DIGITAL CARDIOTACHOMETER FOR SMALL LABORATORY ANIMALS

V. P. Lebedev and M. A. Sokolov

UDC 612.172.2-087.77

An instrument for the discrete measurement of the heart rate directly in the course of an experiment is described. It supplies a numerical result in the dimensionality of pulses/min.

* * *

A simple instrument for the discrete measurement of the frequency of cardiac contractions directly in the course of an experiment and supplying a numerical result in pulses/min is described in this paper. The instrument differs from the analog cardiotachometers described in the literature [3,4] or from the PT-2 instrument, in large scale production, by its simplicity, by the absence of adjustable elements and by the low inertia of the digital indicators. These are decatrons, which we have used previously in other bioelectrical wave counters [1, 2]. The instrument can be fitted to any standard electrocardiograph; it operates on a cyclic system and can measure the frequency of cardiac contractions automatically every 10 or 20 sec. A single cycle consists of three periods: measurement, indication and discharge, occupying 5 (10) sec, 4 (8) sec, and 1 (2) sec respectively. In the measurement period the number of R waves of the electrodardiogram is counted and the number is multiplied by 12 or 6 (corresponding to the duration of the measurement period).

The principle of operation of the instrument is illustrated by the block diagram with voltage graphs (Fig. 1) and the theoretical circuit (Fig. 2). Amplified cardiac potentials with the R wave in negative polarity are fed into the input from an electrocardiograph. The input unit 1 (see Fig. 1), constructed on tubes L_1-L_2 (Fig. 2) is an amplifier-clipper with differential circuits. It transforms the R wave into a short pulse corresponding in time to the initial part of the ascending limb of the R wave. The input unit contains filters (C_1, C_2-R_1, R_3 and C_4, C_5, C_6-R_6, R_7, R_8) ensuring considerable suppression of low-frequency and high-frequency interference which could enter from the output of the electrocardiograph.

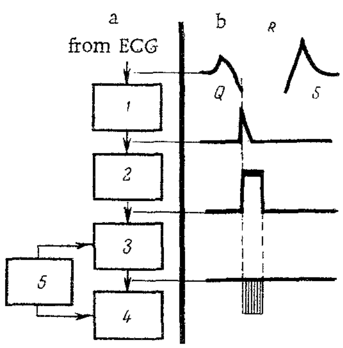

Fig. 1. Block diagram of the cardiotachometer (a) with graphs of voltages on its components (b): 1) input system; 2-3) multiplier stage; 4) counter-indicator unit; 5) controlling system.

The pulse from the input is fed into the multiplier stage 2-3 (Fig. 1) and triggers the driven multivibrator on tube L_3, which gives the pulse a preselected duration. This switches the multivibrator on tube L_4 to a self-oscillating mode of operation, which ceases when the pulse from the driven multivibrator ends. The multivibrator on tube L_4 fills in the pulse from tube L_3 with a certain number of pulses, i.e., it multiplies by an assigned coefficient. Transfer from one multiplier to the other is effected by a change in duration of the pulse from the multivibrator on L_3, by changing the capacitance in the anode-grid circuit (switch BK – capacitors C_{11}, C_{12}). Pulses from the multivibrator on tube L_4 reach the counter-indicator stage, formed from three decatrons (L_5, L_7, L_8), where the measurements for the whole period are summated.

The cyclic operation of the instrument is ensured by a controlling system based on the commutator decatron L_9. Electric pulses with a frequency of 1 or 0.5 cps, with the function of time markers, are obtained from closure of the corresponding contacts (KM_{1-2}) by a small synchronous motor. They are activated by the tumbler switch BK, which simultaneously connects the corresponding capacitors to the anode-grid circuit of tube L_3. In the measurement period the grid of tube L_3 is under a negative potential created by the fall in voltage on the cathode resistor R_{24}.

Department of Pharmacology, First Leningrad Medical Institute (Presented by Active Member of the Academy of Medical Sciences of the USSR D. A. Biryukov). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 65, No. 1, pp. 121-123, January, 1968. Original article submitted April 30, 1966.

