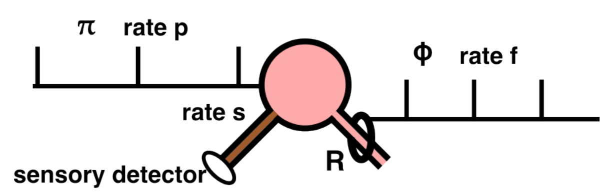
Suppose that a researcher interferes with the branching projection so that f is reduced below 8!/3t. Then p will increase by a corresponding amount. Next suppose that the interference ceases. Faster p and f will tighten the sphincter constriction and thus reduce p. A sufficiently slow response of the sphincter to changes in f will result in a smooth return to 8!/3t. This stabilizing response resembles that of a sufficiently damped harmonic oscillator in mechanics.

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; such 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



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R is no longer equal to p; rather a conservation principle requires that: R = p + s. Recall that R= 16!/3t. – f. Hence, f + p + s = 16!/3t.

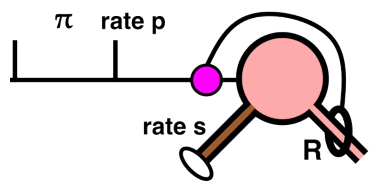
f	5	6	7	8	9	10
p	9	8	7	6	5	4
s	2	2	2	2	2	2
R	11	10	9	8	7	6

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

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!/3t., when f equals p, both are equal to 7!/3t. Rate p has dropped by 1!/3t. as a result of sensory dissipation. Generally, p = (8! – s/2)/3t. An increase in s is measured as a decrease in p.

Fig. 12: sensory pulser



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v. sensory module with direct readout

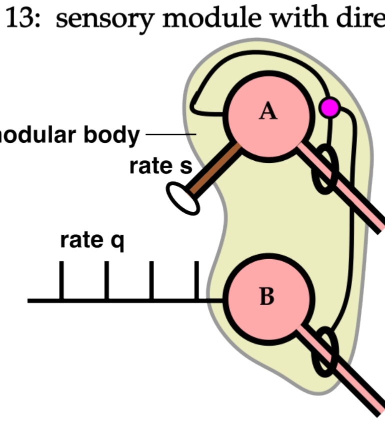
A simple principle of coordination suggests that a stronger sensation should result in a faster rate of pulses in the output of the sensor, leading to a faster and stronger movement. The Fig. 12 design produces a contrary result. To correct this, the sensory module with direct readout in Fig. 13 produces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

A (modular body)* is enclosed by an envelope; it has specified inputs (source VE for each pulser) and specified outputs (sensory dissipation at rate s and pulses on a projection at rate q). Modular bodies in more advanced designs can influence operations of internal VE devices; however, the modular body in Fig. 13 has no influence. There is no correlation in operations of the two devices A and B. In this first step of development, the modular body is only a package.

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(φ) = 16!/3t. – p, much as in Fig. 9. And p = (8! – s/2)/3t. from the previous step.

The result: q = 8!/3t. + s/2. When there is no sensation, q = 8!/3t. An increase in sensation produces an increase in q.

Fig. 13: sensory module with direct readout



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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 "Brain Models Built From Timing Devices," a web project; these are accessible on the website. More advanced designs have been used in more recent projects.

This construction is smaller 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 device" modules used in that project.

The concept of Virtual Energy starts as a pulse on a projection and develops into a VE distribution inside a linear array of entrained devices operating within a sensorial body. Final development of "VE centering devices" investigates processes driven by VE potentials that resemble pressure in water flows, voltage differences in electric current flows and sources of heat in thermodynamics.

Steps in this construction are:

a. primal timing device

b. signal generators

c. pulse waves in linear arrays of primal 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 constructed from timing devices

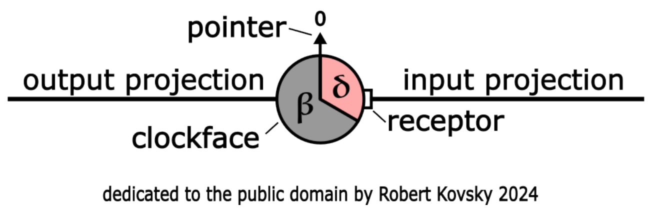
g. centering module designs are extended to distributive processes

h. further extension to potential-driven processes

a. primal timing device

A functional design for the primal timing device is shown in Fig. 14. An input pulse arrives over the input projection, triggers the receptor and starts an 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 discharge by the device of a pulse on the output projection. The VES, which has produced the output pulse, is re-filled with VE 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 pointer sits unmoving at 0. The arrival of a trigger pulse at the receptor at time t_0 changes the condition to the (responding condition)* and starts the pointer on its round. At time ($t_0 + \delta$), the pointer has traveled through the δ region of the clock face. Time period δ is called the responding period. On the final instant of the responding period, the device discharges a pulse. After discharge, the device condition changes to the (restoring condition)* and the cycle continues for an additional time period β, called the restoring period.

As part of the cycle of operations, the receptor is inactive* (blocked) during the ($\delta + \beta$) period and cannot process an arriving pulse. When time reaches ($t_0 + \delta + \beta$), the pointer reaches 0 and stops, the receptor becomes active* and the device returns to the ready condition.

The form or schema of the cycle is:

ready – responding (including discharge) – restoring – ready.

Fig. 15 shows VES operations of the primal timing device. V_r marks the return to readiness. The active segment of the VES functional in the lower right of Fig. 15, taken from Fig. 5, is exaggerated vertically for purposes of presentation. For faster operations, V_b would be just below V_r, V_s just above V_m and $V_s - V_r$ slightly less than 1 ! so that $V_r + 1! > V_s$, resulting in discharge of a pulse after the period δ.

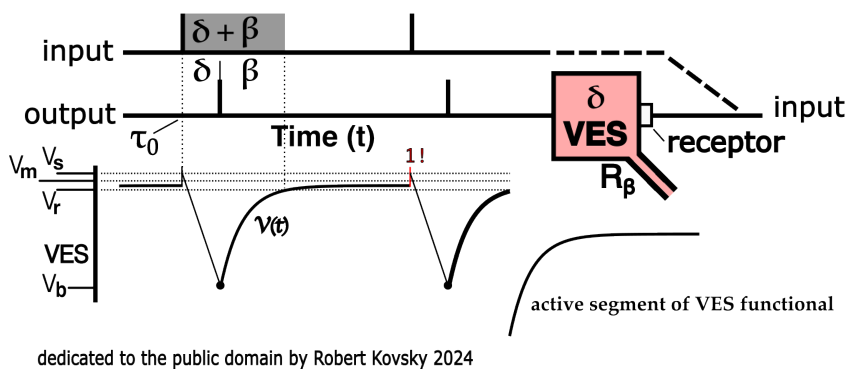
$\mathcal{V}(t)$ approaches V_m from below but does not reach V_m on its own. An input pulse arriving at time τ_0 is converted and added to the VE in the VES, momentarily pushing $\mathcal{V}(t)$ above V_s and starting the discharge process. Applying a finality principle, the discharge process is complete at the end of period δ. At the last instant of that period, the device starts to discharge a pulse.

The responding period δ is a specification of the timing device. In the primal timing device, δ is conveniently set at 0.01 sec. Later timing device designs have responding periods of 1 tick or 4 ticks.

The restoring period β has different values and functions in various designs.

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 when a fresh input pulse arrives.

Fig. 15: VES operations of the primal timing device



Energy economy in the primal timing device starts with idealized operations where $V_s = V_m$, $V_s - V_r = 1!$ and $V_b = V_r$. A useful benchmark value for β is $\beta = \delta$. Then, where $\delta = .01$ sec, the maximum production rate of pulses is 50/sec.

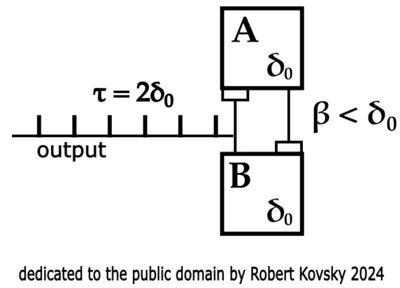
In a cycle of idealized economic operations, 1 external pulse is added to the VES and 1 pulse is discharged from the VES. From a certain perspective, operations are conservative despite the dissipative operations.

b. signal generators

The signal generator shown in Fig. 16 is built from two identical primal timing devices A and B; the two 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 both devices.

Suppose that device A discharges a pulse that triggers device B at time $t = t_0$. 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. Another δ_0 passes before discharge of device A results in arrival of a pulse at device B at time $t = (t_0 + 2\delta_0)$, completing one cycle of signal generation. The next pulse will be produced in identical operations during the next cycle.

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

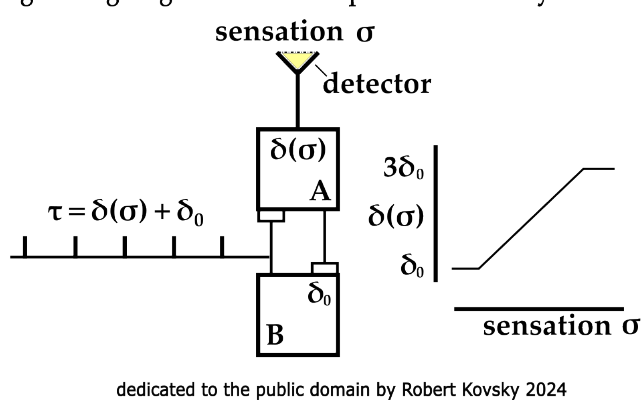


One constraint on operations of this design is that β must be less than δ_0. The VES of a timing device that has just discharged must be restored and ready when the other timing device discharges.

The signal generator in Fig. 17 is a variant of that in Fig. 16. It responds to an increase in a variable sensation σ by increasing the period between pulses in the resulting output. 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.

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



The Fig. 17 signal generator responds more quickly than sensory modules constructed from pulsers, e.g, in §7(e). A timing device pulse stream responds more quickly and has a larger range of value.

c. pulse waves in linear arrays of primal 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, devices produce a wave of pulses.

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

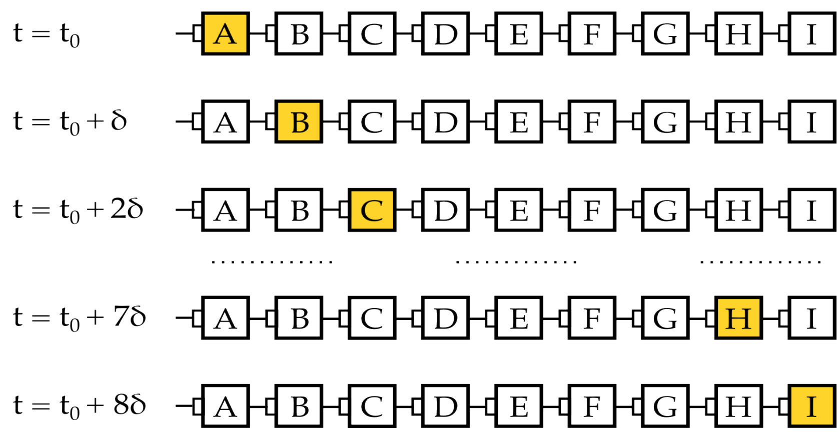
At time $t = t_0 + \delta$, timing device B discharges.

At time $t = t_0 + 2\delta$, timing 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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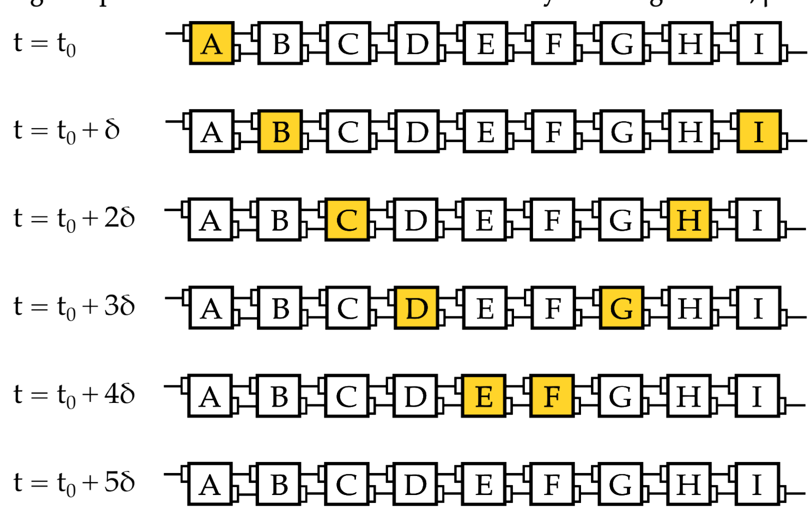
The array in Fig. 19 performs a function of pulse cancellation. It resembles the array of Fig. 18, but devices are modified: two projections and two receptors in a device mean that the array is bi-directional. When a device discharges, it produces two pulses, one on each output projection. If a device 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 new feature is introduced: a pulse wave starting 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 pulses cancel each other.

