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SELF-GOVERNING ELECTRONIC AND MECHANICAL SYSTEMS

BY

RICHARD ELLIS

DEFINITION OF TERMS

1. **Input:** What the system 'senses'.
2. **Transducer:** A device that translates the input into a *voltage*. The *voltage* may be directly related to the input, or to a rate of change of the input.
3. **Reference:** An internal *voltage* which stands for, but is not necessarily itself caused by, an input to a transducer. It can be 'built in', retained from a past input or provided by another transducer.
4. **Discriminator:** A device which compares the *voltage* from the transducer with the reference *voltage* and provides a *voltage* proportional to the difference, taking into account whether one is bigger or smaller than the other.
5. **Actuator:** A device capable of using the *voltage* from the discriminator to control a much larger power.
6. **Output:** A device that can convert electrical or mechanical power into a suitable form so as to alter the environment providing the input.
7. **Power supply:** Any suitable source of energy that can be controlled so as to provide the necessary output and *voltage* changes.

Note: *Voltage* can be replaced by 'position', 'pressure', 'current' or any other suitable phenomenon.

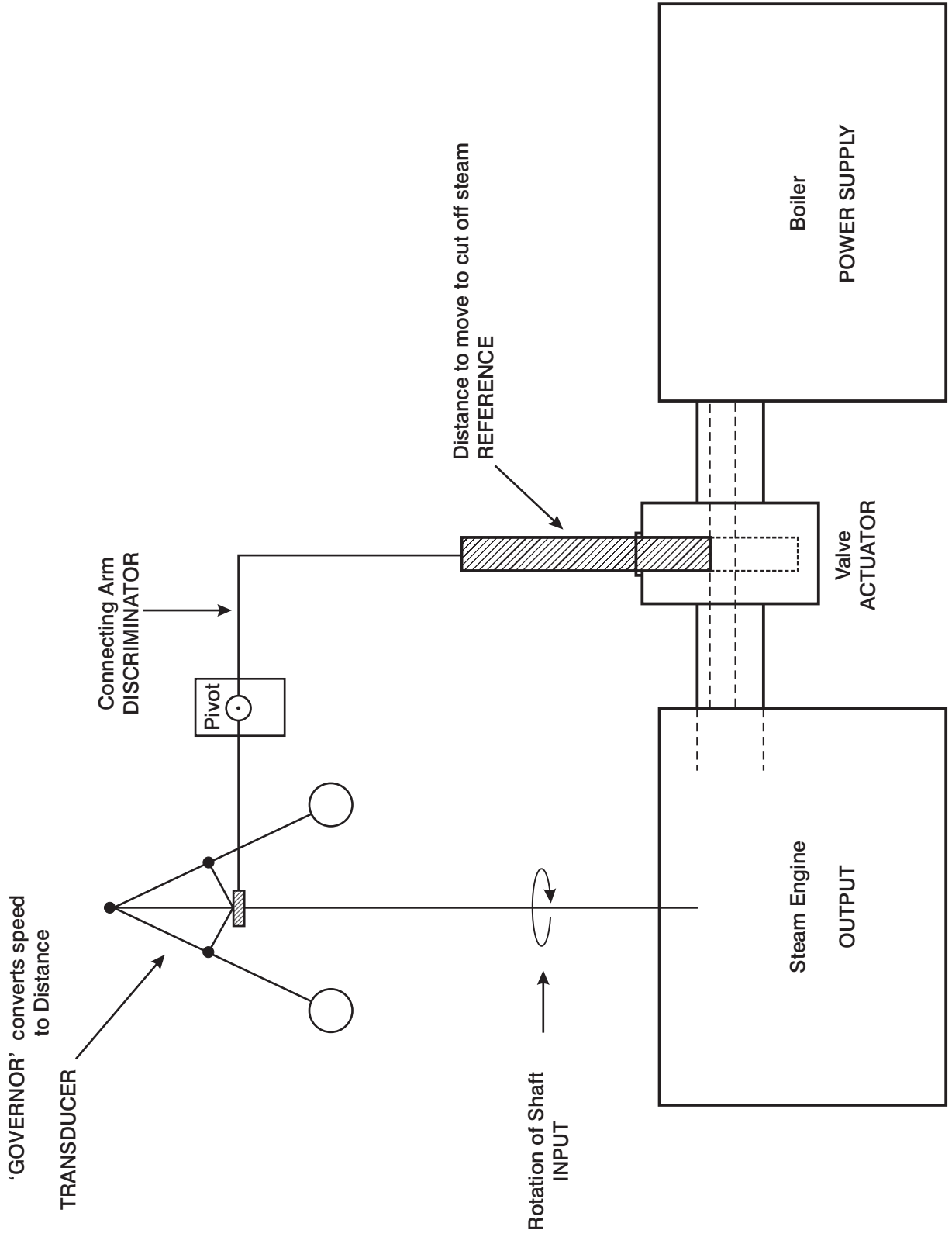
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OPERATION

