Overdruk uit „TNO-Nieuws" 21 (1966) 285-287

„Logarithmic clock", an electronic device for producing a discrete logarithmic time scale

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Samenvatting

Er werd een elektronisch apparaat ontwikkeld dat een discrete logarithmische tijdschaal kan genereren. Het apparaat produceert een rij elektrische pulsen op de tijdstippen

$$\tau,\ 2\tau,\ 2^2\tau,\ 2^3\tau,\ \ldots\ldots,\ 2^k\tau,\ \ldots\ldots,\ 2^{20}\tau$$

na een startpuls.
De grootheid τ is een willekeurige tijdseenheid met een waarde tussen 10^{-6} tot 10 seconden.
Het apparaat is bedoeld voor de besturing van registratie-apparatuur.

Summary

An electronic device for producing a discrete logarithmic time scale has been developed. It produces a series of electrical pulses at times

$$\tau,\ 2\tau,\ 2^2\tau,\ 2^3\tau,\ \ldots\ldots,\ 2^k\tau,\ \ldots\ldots,\ 2^{20}\tau$$

after some starting pulse. The quantity τ is an arbitrary time unit with a value between 10^{-6} and 10 seconds. The device is intended for the control of registration units for the measurement of physical relaxation processes, which should be measured against a logarithmic time scale.

Introduction

Many physical processes should be measured against a logarithmic time scale [4]. Examples are found in mechanical [1], dielectrical [2] and volume-relaxation experiments [3] on amorphous polymers, especially when performed in the glass transition region. To avoid redundant information, often a discrete number of observation times is sufficient. For this purpose, a simple electronic device has been developed.

Principle

A logarithmic equidistant series of pulses at times:

$$\tau,\ 2\,\tau,\ 2^2\,\tau,\ 2^3\,\tau, \ldots,\ 2^k\tau, \ldots,\ 2^{20}\tau \qquad \text{(series 2)}$$

is derived from a series of pulses with fixed repetition time

$$\tau,\ 2\,\tau,\ 3\,\tau,\ 4\,\tau,\ \ldots \qquad \text{(series 1)}$$

The primary series, series 1, is produced by usual frequency division from an accurate standard frequency. The pulses of this series are counted with an electronic binary counter. Fig. 1 gives an illustration. The counter consists of 21 binary counting elements, BC_1, BC_2, BC_3, ... etc. in a row. Five of them are given in Fig. 1. (Note that the signal flows from right to left.)

The state of each counting element [1]) as a function of time is given by the step functions plotted against a vertical dimensionless time scale. For time the quantity t/τ is used. At $t/\tau = 0$, all elements are in the „0" state.

For other times, the content of all counting elements together represents the number of counted pulses of series 1 in a binary form. The moments $t/\tau = 2^0, 2^1, 2^2, 2^3, 2^4, \ldots, 2^k, \ldots, 2^{20}$ are characterized by a first change of the content of the 1st, 2nd, 3rd, 4th, ... (1 + k) th, ..., 21st counting element from „0" to „1". This is because the number of pulses in a binary code at those moments changes respectively from 0 to 1; from 01 to 10; from 011 to 100; from 0111 to 1000; etc (see Fig. 1). This desired series of first jumps is selected by gates, connected to each counting element. The gates have the property only to transfer the jump offered first. The gates are indicated in Fig. 1 by G_1, G_2, G_3, ... etc. G_1 transfers only the first step of BC_1 at $t/\tau = 1$, G_2 only the step at $t/\tau = 2$ of BC_2, etc. The outputs of these gates are summed and constitute the desired series, series 2.

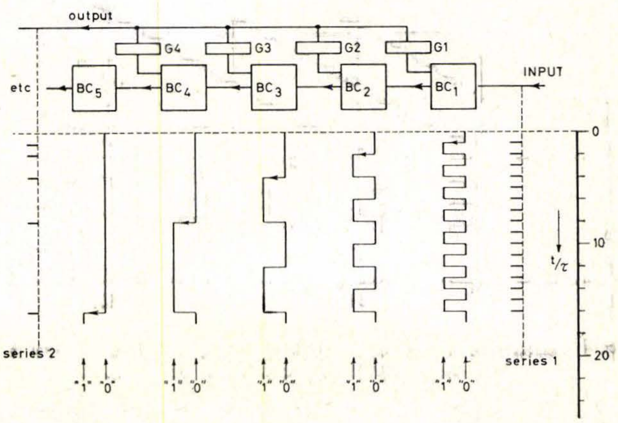

Fig. 1. Principle of the „logarithmic clock".

1) A binary counting element has two stable states, representing „O" and „1". It jumps from one state to the other by a positive pulse or step at its input. Therefore, only one positive step is transferred to its output for two positive pulses or steps at its input (division by two).