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



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Movements of the two waves in Fig. 19 are synchronized, simplifying the figure. Cancellation also occurs the same when waves are not synchronized.

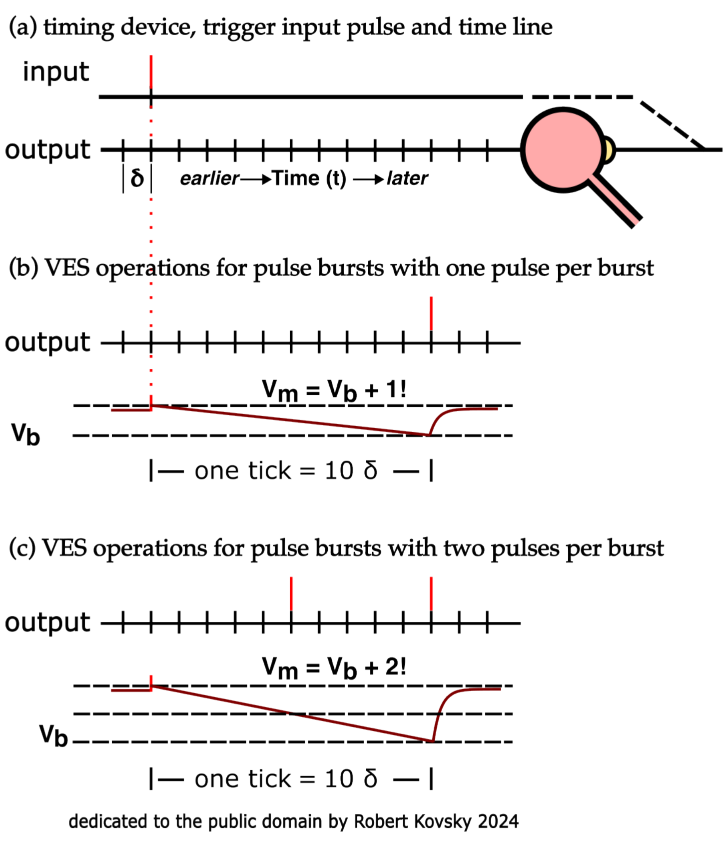
d. pulse bursts produced during extended discharge periods

In Gazer designs, certain timing devices denoted 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 below. This construction also defines the class of pulse burst signals used in the Gazer project.

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

Outputs of these modules resemble those of pulsers with extended discharge periods. (Fig. 7.) Fig. 20 shows operations of two simple timing devices with extended discharge periods.

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. A trigger input pulse starts operations.

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

In the Fig. 20(c) device, the first output pulse is discharged 5δ after arrival of the input pulse, when one ! of ready VE has accumulated in the body of the device. The second pulse at the end of the tick again applies a finality principle.

Fig. 21: more timing devices that discharge pulse bursts

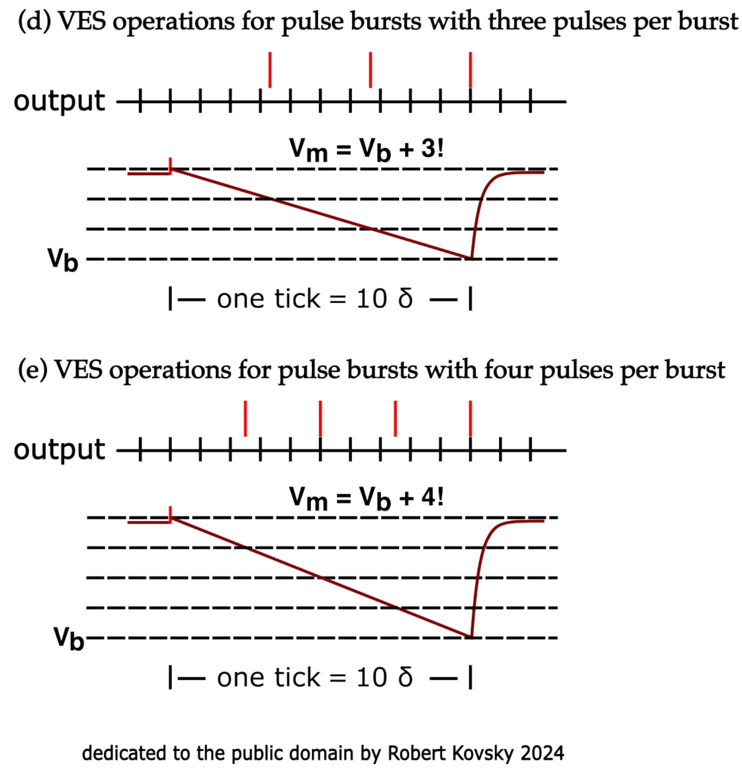


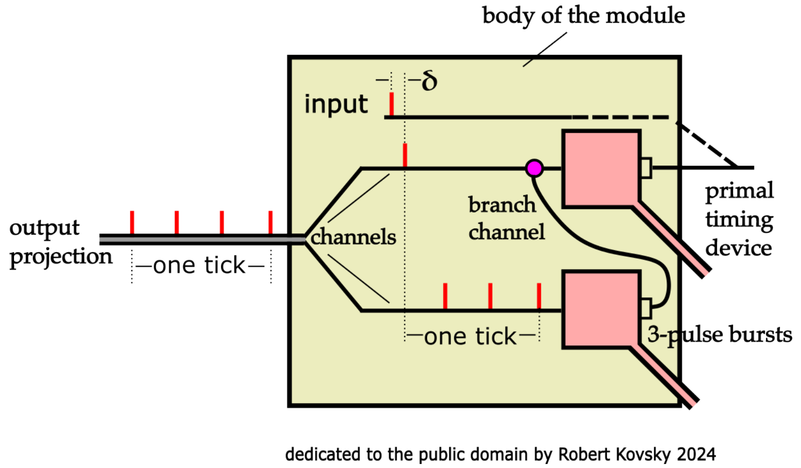
Fig. 21 rounds out the class: a 3-pulse device is shown in Fig. 21(d) and a 4-pulse device is shown in Fig. 21(e). The finality principle is again applied.

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 that contributes physical properties to operations. The primal timing device and the 3-pulse burst device both discharge VE into internal channels that carry VE instantaneously just like projections. Channels merge and transport VE into the output projection. A branch channel from the primal device output projection carries the trigger 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 that results from both:

(1) the branch channel that connects devices and synchronizes timing; and also

(2) bodily entrainment of operations. Entrainment in Fig. 22 resembles drumming one's fingers on a table.

Fig. 23: pulse burst signals

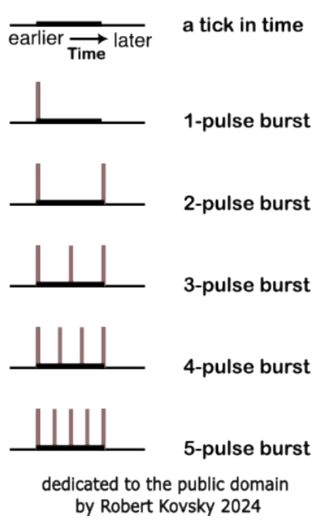


Fig. 23 shows the repertoire of pulse burst signals that are produced by the class of timing device modules based on the Fig. 22 design. Bursting devices produce 0, 1, 2, 3 and 4 pulses (depending on the size of the VES), which are unified with the first pulse from the primal timing device.

This is also the repertoire of signals set forth in § 2 of the Gazer project and in §9 below (bursters).

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

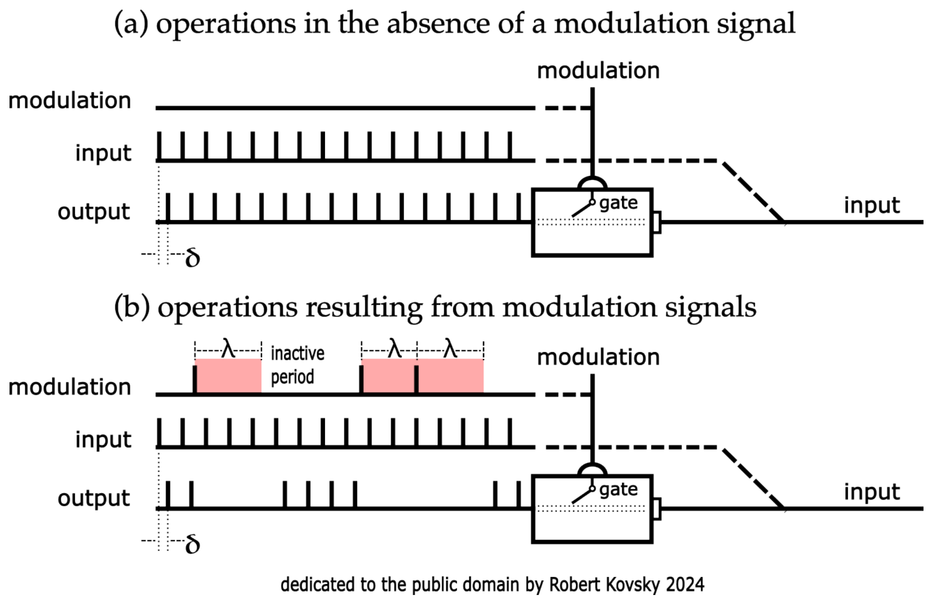
As discussed above in §5, a schema is a sequence of conditions that organizes the operations of a VE device. Many devices have two or more schemata and are switched between schemata by pulse signals or internal operations. Such a device has "multiple modes of operation" and "the device changes modes." A change between modes involves changing conditions of receptors or of the device body. 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 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. Such devices can be assembled into systems that perform logical operations.

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.

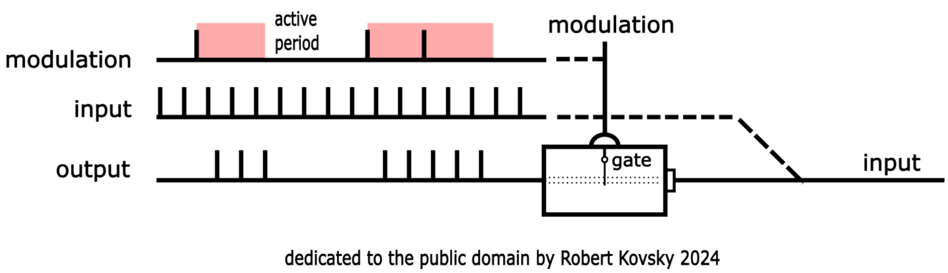
Fig. 24: operations of a normally-active gated timing device



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 in an ongoing way.

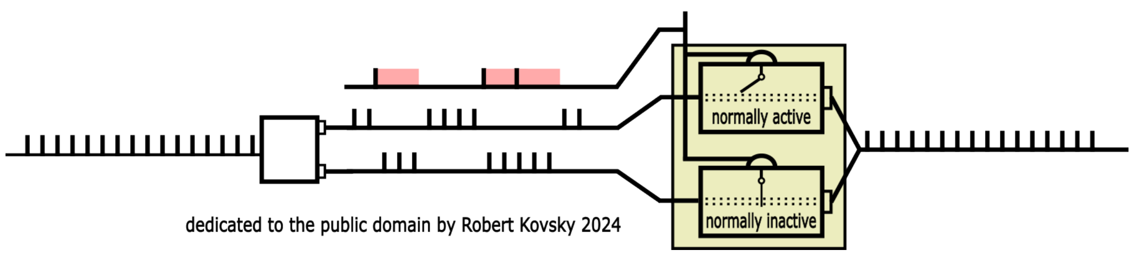
A similar device is shown in Fig. 25, except that the condition of the receptor is normally inactive. The receptor becomes active for a period λ after arrival of a pulse over the modulation projection. Repeated modulation pulses at a sufficiently high rate keep the receptor in an active condition.