If the input causes a *voltage* from the transducer which is different from the reference, the discriminator actuates the output in a manner such that the input will reduce the difference between the *voltage* from the transducer and the reference. Thus there is always an attempt to keep the transducer's *voltage* equal to the reference; in this way the system governs its output, and therefore its input.

On page 80 is shown a schematic diagram of a mechanical self-governing system for self-regulation of the speed of a steam engine. (It is chosen as example because of the relative simplicity).

When power is available in the form of steam, the engine speeds up. If the steam is not restricted, the engine will go so fast it will damage itself. As it speeds up the shaft to the (so-called) Governor rotates and the heavy weights fly out pulling up a disc on the shaft. The disc moves a lever, which moves down a plunger that can cut off the steam supply. If the speed is low, the plunger does not reduce the steam supply. When the disc has moved the distance equal to the distance necessary to reduce the steam supply, the steam to the engine is reduced and it no



longer speeds up. If the speed *were* to become higher, the steam would be cut off altogether and the engine would slow down.

Below is shown a schematic diagram of a voltage regulator (self-governing) system.

The output is already a voltage, so it can provide the input, the only 'translation' being a change in relative value.

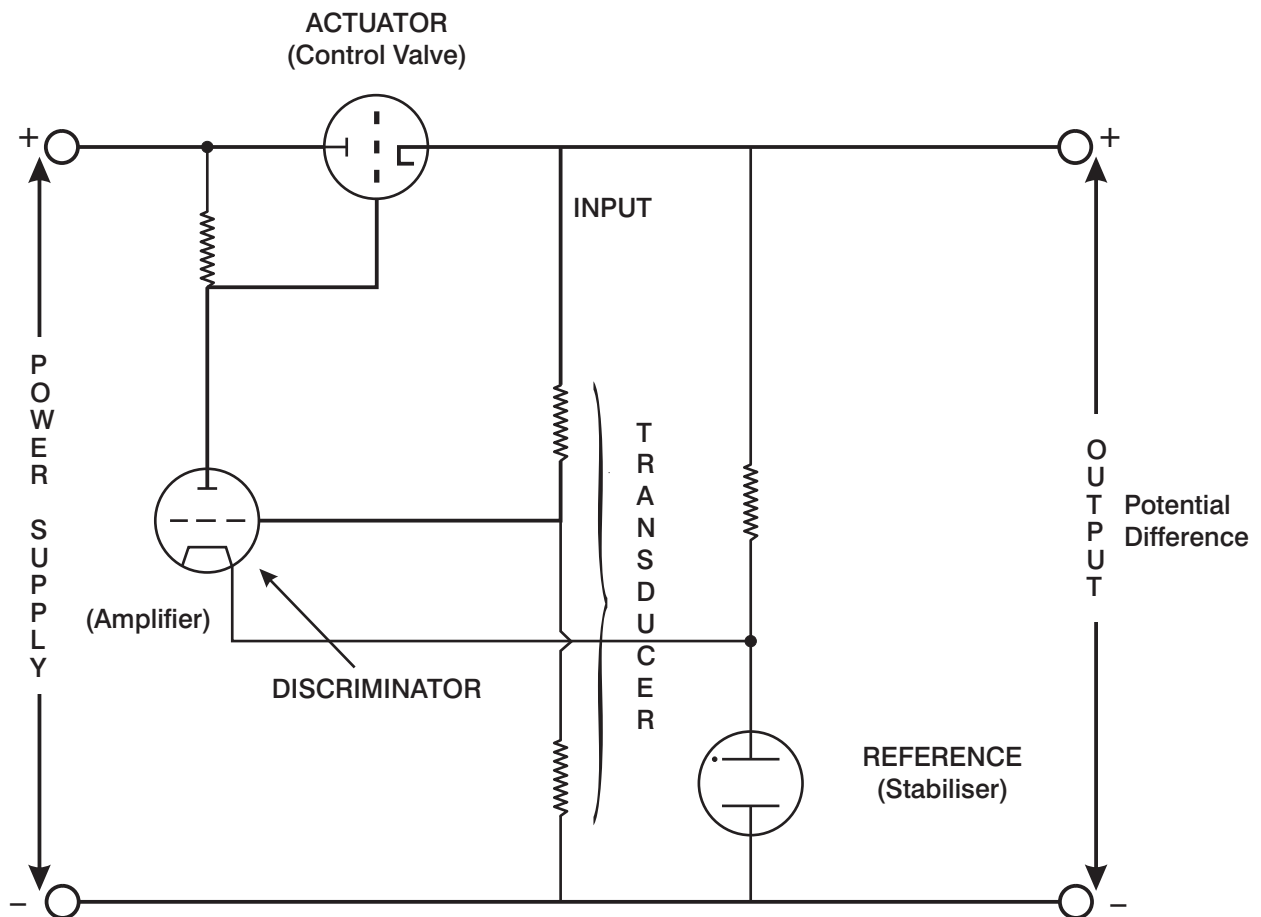
The discriminator provides a current proportional to the difference between the potential from the potential divider (transducer) and the reference voltage from a 'gas filled stabiliser'.

This current determines the potential applied between grid and cathode of the actuator or control valve.

If the output potential falls, the discriminator current falls and raises the potential on the grid of the control valve, which will increase the output potential.

If the output potential rises, the discriminator current rises resulting in a fall in potential on the grid of the control valve, which will reduce the output potential.

The system also compensates for changes in power-supply voltage providing it does not fall below a certain value.