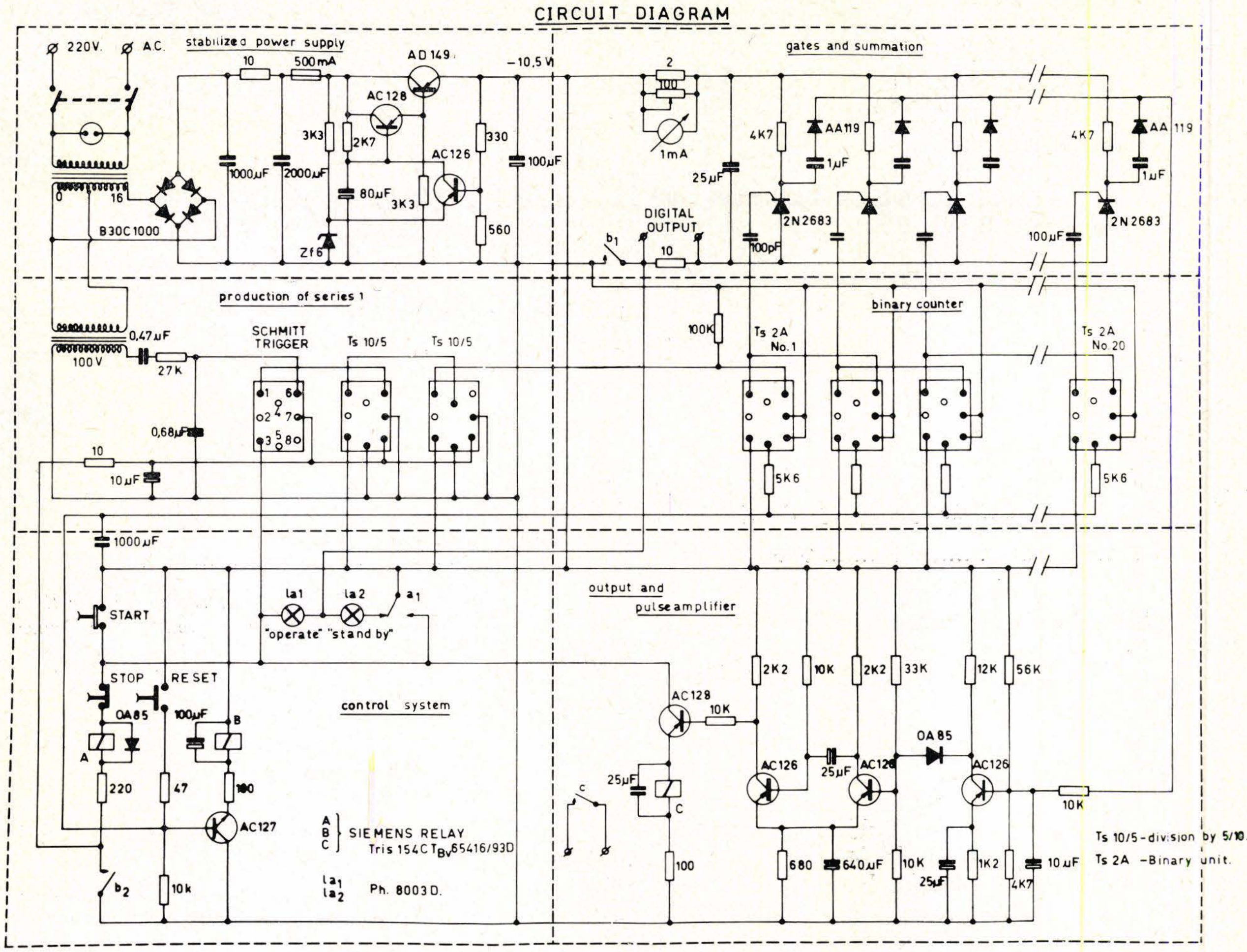

Fig. 2. Circuit diagram for a clock with a time unit of 1 second.

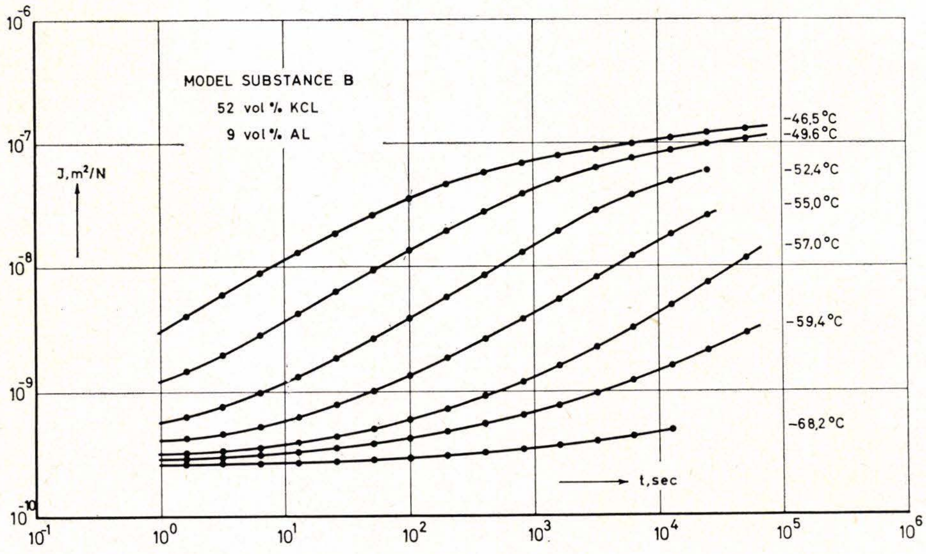

Fig. 3. Creep compliance, J, in shear vs creep time, t, for a polyurethane rubber filled with 52 vol. % KCl and 9 vol. % Al at various temperatures in the glass transition region. Clock is used for the control of a digital registration unit for the angle of torsion.