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 feeds both timing devices equally. 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 input projections that operate identically. It produces an output pulse when separate pulses on input 1 and input 2 arrive within a time period λ of each other. The device detects (approximately) coincident pulses.

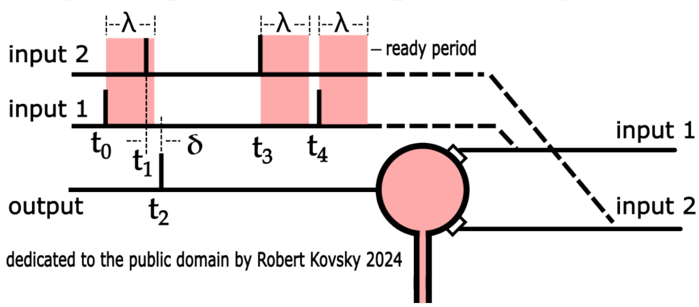
Schemata of the 2-pulse device are developed from the schema of the primal timing device:

primal schema: ready – responding – restoring – ready
2-pulse 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 for the "modulation period λ". For this version of the two-pulse device, the input receptor that carried the first pulse is blocked during λ.

If a pulse arrives over the other projection during the modulation period, it triggers the response process. After discharging and restoring, the device returns to the unready condition. This cycle of operations is mode 2. If a second pulse does not arrive over the other projection during the modulation period, the device returns to the unready condition without discharging; this is mode 1.

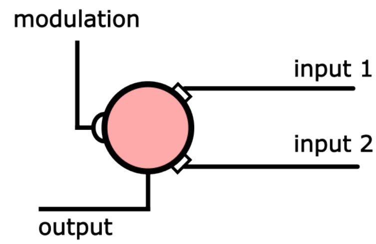
Fig. 27: operations of a 2-pulse timing device



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 in pink 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 ready 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 normally-inactive devices are blocked except for an active period after the arrival of a modulation pulse.

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



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The following list sets forth the distinct schemata of the normally-inactive 2-pulse timing device. Additional pulse patterns can be constructed, e.g., the schema shown around t_3 and t_4 in Fig. 27; such patterns are not in the list but can be constructed from schemata that are on the list. Listed schemata thus serve as "atom-like" elements in "molecular" structures of combination.

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.

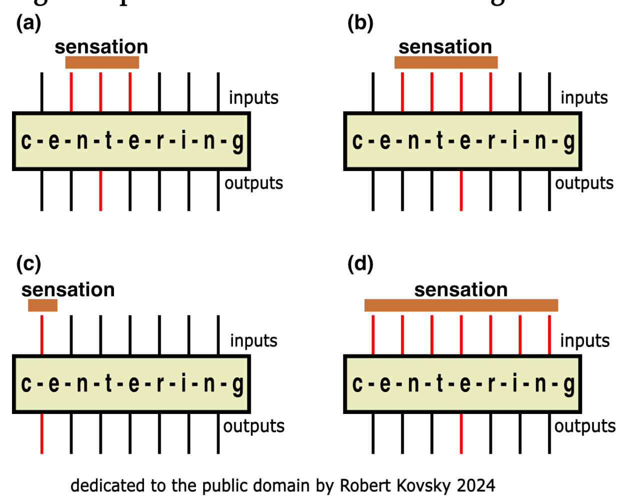
f. centering modules for Gazer designs are constructed from timing devices

In Fig. 29, inputs to a centering module are provided by 7-location stimulus signals from §2 of the Gazer project. 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.

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.

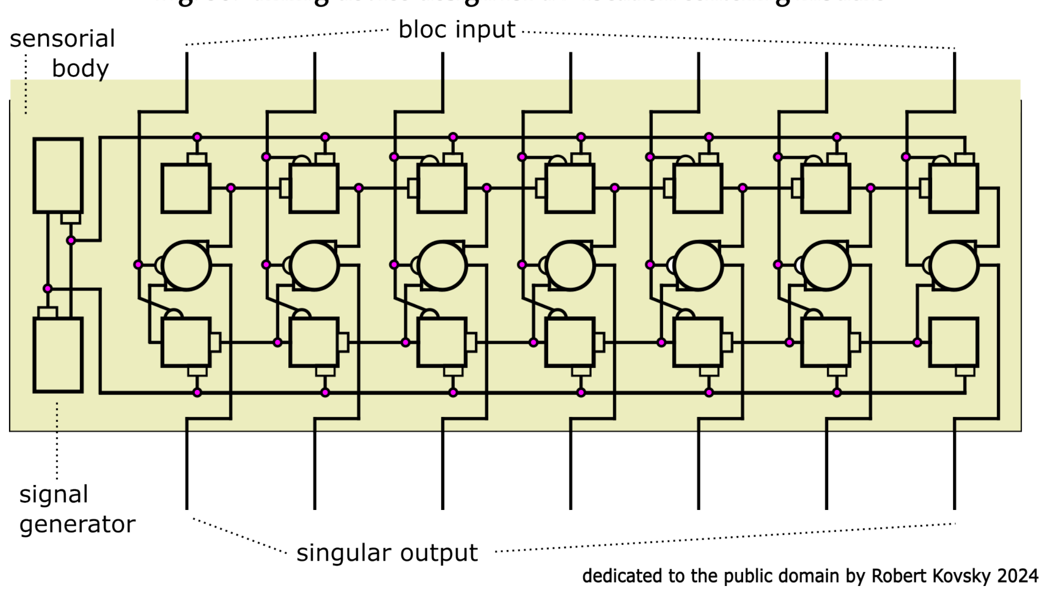
The module produces appropriate results for a single stimulus at an edge of the module (Fig. 29(c)) and for a stimulus that covers the whole module (Fig. 29(d)).

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



In Fig. 30, the timing device design for the centering module shows bloc input and 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). The sensorial body, incorporates all the devices in the module, synchronizes their operations and may extend to neighboring modules.

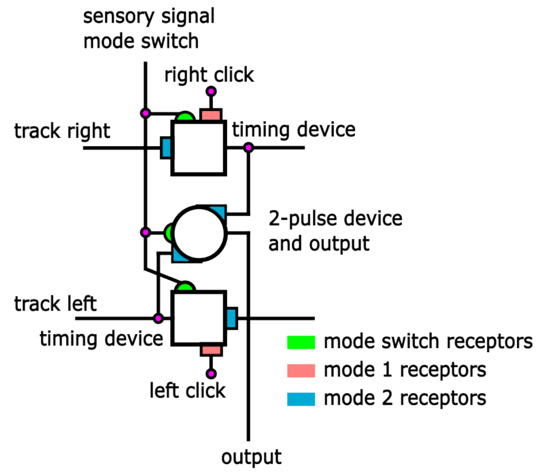
Fig. 30: timing device design for a 7-location centering module



In operation, the module starts with all devices in mode 1. A bloc of input pulses switches a bloc of columns from mode 1 to mode 2. Inside the bloc of columns, timing devices along the tops of the switched columns 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.

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

Fig. 31: column in centering module



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Devices in the module have the following specifications for periods of timing controls. A convenient application uses a fixed $\delta = 0.01$ 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

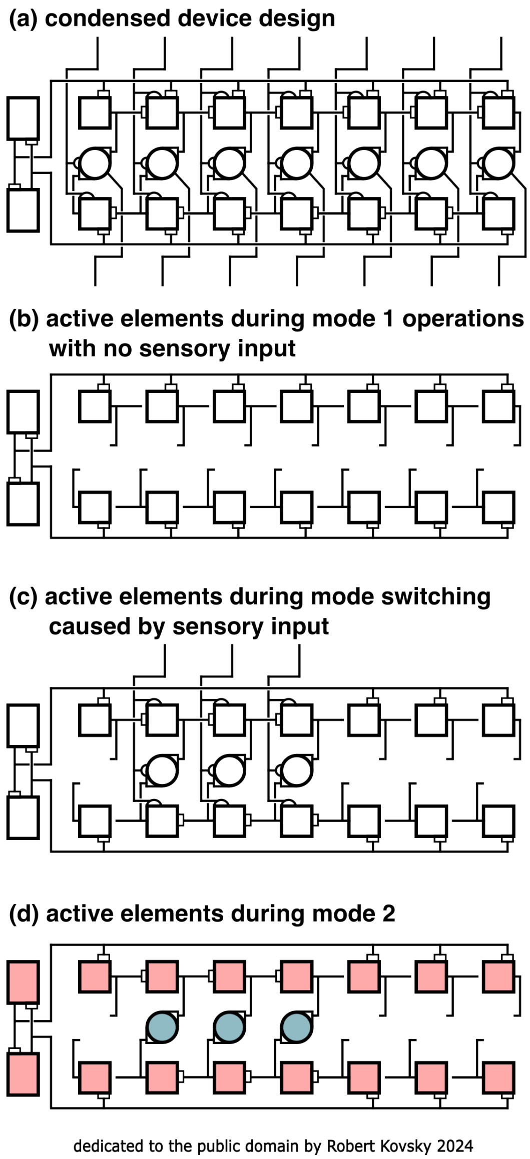


Fig. 32(a) shows a condensed version of the centering module.

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

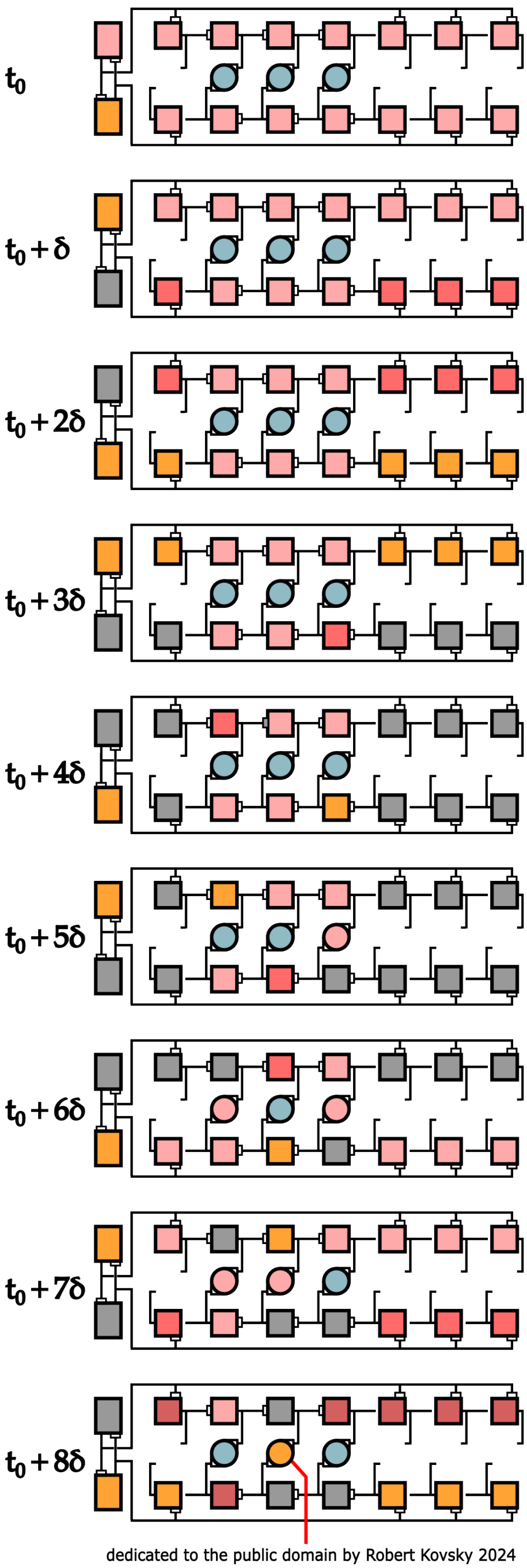
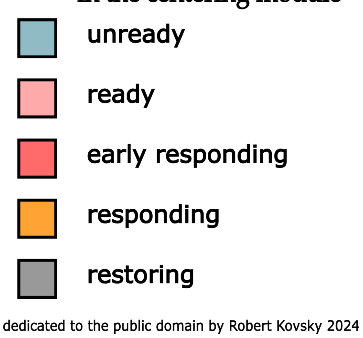


Fig. 33 shows operations of the centering module for the ongoing example. Operations start with the triggering of a timing device in the signal generator. Conditions of devices are shown at time t_0 "just after" that first trigger.