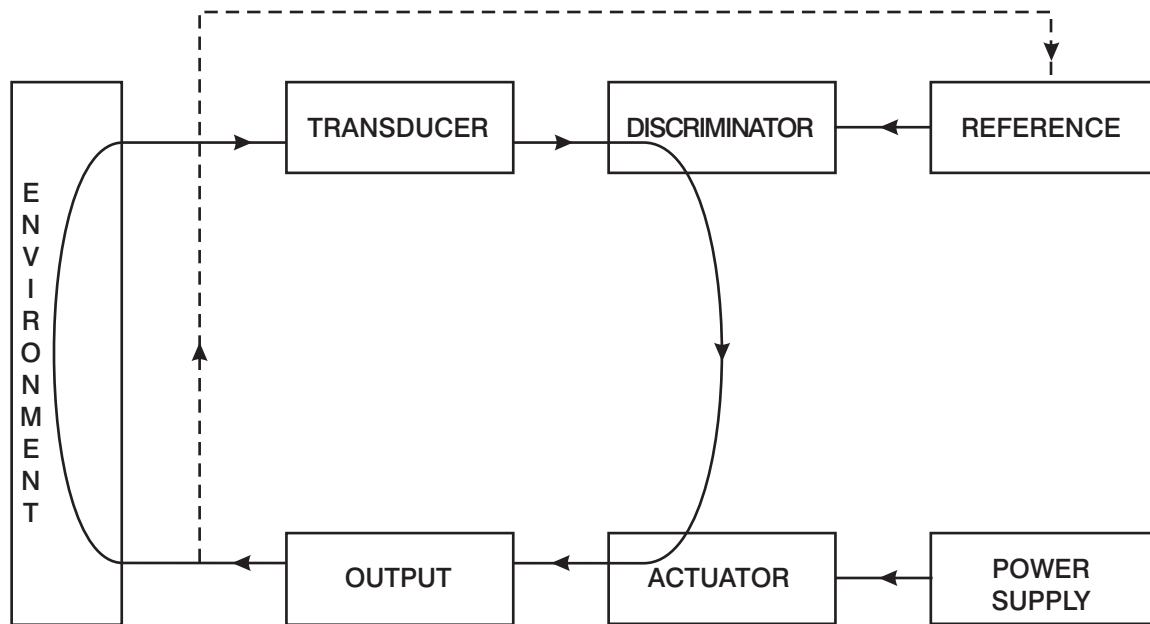


There are many more circuits of a similar nature:

- Automatic current control
- Automatic frequency control
- Automatic gain control
- Automatic 'follow' control, etc., etc.

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Below is shown a 'block' diagram which covers all cases, electrical or mechanical. The 'Negative feedback loop' is clearly in evidence on all diagrams. The dotted line shows how in some circumstances the output can be 'switched' so as to alter the reference in order to 'set' the reference to an 'ideal' environment instead of attempting to alter the environment to suit some unsuitable reference. What is called the 'environment' is of course meant *very* loosely, since it only refers to that aspect which can be sensed by the transducer. The system in operation seems 'purposive', the 'purpose' being another term for the reference.



I have a model which illustrates the self-governing system. It is a small toy that seeks light, actively avoids dark and turns from objects which it touches. It doesn't work very well because of the mechanical difficulties of construction. If you wish this can be brought in. The basic principles can be illustrated even if it does go 'sulky'.

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COMMENTS ON MR. ELLIS'S PAPER

on 'Self-governing Electronic and Mechanical Systems'

There seem to be 7 basic elements in the simplest forms of self-governing systems as here described. Can we relate these in any way to our biological and neurological problems? I believe we can make a start:

- 1) **Input:** That part of the environment that a particular system 'senses'. Thus our eyes pick out a single octave of the electromagnetic spectrum; our ears make sense of ten or a dozen octaves of the sound waves in air. In biology 'every animal, if it has perceptions at all, must have *its own* perceptual world which may be very different from ours.'

(E.S. Russell, *The Behaviour of Animals*, p.16)

- 2) **Transducer:** A device which translates the Input into what we might call 'nervous currency'. In mechanical systems, as Ellis says, it might be a voltage, position, pressure, current or other conveniently handled phenomenon. In living systems we are apt to call this a 'Code' translatable into a biochemical 'helix' or 'cycle'. For example, some 'transducers' convert electrical into chemical energy in the body. Good examples have been found in several of the Endocrine glands – the anterior lobe of the Pituitary, 'the islets of Langerhans' in the pancreas, the adrenal medulla, and the 'interstitial cells' of the sex glands.

The 'chemical mediator' adrenaline, for example, (manufactured by the adrenal gland) is liberated at every terminal nerve ending of the Sympathetic nervous system. Recently a 24-hour rhythm in the sex hormones has been traced to a dual hormone mechanism in the pineal body governed by light stimuli falling on the retina of the eyes. (*Scientific American*).