Design

Several devices, working with a time unit in the order of 1 second, were designed. Their electronic system was made up from standard units, commercially available [2]). Circuits are given in Fig. 2; we shall not describe them in detail.
For gates, G, (see Fig. 1), we used silicone controlled rectifiers (S.C.R.) [3]). The output of each binary unit is connected to the gate electrode of its corresponding S.C.R. The S.C.R. is fired by the first voltage step offered. Once fired, other steps have not any effect. Of course, different components such as binary units, neon bulbs etc. can be chosen instead of the S.C.R.'s.

Application

Three of these „Logarithmic clocks" are now in use at our Institute. The first for the control of a digital registration unit for torsional creep measurements [1]. Some results are given in Fig. 3. This work is part of an investigation on the mechanical properties at small deformations of filled and unfilled rubbers.
Another application is illustrated by Fig. 4. Those measurements concerned the investigation of the ultimate properties of filled rubbers by tensile creep [1].
A third application is illustrated by Fig. 5. It concerns volume relaxation. Volume equilibrium is disturbed by a sudden change in temperature. The delayed approach of specific volume to its new equilibrium is studied as a function of time [5].
The three examples clearly show the wide applicability of these „logarithmic clocks" in experimental studies involving relaxation phenomena.

Acknowledgement

Many thanks are due to Mr. J. A. M. van Veldhoven, who carefully designed and constructed the device.

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[2]) Venner Ltd., type T.S. 2A.

[3]) Transitron S.C.R., type 2 N 2683.

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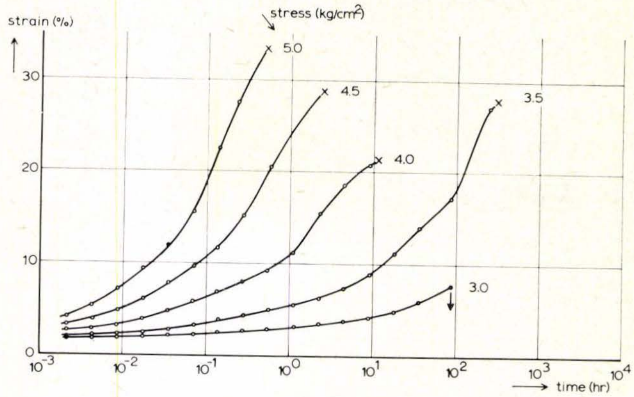

Fig. 4. Tensile creep at various high stress levels for a polyurethane rubber filled with 40 vol. % of sodium chloride fraction no. 4 (90 - 105μm). Temp. 21 °C; R.H. 65%.
Clock is used for the control of an automatic photographic camera for registration of strain.

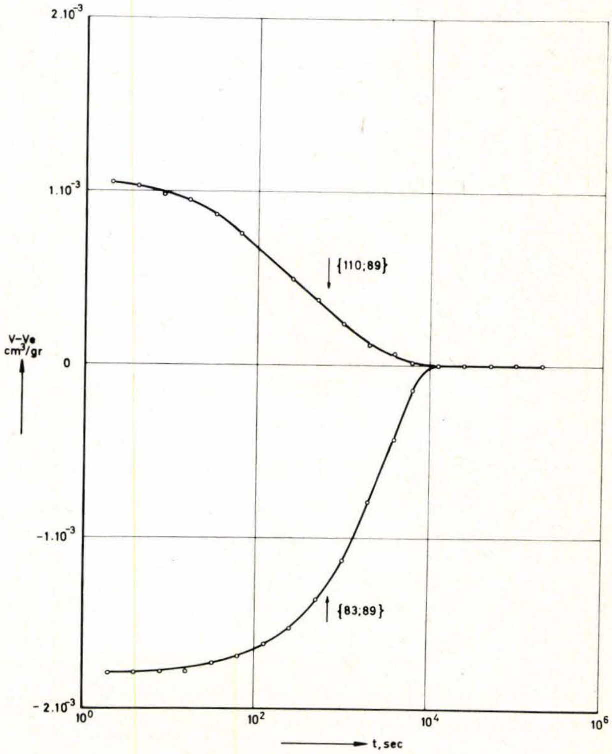

Fig. 5. Isothermal volume relaxation for a commercial polystyrene (Styron 666). Temp. 89 °C.

↓{ 110; 89 } quench from 110 °C to 89 °C

↑{ 83; 89 } sudden heating from 83 °C to 89 °C

Clock is used for the control of an automatic photographic camera for reading of dilatometers.