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 the center of the switched bloc and will discharge just before $t_0 + 9\delta$, terminating the centering process.

g. centering module designs are extended to distributive processes

The centering module constructed from timing devices has features that suggest development beyond timing devices, leading to collective operations of uniform cells organized in bodies. This step introduces (VE distributions)* in collective devices that are interconnected by junctions*, which perform centering functions by means different from timing devices. The linear one-dimensional form is useful for development and serves as a precursor of two-dimensional forms (quadnets).

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 the Fig. 30 centering module. For the operations shown in Fig. 33, the ***time required for performance*** **T** is defined as T = 9δ. 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 will require two more steps and T = 11δ. If all seven input projections carry switch signals, T = 13δ. From another perspective, if an operational period of T > 13δ is always provided for performance of the Fig. 30 centering device, 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 required to center an image that covers the whole linear dimension of 31 inputs, namely, T = 37δ.

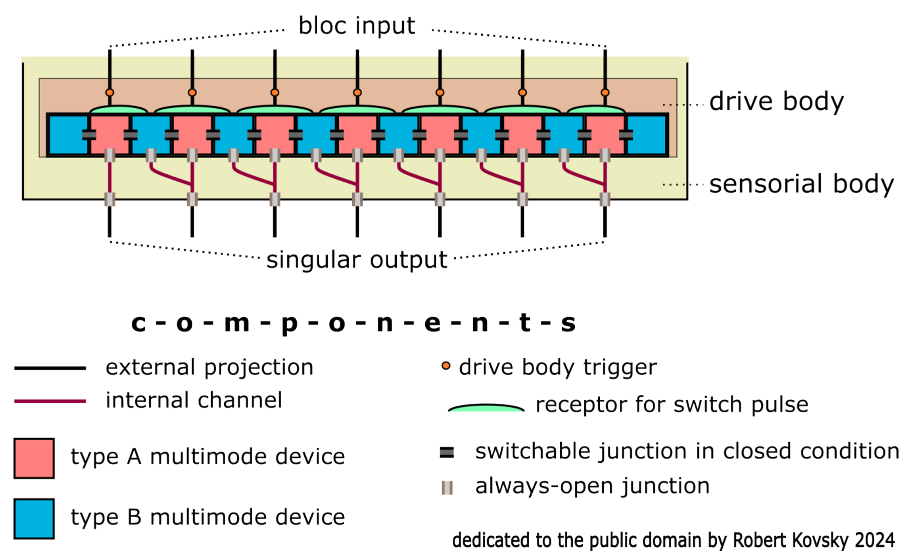
Gazer operations are controlled by a repeating cycle of eight ticks or 80δ. In this cyclical time structure, a fixed amount of time Δ separates the commencement of distinct functions in a sequence, including a margin of silence. Performance time for a 31-input centering module appears to fit into a structure where Δ = 40δ. In this time period, the module will always complete performance and become ready for a new stimulus. This 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 Δ = 40δ is just feasible. The system can work; but a lot of time is required for centering and time requirements limit further enlargement of the sensorial field.

ii. faster speed through use of junctions

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

Looking first at similarities, the Fig. 35 design has a linear arrangement, input projections and outputs similar to those in the Fig. 30 design. In both designs, a bloc of inputs produces a single output at or near the center of the bloc. In both designs, operations of elemental devices are organized in collective cycles. In both designs, timing devices have multiple modes; and input signals cause devices to switch from one mode to the other. Unswitched devices feed signals into both sides of a bloc of switched devices and those signals step towards each other, meeting at the center and triggering an output pulse.

Fig. 35: 7-location centering module with junctions



The Fig. 35 design includes new components. The timing device module had seven columns; the junction module has 15 multimode devices. Internal channels transport VE pulses inside the sensorial body and two output channels from timing devices merge into one output projection. (In the Fig. 35 design, only one channel feeds pulses into a merger at any moment.)

Another new component 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 device.

The (multimode devices)* has pulse operations and storage/transfer operations. The VES of the multimode device is conservative; it can hold a quantity of VE for an indefinite period, subject to operations of the device.

As to pulse operations, a multimode device has a $\mathcal{V}(t)$ and a V_s like those of pulser devices. In the Fig. 35 module, $\mathcal{V}(t)$ is limited to values of 0, 1! and 2!. A convenient value for V_s is $V_s = 1.5!$. When, for a particular device, $\mathcal{V}(t) = 2!$, the device discharges a pulse into its output channel; and the pulse travels through the always-open junction that connects the channel to an output projection. Such a discharge completes performance of the centering function; immediately after discharge, the module terminates operations and enters into a restoration period.

As to storage/transfer operations, a type A multimode device has two (switchable junctions)* that connect the device to two adjacent type B multimode devices. Switchable junctions in Fig. 36 can operate in either direction; they are initially closed (blocked) and are switched between (closed and open conditions)*.

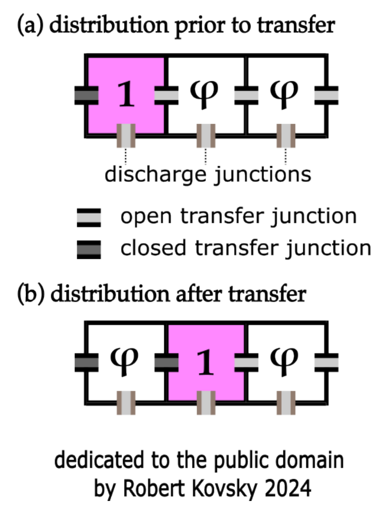
VE in the conservative VES of a multimode device is held at a constant value unless changed. Changes occur during the following operations.

(1) Loading* during the restoration period. In the Fig. 35 module, each multimode device is loaded with 1! of VE. A colored box in the figure denotes 1! in a VES.

(2) Clearance* on command. During clearance, the VE in the VES is dissipated. The VES condition of a device that has been cleared is denoted as $\mathcal{V}(t) = \varphi$ (nil).

(3) Transfer* as a result of a squeeze from the drive body. Transfer in the Fig. 35 module is restricted to a loaded device with a single open junction that is connected to a cleared device. A small example is shown in Fig 36.

Fig. 36: VE transfer through a junction



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 without dissipation) and the transferred VE is held in the previously-cleared adjacent device; also, the junction that carried the transfer has been closed. Presumptively, it enters into a restoration period. Closing a junction after transfer is required for further transfer in the array.

In a linear array or other collective module, quantities of VE in various device locations can be added like arithmetic numbers to define a (collective VE)* that is equal to all the VE in the array. The transfer operation in Fig. 30 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 (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 inside edges of the bloc.

Also: when a multimode device is switched (Fig. 37(b)), its 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

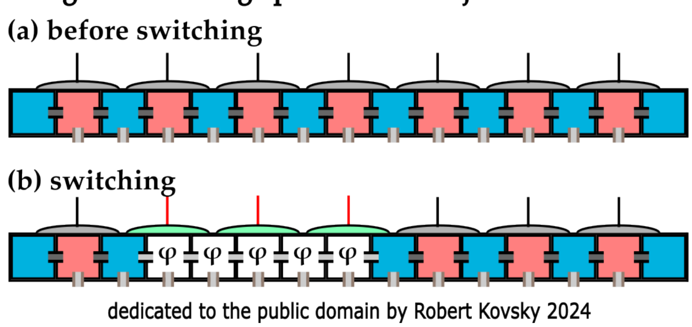
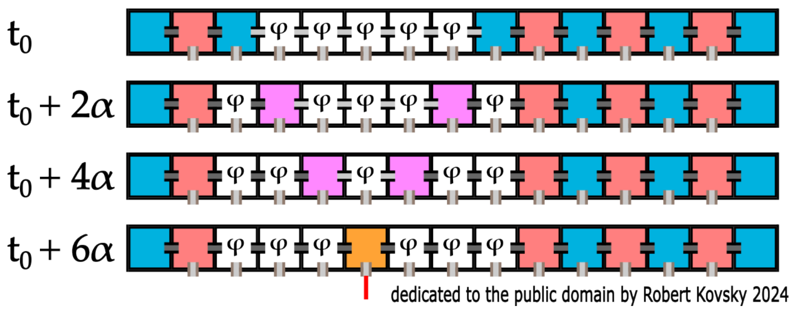


Fig. 38 shows operations of the junction centering module starting just after switching and leading to a pulse discharge onto an output projection. Initial conditions at time t_0 are shown just before the first squeeze from the drive body.

Fig. 38: internal flow operations in the junction module



Suppose that squeezes occur every 2α where α is the time required for the transfer This is the fastest speed conceivable in 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 between individual devices from outside the switched bloc into the switched bloc.

Successive squeezes transfer VE inside the switched bloc of devices from both ends towards the center. There is nothing to prevent the final transfers of VE from two adjacent devices into both junctions of the central device. The VES of an individual device operates in a conservative fashion and the VE in the central device is summed to 2!. This quantity exceeds the V_s of pulse operations; as a result, the device discharges a pulse, leading to completion of performance.

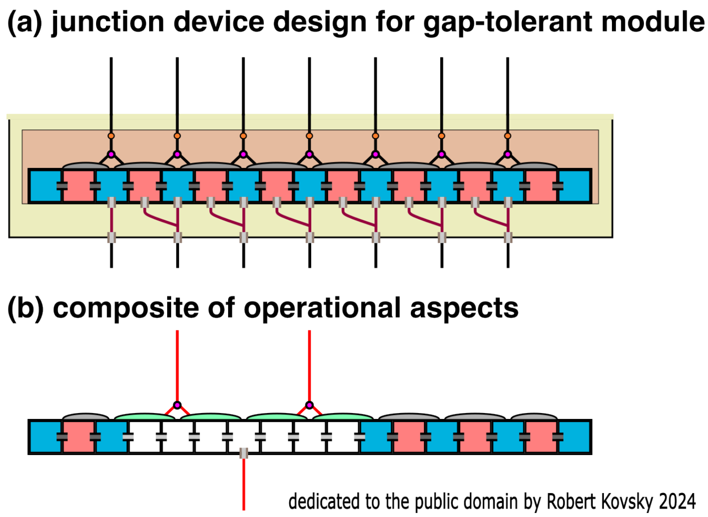
Compare the performance time of the two centering modules using convenient values for δ and α. A Fig. 30 step requires .02 sec. A Fig. 35 step requires .002 sec. Disregarding preliminary operations, the performance time for the Fig. 30 example is 9δ. A comparable performance time for the Fig. 35 example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

iii. centering module that tolerates gaps

In the Gazer project, it is said that centering devices "require an input with a nearly continuous bloc of stimulated sensors — a single group with no gap larger than a single [input projection]." In other words, some Gazer centering devices tolerate gaps of one inactive input projection in a bloc of active input projections.

The design in Fig. 39 incorporates the 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

The following course of construction leads to a new method for centering of a bloc of signals in VE devices. This new method employs whole-body operations that 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 the signals control VE inflows from sources and VE outflows by way of dissipations;

iv. Additional timing devices – (difference devices)* and (balancing units)* – provide more efficient controls for diffusion designs based on detectors;

v. The concept of potential VE is extended to define a (gradient distribution of potential VE)* in a bloc of 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 signal on the proper central output.

vii. Comparative performance 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 and Adolf Fick applied them to movements of salt dissolved in water.

In such models, a substance is distributed with different concentrations (quantities) in different locations. When adjacent locations contain different concentrations of the substance, some substance will move from the location with the higher quantity to the location with the lower quantity. The movement is modeled by Newton's Law of cooling mentioned above in § 7(b) and by conservation principles.

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 (Fig. 40) adapts common features of diffusion models for chemicals in water, electrical charge and heat. An interconnected linear array of uniform VE devices has a collective form of cells in a body.

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 energy" 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.

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. The sum of amounts of VE in the cells is the same before and after any movement of VE between cells.

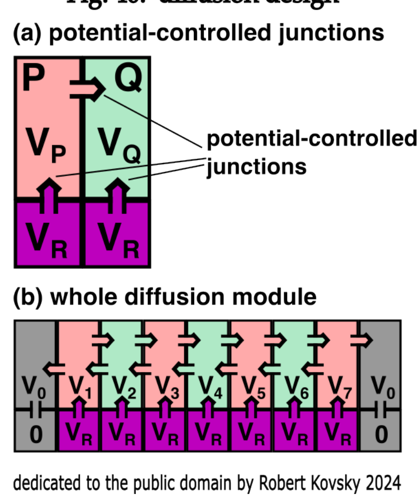
Such a diffusion paradigm can be defined either by iterations* (repetitions) of step-by-step cycles suitable for computation or by multiple co-existing streams* of flow. VE designs in this construction use interchangeable iterations and streams.