- 3) **Reference:** An internal standard, perhaps another circuit, with, say, a 'voltage' or a 'code' or a 'body image' or 'memory store' with which the input is all the time compared. Ellis states that it can be 'built-in, retained from past input or provided by another transducer'.
- 4) **Discriminator** is the device which does the comparison.

a) 'Whenever one reaches with his hand for an object, a series of signals flows back (as with the self-pointing gun) through eye, skin (touch), muscle and joint sensations, to inform the 'central mechanism' how much the hand is overshooting or undershooting. The amounts of error determine the return input until the error becomes zero', and the movement being 'learnt' is added to the long-term 'memory store'. Such a mechanism to control the search for a goal is called 'negative feed-back'. It accompanies every 'motor act', and until a baby establishes this mechanism it cannot learn to crawl or walk. In 'spastics' this possibility is absent, whether in part or whole.

b) Central modulation of sensory perception seems to have been proved for vision, hearing, and smell, as well as for muscle. Stimulation of the alerting (reticular) formation in the mid-brain affects the *input* from cells of the retina. (Granit 1954)

(Ref. Stanley Cobb, *Foundations of Neuropsychiatry*, 1958)

- 5) **Actuator:** 'A device capable of using the voltage from the discriminator to control a much larger power' – e.g. the 'governor' of a steam engine restricts the steam, otherwise the engine would go so fast it would damage itself.

The actuator appears to produce an effect which oscillates between the two extremes of activation and inhibition, and if we consider it this way, it would bring it in line with well-known mechanisms all through the body.

Such 'activating and damping mechanisms' are everywhere seen in the nervous system – in particular the 'parasympathetic' everywhere opposes the 'sympathetic' which rouses the body for 'fight or flight'. The 'governor' for this seems (like many others) to be situated in the hypothalamus. Also the 'respiratory centre' in the brain-stem may be seen as the chemical 'governor' in breathing, terminating each in-breath or out-breath by 'damping' impulses along the Vagus nerves.

May we see the resort to drugs today as an artificial means of getting over defects in the Actuator? The young seek 'activation' through dexedrine, hashish or LSD, while the older generation demand sedatives and tranquillisers.

- 6) **Output device:** ‘That can convert electrical, mechanical or chemical power into a suitable form to effect a change in the environment that provided the input’ – like a mechanism for putting a group of muscles or the whole body into movement.

Thus in the complex mechanism of *speech*, there is a circuit which goes to the ‘reference’ for the right phrase; compares what is being said with the intended meaning (‘discriminator’) and by some ‘output device’ moves the small muscles controlling the vocal cords as well as the respiratory muscles. ‘Stammering’ often seems to be a defect in the ‘actuator’, whereas ‘motor aphasia’ is a defect in the ‘output device’. There can also be ‘word blindness’, and ‘word deafness’, which may mean defects in the ‘reference’ or ‘discriminator’.

- 7) Finally, there must be a **Power supply**. Here our System mentions the ‘three kinds of food’ as the source of physical and mental energy, and describes the storage ‘accumulator system’. Physiologists, on the other hand, speak in terms of ‘energy yielded by combustion’ as in the burning of sugar into carbon dioxide and water, and its storage as glycogen. But again, ‘circuits’ are currently in evidence as in the ‘Krebs cycles’ or in the high energy phosphates (ADP and ATP) where energy is rapidly liberated by the breaking of chemical bonds.

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Ellis has given us this ‘block’ diagram (see Figure, p.82) ‘which covers all cases, electrical or mechanical. The negative feedback loop is clearly shown. The dotted line gives the means by which, in some circumstances, the output can be switched to an ‘ideal environment, instead of attempting to alter the environment to suit some unsuitable reference.’ I take it that this might be considered in relation to the heat-regulating mechanism of a ‘warm-blooded’ animal or to ‘acclimatization’ in general, and to altitude adaptation.

I hope people will be able to improve on this quite puerile attempt to relate the discoveries in electronics to the devices provided by Nature in the building of nervous systems.

F.C.R.

17.10.67

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