A pink device P and a green device Q in Fig. 40(a) are each independently connected to a VE source with a high potential V_R. The connection is by means of a one-way (potential-controlled junction)* that can be opened or closed during operations or by the researcher. The diffusion process starts with closed junctions and uncharged cells P and Q. Then V_R junctions are opened; VE is transferred 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 $V_R > V_Q$.

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 at a rate proportional to $V_P - V_Q$. If V_P is less than V_Q, there is no flow. The flow rate of VE through the P-Q junction is: $f_{PQ} = F_0 \times (V_P - V_Q)$; $V_P - V_Q \geq 0$ 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.

Fig. 40: diffusion design



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 alternating step, energy transfers $\Delta\mathcal{VE}$ occur through a junction according to the formula $\Delta\mathcal{VE} = G_0 \times \Delta V$ 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 process similar to a centering process: activated cells in a bloc or segment are selected by inputs; cells that are not selected are set at V = 0. Suppose that the selected bloc is the segment 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

The later PE distributions, like those of standard diffusion paradigms, have a peak at the center of the bloc and symmetrical, moderate declines on the sides.

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

In the Fig. 41 design, a new kind of VE operations mimics those of the prior diffusion model. The Fig. 41(c) module functions like the diffusion module in Fig. 40, with seven cells and a distribution of potential energies that undergoes similar changes. Unlike the Fig. 40 design, the Fig. 41 design uses streaming.

VE potential difference detectors are new VE parts. They are embedded in walls 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 has an independent source of VE and measures the difference in one direction only.

Functionally, operations of the VE difference detectors resemble certain phenomena of piezoelectricity in the domain of natural materials.

Fig. 41: VE potential difference detector design

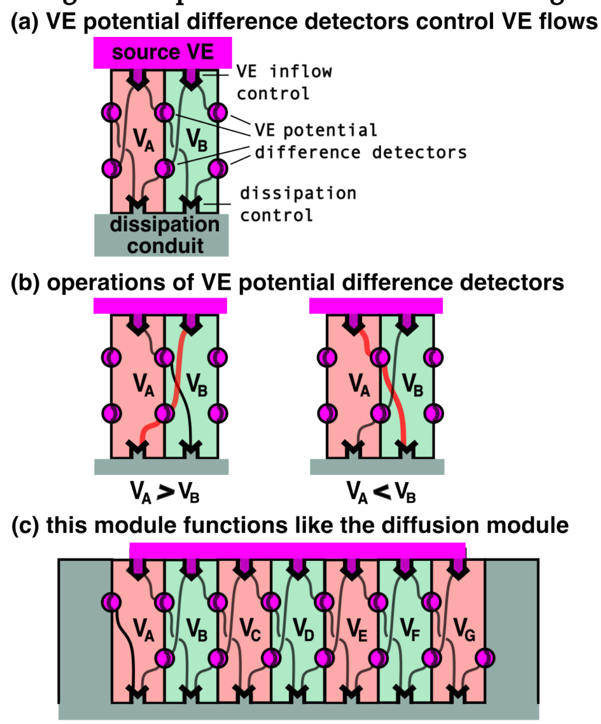


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Fig. 41(a) shows potential difference detectors; these produce signals that control VE inflow and dissipation (VE outflow). Each potential difference detector sends signals to the source VE inflow control in one cell and to the dissipation control 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. Each 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. It is "the same" as if 1! was transferred between the cells. The VE potential difference model in Fig. 41(c) functions "the same" as the prior diffusion model.

iv. Additional timing devices – (difference devices)* and (balancing units)* – provide more efficient controls for diffusion designs based on detectors.

From the perspective of the energy economy, the Fig. 41 design wastes energy when VE both comes into a cell because of a potential difference on one side and also leaves the cell because of a potential difference on the other side. Energy is both coming in from the source and also leaving via dissipation, like running an apartment heater and air conditioner at the same time.

Waste energy is reduced in designs that use difference devices and balancing units that are constructed from difference devices. The improved-efficiency diffusion module shown below otherwise functions much the same as prior modules.

Difference devices. Fig. 42 shows operations of a difference device. In the schematic form, Fig. 42(a), input signals are pulse trains (uniform strings of pulses). 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.

The momentary level of VE in the VES is denoted as V(t). Each pulse arriving over μ raises V(t) by 1!. Each pulse arriving over σ lowers V(t) by 1!.

The device produces an output only if $\mu \geq \sigma$. If $\mu \leq \sigma$, there is no output.

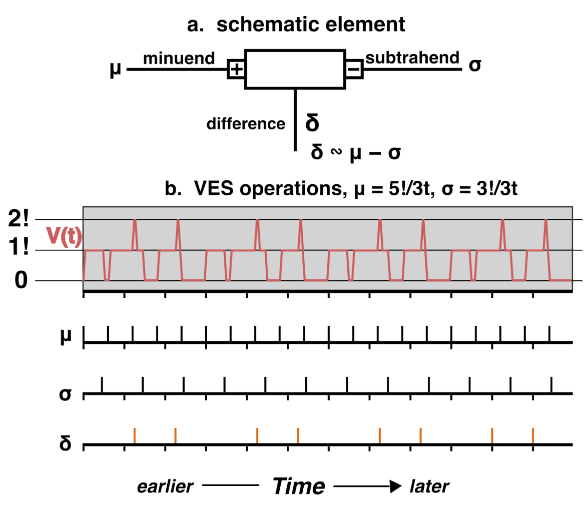
The device produces an output signal δ over the "difference" projection with an approximate pulse rate of $\delta \sim (\mu - \sigma)$. The difference signal is irregular and "gappy," but such irregularities do not interfere with operations in this project.

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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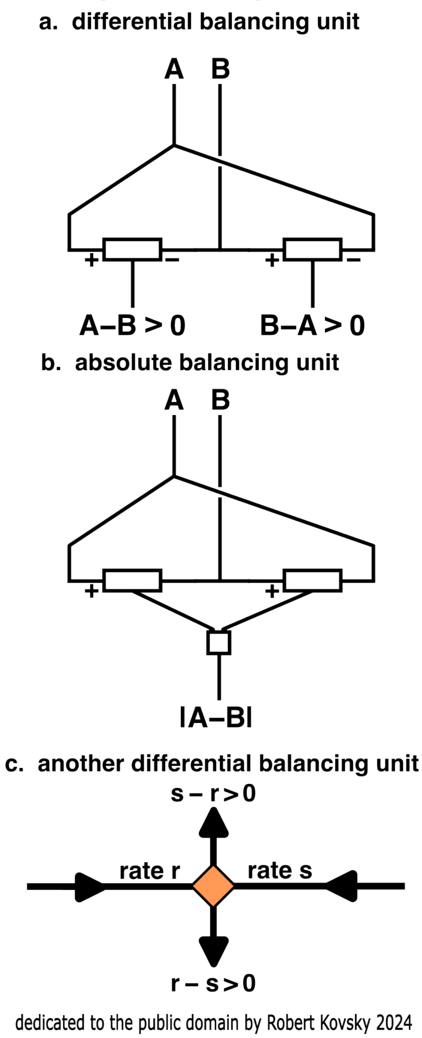
The effect of VES operations is that the difference pulse stream on δ is constructed from the minuend pulse stream by removing or "canceling" certain pulses from the minuend stream and allowing the other pulses in the minuend stream to produce output pulses. A subtrahend pulse cancels the next minuend 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.

Fig. 43 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 provide functions of "left and right" and "up and down."

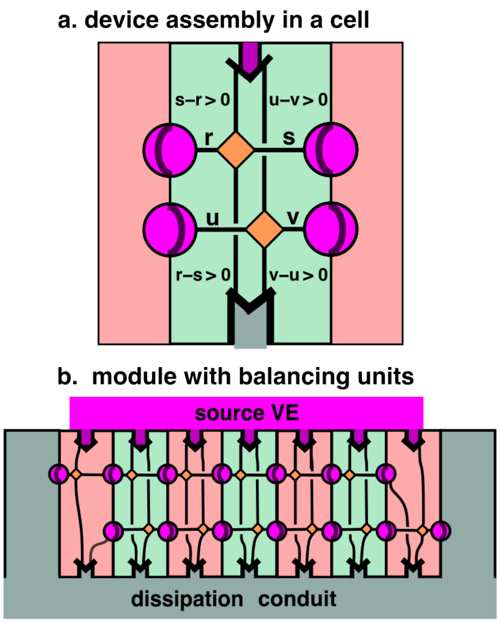
In Fig. 43(b), the "absolute balancing unit," outputs of both difference devices are connected to a primal timing device that produces pulses at a rate equal to the absolute value of A – B.

Fig. 43(c) shows an iconic symbol for a differential balancing unit. Two pulse trains r and s arrive at the balancing unit, which produces one of two possible resulting streams, depending on which pulse stream has a faster rate. In either case, the irregular pulse rate in the output stream is equal to the difference between rates in the two input streams.

The improved-efficiency module in Fig. 44 functions much like that in Fig. 41. Balancing operations are carried out between VE potential difference detectors and VE source and dissipation controls.

The balancing units have four output lines , s–r>0, u–v>0, r–s>0 and v–u>0.

Fig. 44: diffusion module with balancing units



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In mathematical mechanics, a gradient is defined as a first spatial derivative of a 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, the second derivative of the VE potential across spatial units drives the change of VE potential in time.

These device operations resemble equations of standard diffusion paradigms, e.g.:

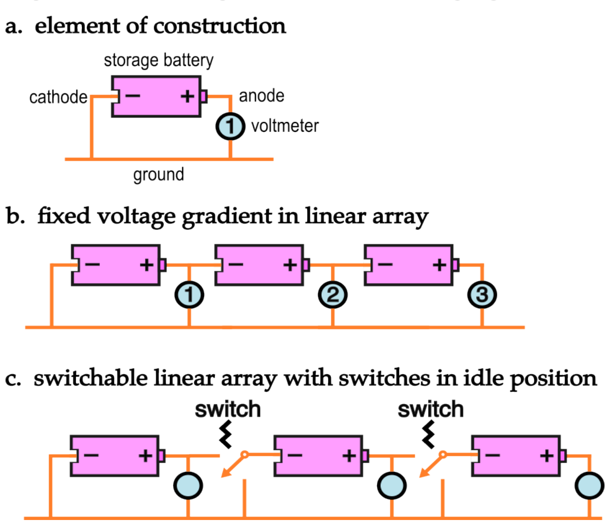
$\partial^2 v(x, t)/\partial x^2 = \varkappa \times \partial v(x, t)/\partial t$. (See Paul J. Nahin, *Oliver Heaviside* (2002) at 30.)

v. The concept of potential VE is extended to define a gradient distribution of potential VE in a bloc of devices.

Convenient guidance is provided by voltage gradients: voltage plays roles similar to those of gravitational potential energy, chemical potentials, and thermodynamic potentials in various models of substances. Bigger potentials can cause bigger changes in substances.

Fig. 45 shows the construction of an array of electrical storage batteries and switches. The array generates a variety of voltage gradients.

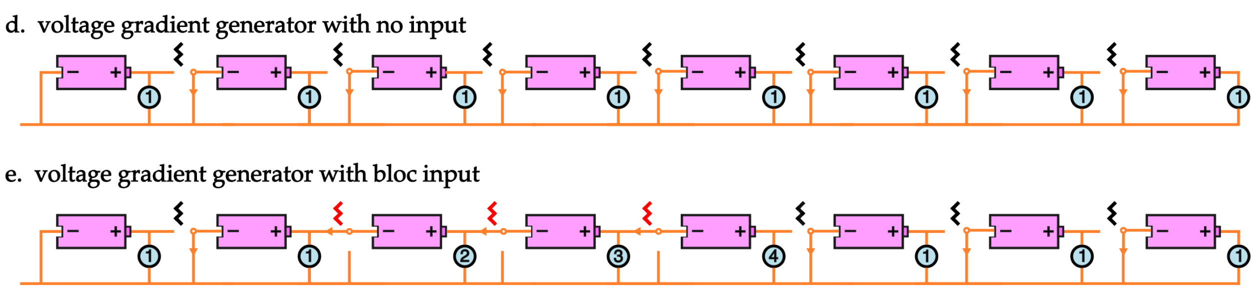
Fig. 45. variable generation of voltage gradients



In the element of construction (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 negligible.)

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

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



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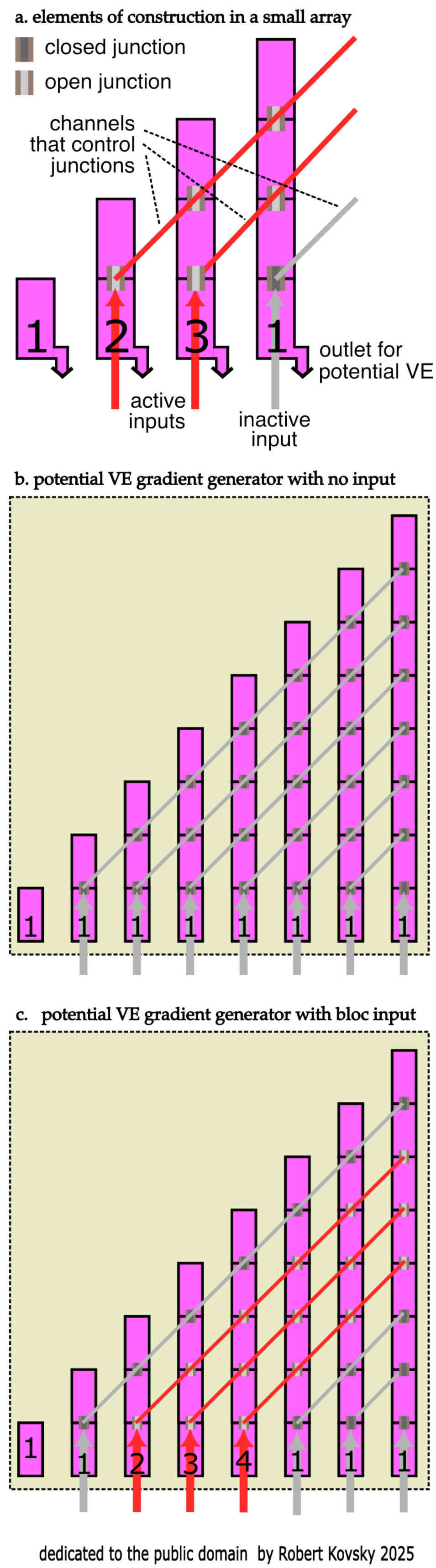
A generator of voltage gradients is shown in Fig. 45 (d) and (e). A row of seven switches provides input and seven corresponding voltmeters provide output.

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



A (gradient of potential VE)* is generated in the design in Fig. 46. The result resembles voltage gradients shown in Fig. 45.

In the Fig. 46(a) exemplar, each device (box) 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 is indicated by a number (of bangs) at the bottom of the column.

VE in the device at the lowest level of a column is always ready. Whether VE is ready in devices at higher levels depends on the open and closed 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. Active inputs produce signals on channels, shown in red. Signals open junctions. Inactive inputs and channels are gray and connect to closed junctions.

The potential VE gradient generator shown in Fig. 46(b) has a "no input" condition. 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 at the bottom of the corresponding columm, resulting in a higher level of potential VE. A bloc of inputs results in a gradient of potentials.

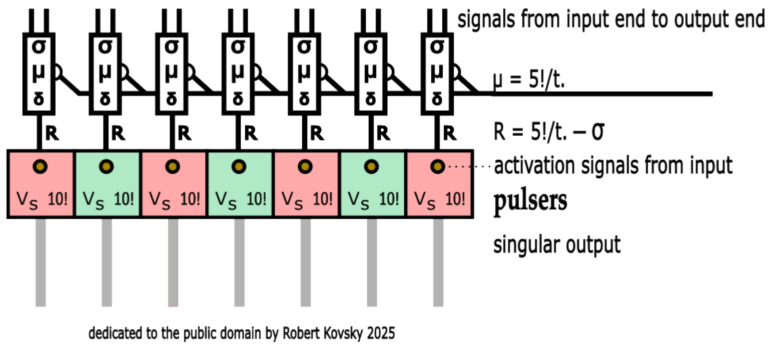
If the switchable junction of the bottom device remains inactive, the potential VE in the column remains at 1! even when there are open junctions higher in the column.

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 the proper central output.

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

In the output end of the module (Fig. 47), output projections are driven by pulser devices with a conservative VES and with pulsers where $V_s = 10!$. At the start of operations, $\mathcal{V}(t) = 0$.

Fig. 47. VE gradient centering module, output end



A Fig. 47 pulser starts operating when it receives an activation signal from the corresponding input. In Fig. 47, these signals arrive at brown dots on the pulsers. Pulsers with inactive inputs do not start operations.

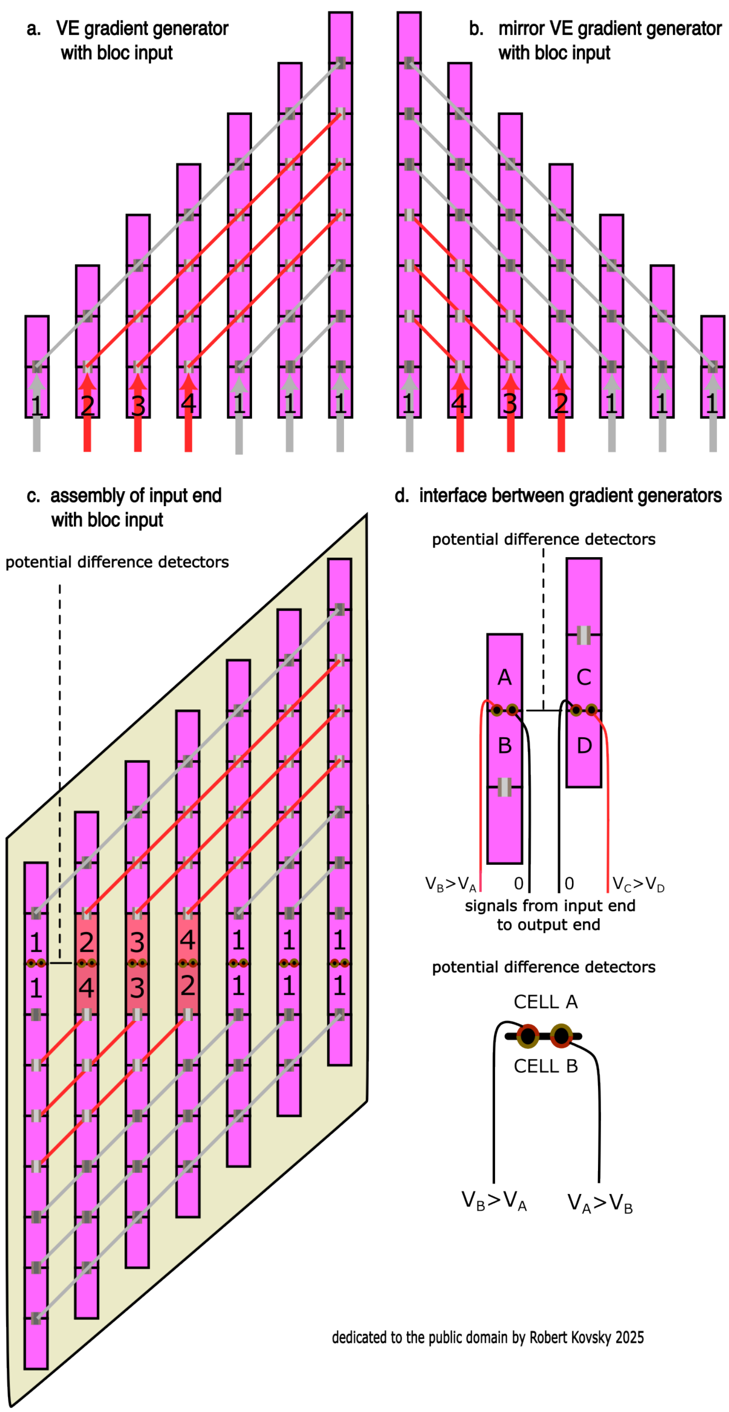
There is a difference between pink and green pulsers. The discharge of a green pulser is delayed by 2δ and will not occur if a pink pulser discharges first and terminates the process. This feature "breaks the tie" when two adjacent pulsers reach $\mathcal{V}(t) = 10!$ at the same instant, as applied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

Pulsers start operations after processing in the input end. VE sources for the pulsers (denoted **R**) arrive on difference projections out of difference devices. All the 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.

The effective result is a contest or race between output pulsers. The first pulser to discharge identifies the center of the bloc and terminates the process.

In sum, an input signal on the subtrahend line into a difference device slows down the corresponding output pulser. The pulser with the smallest signal from the input wins the race. Any tie involving 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 of the VE gradient centering module 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.

The "mirror version" in Fig. 48(b) generates a mirror gradient that runs in the opposite direction from the original.

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

In operations, the VE potential in the original gradient is compared with the corresponding VE potential in the mirror gradient. If the two VE potentials are different, one detector will produce a signal with a pulse rate reflecting the difference; it doesn't matter which of the two detectors is producing pulses.

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

In this design, the rate of pulses generated on a projection from a detector (n!/t.) is equal to the difference (n!) between values of potential VE in the two cells subject to the detector. As a practical and economical limit, the highest flow rate from a difference detector is set at 5!/t. regardless of levels of VE in the cells.

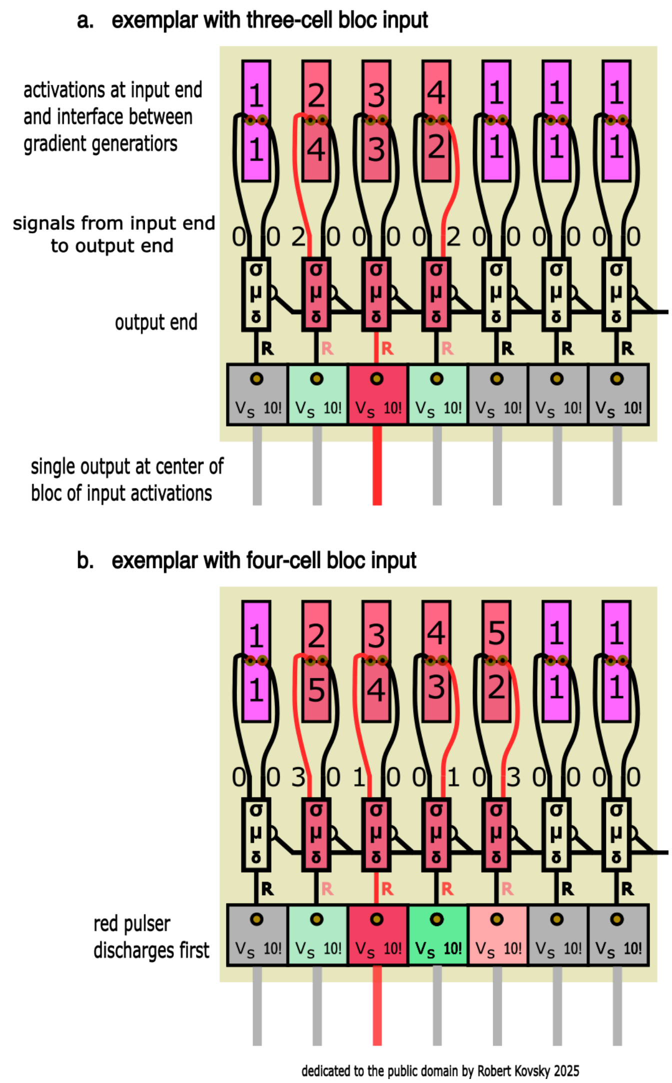
In Fig. 49, the input end of the VE gradient centering module is connected to the output end. Operations are restricted to the bloc of devices defined by the inputs.

Inside the activated 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 $\mathcal{V}$(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 that $\mathcal{V}$(t) 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 kinds of centering modules have been constructed: (1) a timing device centering module (Fig. 30); (2) a linear-array junction centering module (Fig. 35); and (3) a VE gradient centering module (Fig. 49). These can be compared as to performance time and number of devices required.

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

Performance time for the input end of the VE gradient design is faster than the linear junction design: gradient-design junctions open immediately and signals from detector devices can start shortly thereafter; a performance time of 1 t. is more than sufficient. Performance time of the output end is slower, requiring 3t. for the slowest result (including a margin of silence). (Faster designs for the output end are readily conceivable.)

The number of devices needed for a module, denoted by $\mathbf{N}$, depends directly on the number of inputs, denoted by $\mathbf{I}$. For the timing device module, $\mathbf{N} = (3 \times \mathbf{I}) + 2$ (thus including the signal generator). For the linear junction module, $\mathbf{N} = (2 \times \mathbf{I}) + 1$, plus the bodies.

For the input end of the VE gradient module, $\mathbf{N} = \mathbf{I}^2 + \mathbf{I}$. For the output end, $\mathbf{N} = (2 \times \mathbf{I})$. The assembly of mirrored gradient generators (Fig. 48(c)) is a quadnet device; and its inputs connect to outputs from the sensorial quadnet device in Gazer models. A sensorial Gazer quadnet is thus connected to two other quadnets in centering modules. This construction is a starting point for assemblies of quadnet devices.

In timing device modules and linear-junction modules, performance times for the centering function increases at a linear rate as the number of inputs increases. For the input end of the potential gradient module, in contrast, performance time remains "the same" no matter how large the number of inputs. In the gradient design, signals travel in channels "instantaneously." Potential difference detectors start producing signals in all columns at the same moment. A performance time of 1t. appears to be sufficient for signal production from the input end regardless of the number of inputs. Such speedy operations resemble transmission of pressure changes in liquid water at the speed of sound and transmission of voltage potentials in electrical conductors at speeds comparable to those of light in a vacuum.

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). Applications were developed in Wriggler projects (2020-2022).

The following construction of mover-burster designs uses the original definitions for steady movers. 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 and steady mover or duet

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

c. self-timed bursters use pulse burst signals augmented with leading pulses

d. a module with coupled bursters drives opposing movers

e. a module with bundled bursters drives opposing bundled movers

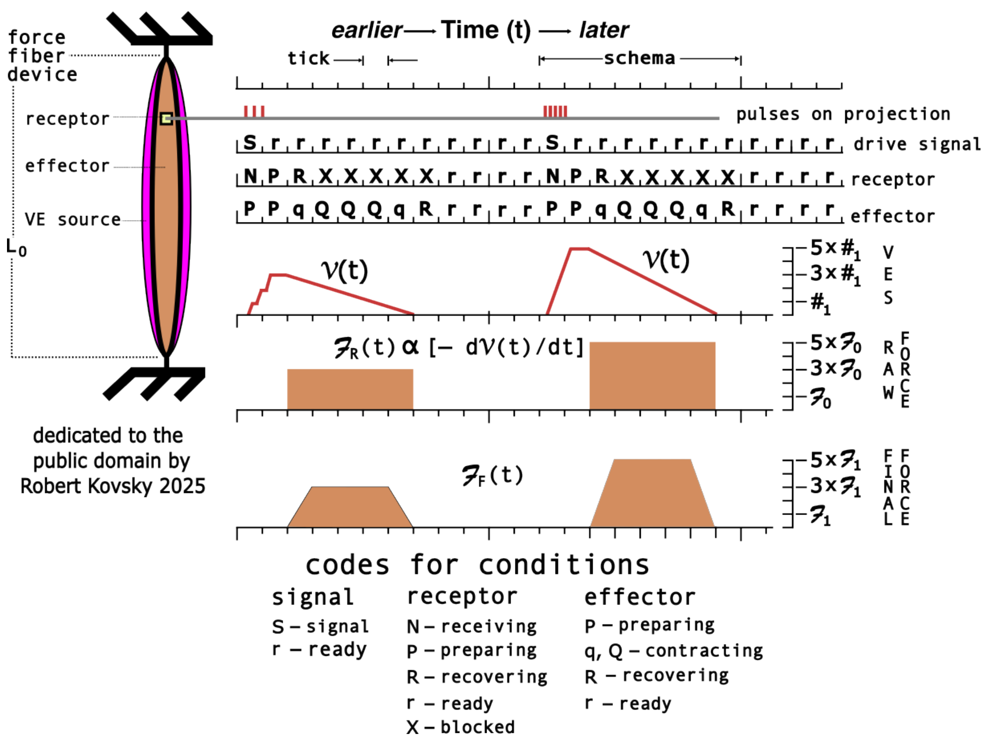
a. primal force fiber device and steady mover or duet

Fig. 50 shows operations of a 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 at the maximum, $L(t) = L_0$.

The function of the device is to twitch after stimulation by a pulse burst. All twitches have the same duration and shape in time. The strength or force size of a twitch corresponds directly with 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`. As charted in Fig. 50, a pulse burst signal (S), after traveling over the projection, arrives at the receptor, which receives the signal during the first tick (N) of the schema. The effector begins preparation (P) during the first and second ticks, followed by effector contraction for five ticks (q, Q). The final tick (R) is for recovery. The device is then ready for a fresh stimulus. Preparation time P includes a margin of silence, which allows for 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, a rectangular shape and a unit size force, all denoted by "$\mathcal{F}_0$." The second process produces the final force with the same unit size force as $\mathcal{F}_0$ but with a different "trapezoidal" or "ramped" shape "$\mathcal{F}_1$." Dissipation during q ticks causes loss of VE and force during the second process.

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 strength $\mathcal{F}_1$. VE flows into the VES at the rate of 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 the 5 ticks of contraction, $\mathcal{V}(t)$ falls at a constant rate to 0. VE in the VES is converted to produce the raw force. The device produces twitches with a final force of $\{1, 2, 3, 4, 5\}\times \mathcal{F}_1$ in response to bursts with {1, 2, 3, 4, 5} pulses. Presumptively, and applying a principle of finality, internal VE flows can be adjusted to perform this function.

The raw twitch is $\mathcal{F}_R = \{1, 2, 3, 4, 5\}\times \mathcal{F}_0$ with fixed $\mathcal{F}_0$. The corresponding values of $\mathcal{V}(t)$ are {1, 2, 3, 4, 5}× #. In other words, n × # in the VES is converted into an $n \times \mathcal{F}_0$ force form. The correspondence relations can be summarized as:

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

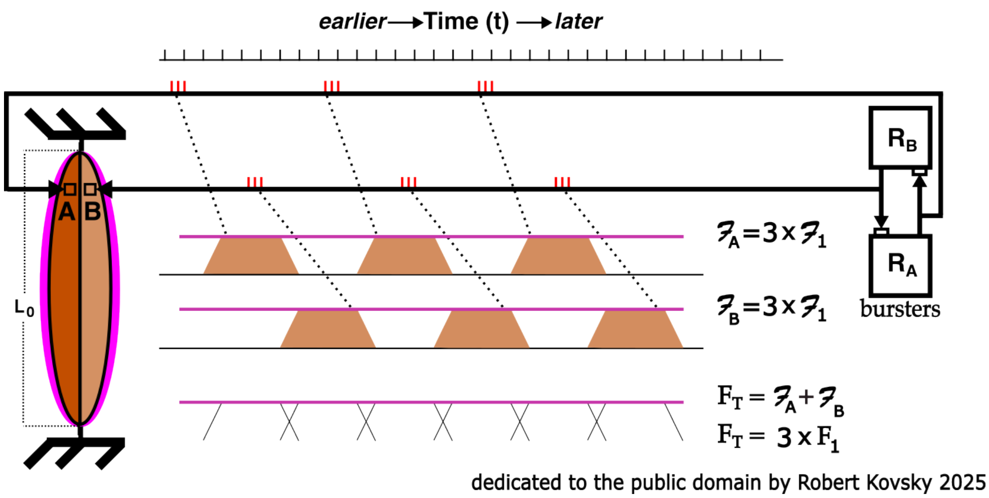
The foregoing force relations are developed for purposes of project goals; they are not necessarily seeking to describe nature. Project goals motivate the "trimming" of the force shape from a rectangle ($\mathcal{F}_0$) to a trapezoid ($\mathcal{F}_1$) and the variation in mover force with length discussed below. Features of force production are imputed to the body of the device.

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 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 sets 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, driving force fiber A and producing 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 device like numbers so that the 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 corresponds to a variable strength of force produced by the mover. L(t) is the variable length of the mover and ΔL is defined as the shortening* of the mover or $\Delta L(t) = [L_0 - L(t)]$.

The force relation for the variable length mover is $F = [n \times F_1 - (j \times \Delta L)]$ where j is the (dissipation factor)*. This factor denotes a loss of converted VE (force) when the mover shortens. It is used to define the length unit of contraction of the mover, namely $\xi = (F_1/j)$, as discussed in the Gazer project. In this project, j is a fixed specification of a mover.

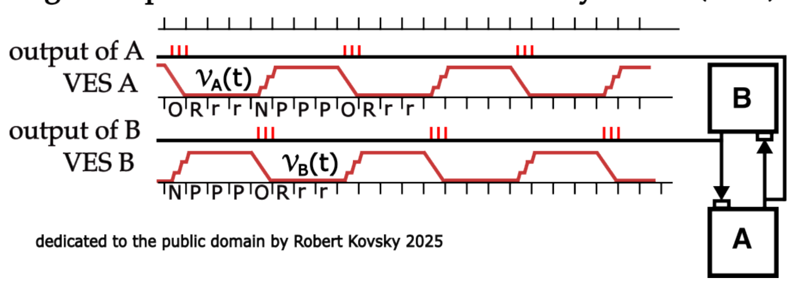
VE operations of bursters in Fig. 51 resemble those of force fibers. Differences include schemata of burster operations, which have the form `NPPPORrr` rather than `NPqQQQqR`. Preparation time (P) includes a large margin of silence, anticipating future developments. A burster produces a pulse burst during the "`O`" tick and uses much smaller quantities of VE than a force fiber device.

Bursters operations of (repeating bursters)* A and B are shown in Fig. 52, where they perform a function "n input pulses results in n output pulses." In a duet, repeating bursters discharge alternating pulse bursts onto each other and generate a steady stream of bursts. Burster A triggers burster B and then burster B triggers burster A. Compare to the timing device signal generator in § 8(b).

VE operations shown in Fig. 52 start with production of a burst of pulses on the output of A by conversion of VE in VES A. Burst production 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 an instantaneous 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 releases one bang of VE from B's VE source into VES B. VE flows into VES B at the rate 5!/t. (recalling VE flow into the force fiber device); 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 into pulses on B's output, leading to reception by A.

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



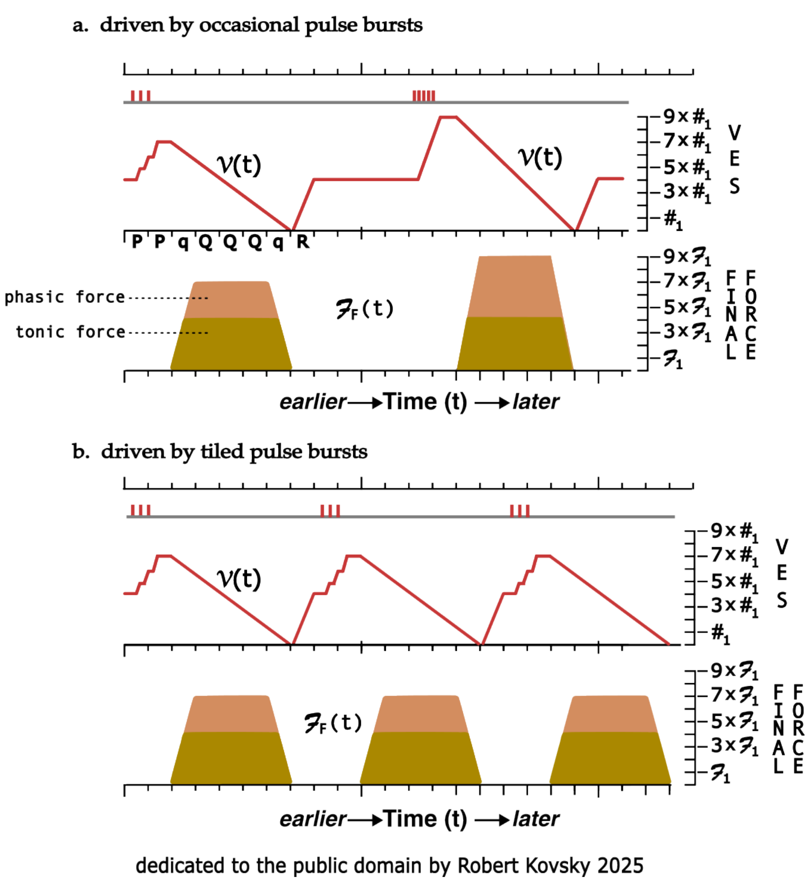
b. steady mover with a fixed tonic force and a variable phasic force

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

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 $4 \times \mathcal{F}_1$ and a phasic force $3 \times \mathcal{F}_1$. In response to a 5-pulse burst, operations combine a tonic force ($4 \times \mathcal{F}_1$) and a phasic force ($5 \times \mathcal{F}_1$).

More precisely, the combination occurs in the VES. During the effector 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 head to toe, as shown in Fig. 53(b); this condition is tiled*. When inactive readiness periods intervene between pulse bursts, the signals are occasional*.

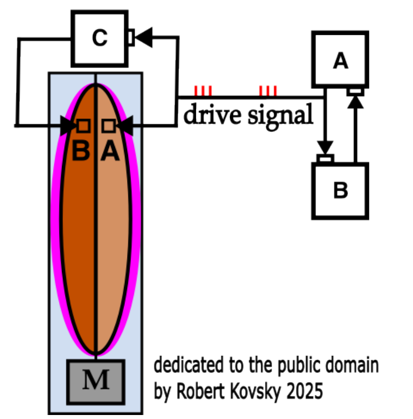
Tiled schemata are used in steady mover designs. Signals arrive continually and movers are always tense. Steady positions correspond to steady signals. When signals change, new signals stay steady while movers shift into new steady positions.

c. self-timed bursters use pulse burst signals augmented with leading pulses

For purposes of simplification, the two projection lines in a duet are reduced to a single "drive signal" line, e.g., drive signal lines used in the Gazer project.

In an example (Fig. 54), a single projection branches from burster A and carries signals both to force fiber A's receptor and also to nearby burster C, which discharges 4t. later onto force fiber B's receptor. Otherwise, mover operations are the same as in Fig. 51.

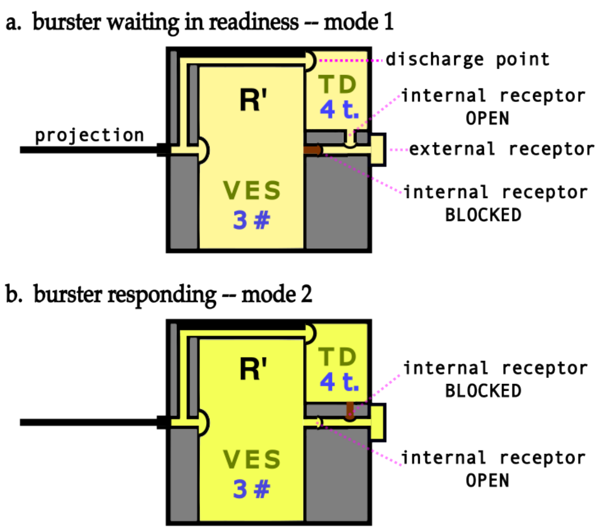
Fig. 54. duet with single drive projection



Pulse bursts with leading pulses are defined as to timing devices in §8(d) and Figs. 21-23. In the extension for self-timed bursting devices shown in Fig. 55, output bursts can have either 1, 2, 3, 4 or 5 pulses. Variable operations of bursters stand in contrast to the Fig. 22 design, 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 devices in bodies acquire temporal independence.

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



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

The arrival of a leading pulse triggers the timing device, blocks the timing device receptor and opens the VES receptor. These operations require a period of 1α. At least 2α intervenes between pulses in a burst. Following pulses in the burst pass through the VES receptor and trigger releases of VE into the VES.

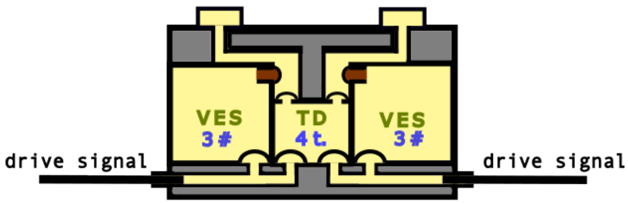
The timing device has a responding period of 4 t. Discharge of the timing device triggers synchronous discharge of the VES. The schema of operations is the same as when the master clock is in control.

d. a module of coupled bursters drives opposing movers

Fig. 56 shows a coupled burster module that drives opposing movers. Such burster modules in Gazer send synchronous drive signals to movers that oppose each other, e.g., left and right movers. Drive signals are streams of successive pulse bursts, one burst every 8 t. The number of pulses in a burst is 1, 2, 3 or 4 (not using the 5th pulse). The first pulse is the leading pulse, which performs timing functions.

The size of successive bursts changes only occasionally, accommodating the slow speed of movers and other body parts. When there is a change in a stream of bursts, both drive signals change simultaneously.

Fig. 56. Module that drives opposing movers



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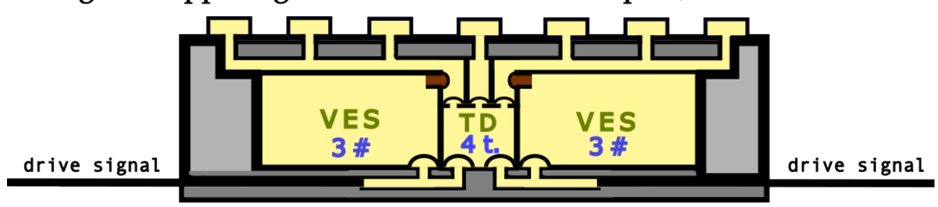
The Fig. 56 design produces drive signals from pulsed burst inputs. Pulse bursts in (left, right) inputs and drive signals have 16 possible values: (a,b) where a = 1, 2, 3 or 4 and b = 1, 2, 3 or 4.

The Fig. 56 design is readily extended to the 7-input design in Fig. 57, which is used in streaming-mode versions of Gazer models:

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



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In a streaming version, detections occur every 8 t. and the results are passed through to produce fresh drive signals every 8 t. The final Gazer design is a streaming version. In a substitution version, a position stays steady in the absence of a drive signal and new drive signals produce new positions. Each burster drives a repeater burster and two reciprocating bursters maintain signal values until new values arrive. A substitution mode version can handle repetitive streaming input but there is a comparative delay in production. The two versions or modes were explored in the Wriggler I project.

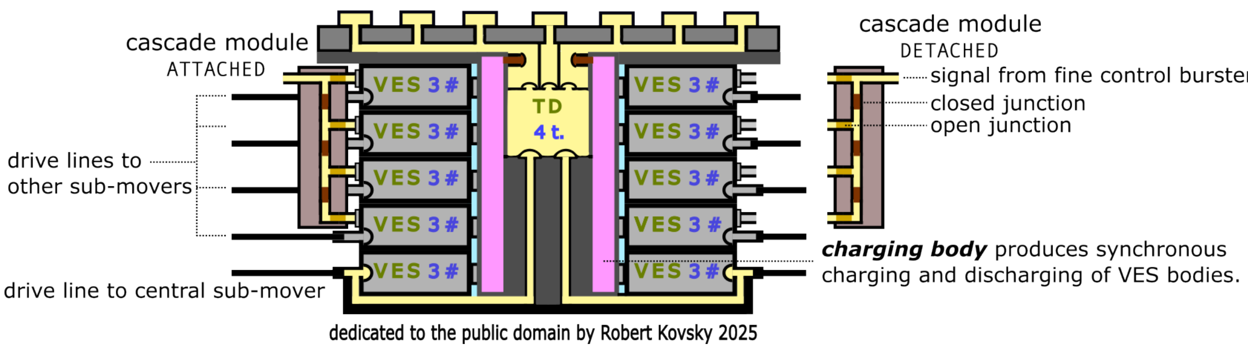
e. a module with bundled bursters drives opposing bundled movers

The Fig. 58 module is a Fig. 57 module that has been enlarged to 10 bursters that each drive five sub-movers in 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 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 feed into each VES, the coarse amount from the central charging body (0 to 3 #) and the fine amount (0 or 1 #) from sources triggered by pulses that arrive through the cascade module from the fine control burster. The two sources add in the VES for production of drive signals.

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. Since the burster schema includes three P ticks after completion of the input pulse burst, there is ample time.

Fig. 58. bundled bursters for bundled movers

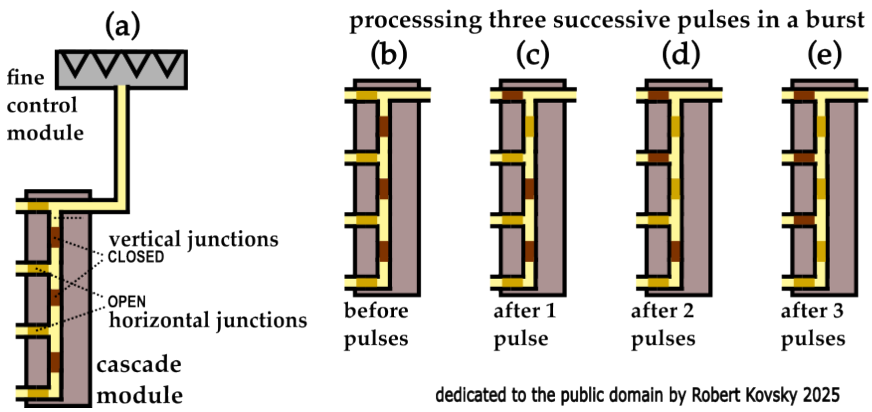


Fine control adjustments to individual bursters involve a cascade module and are based on pulse burst signals produced by a fine control burster. Operations of such a fine control burster are triggered by arrival of a pulse burst from a bursting timing device attached to the sensorial body.

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 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 except that they take place 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).

§ 10. retrospective views and prospective development

The foregoing project sets forth VE definitions, constructions and operations for all 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, diverse investigations of predation and its cousins started with the first page of the first project, which cites a scientist who identifies apparently conscious 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) quoting from Errington, Of Predation and Life.)

The earliest designs for "Engineered organisms that move and sense from a condition of balance" incorporate 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." Large repertoires of movement will respond to complex signals from large sensory arrays.

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, investigations are possible into other aspects of predation, such as maneuvering (sudden 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. The capacity of an organism to "win a race" against other organisms and the ranking of the organism in the hierarchy of racing speeds are measures of success. Maneuvering and opportunism can also be tested in competition.

Evaluating current VE designs against these standards leads to the conclusion that steady mover movements (e.g., in Wriggler and Gazer) are very slow, especially as the movers approach a final position. Steady mover designs have many advantages for early development including simplicity and clarity. "Final position" is a useful feature of steady mover operations that will be carried forward. Steady mover operations provide guidance for faster saccadic mover operations.

For faster operations, movers must be modified. First, the duet with two units (each with a burster and force fiber device) is developed into an octet with eight units. In one mode of production, each unit is receptive to an input for one tick out of every eight ticks; receptive periods of devices link up to provide continuous receptivity.

Next, the force fiber device is developed into a two-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 parts 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 value, almost 2/3 of the total force production will occur during the first tick. $\mathcal{G}(t) = [n \times \mathcal{G}_1 - (j \times \Delta L)]$.

Saccadic twitches do not connect like steady twitches. Instead, twitching in an octet is organized by an action pattern (schema), e.g., one unit starts each tick in a cycling sequence. The saccadic forces are irregular or "trembling." The sum of forces includes steady forces and trembling saccadic forces. If the combination of forces can impart momentum to body parts or to the whole organism, "flywheel effects" will 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 that can be activated in different patterns (like different gaits of horses) and that could provide large repertoires of speeds and strengths.

Another possible improvement involves the rigid hierarchy of time in current designs. Guiding values of α (1/1000 sec.), δ (1/100 sec.) and t. (1/10 sec.) can be reduced and, more importantly, amalgamated in many situations. Achieving a "top speed" will require maximum compression of operational timing intervals.

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. One inviting approach would incorporate "training," e.g., initial movements of the body carried out by an external power; and also "practice," e.g., repeated movements carried out by the organism that perfect performance through adjustments in properties of collective bodies.

The development of centering modules in §8 shows that synchronous operations in large collective bodies achieve high speed performance. Each device requires a period of time to operate; series of devices will slow the response as the number of devices grows larger. Designs where multiple large collectives are functioning simultaneously will produce the fastest possible responses.

Development of multiple large bodies of collective devices that operate synchronously and that perform different kinds of functions together — these steps appear to lead towards Shimmering Sensitivity.

Images prepared using Inkscape 1.2

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