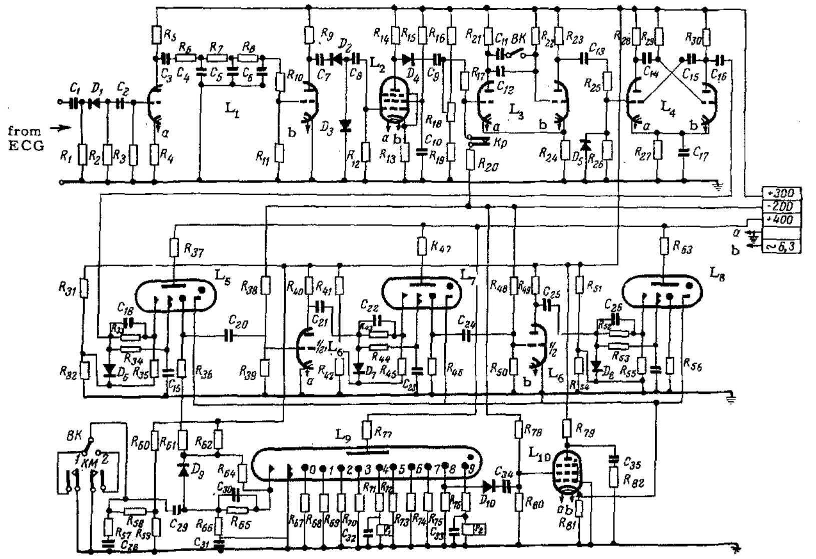

Fig. 2. Theoretical circuit of the cardiotachometer. Tubes: $L_{1,\,2,\,3,\,4,\,6}$ – 6N3P, L_2 – 6Zh1B, $L_{5,\,7,\,8}$ – OG-4, L_9 – A-102, L_{10} – TG-3 0.1/1.3. Crystal diodes: $D_{1,\,2,\,3,\,4,\,5}$ – D103, $D_{6,\,7,\,8}$ – D7Zh, $D_{9,\,10}$ – D103. Resistors: $R_{1,\,12}$ – 910 kΩ, $R_{2,\,3}$–510 kΩ, R_4–5.6 kΩ, $R_{5,39,50,77}$– 200 kΩ, $R_{6,\,7,\,8,\,10,\,35,\,55,\,64,\,65}$ – 100 kΩ, R_{11} – 300 kΩ, R_{13}–3.6 kΩ, R_{14} – 430 kΩ, $R_{15,\,26}$ – 2 MΩ, $R_{16,\,31,\,41,\,51,\,62,\,79}$ – 360 kΩ, R_{17}–68 kΩ, $R_{18,\,21,\,23,\,28}$ – 22 kΩ, $R_{19,\,33,\,34,\,43,\,44,\,52,\,53}$ – 82 kΩ, $R_{20,\,58,\,59}$ – 390 kΩ, R_{22} – 1.5 kΩ, $R_{24,\,27}$ – 10 kΩ, $R_{25,\,37,\,47,\,63}$ – 820 kΩ, R_{29} – 2.4 kΩ, R_{30} – 56 kΩ, $R_{32,\,42,\,54}$ – 47 kΩ, $R_{36,\,40,\,46,\,49,\,56}$ – 51 kΩ, $R_{38,\,48}$ – 5.1 MΩ, R_{57} – 75 Ω, R_{60} – 330 kΩ, R_{66} – 39 kΩ, $R_{67,\,68,\,69,\,70,\,72,\,73,\,74,\,75}$ – 20 kΩ, $R_{71,\,76}$ – 3.3 kΩ, R_{78} – 2.7 MΩ, R_{80} – 180 kΩ, R_{81}–690 Ω, R_{82}–100 Ω. Capacitors: $C_{1,\,2,\,3}$–0.01 μF, $C_{4,\,5,\,6,\,17,\,21,\,25,\,28,\,29}$–0.5 μF, C_7–820 pF, C_8–0.25 μF, $C_{9,\,10,\,35}$–0.5 μF, $C_{11,\,12}$–0.15 μF, $C_{13,\,14}$–1 μF, $C_{14,\,15,\,19,\,23,\,27}$–680 pF, $C_{16,\,20,\,24}$–2200 pF, $C_{18,\,22,\,26}$–1500 pF, C_{30}–510 pF, C_{31}–200 pF, $C_{32,\,33}$–0.025 μF, BK–switch for changing mode of operation; KM_{1-2}–contacts closing synchronous motor; P_1, P_2–windings of polarized relay; KP–contacts of relay.

The pulse from the anode of tube L_2, which is larger in amplitude than the negative displacement, is able at this time to trigger the multiplier unit. This occupies the period of time in which the discharge moves from the 9th to the 3rd cathode of the commutator decatron. At the moment when the next time marker arrives, when the discharge appears at the 4th cathode, the cathode current reaches one of the windings of the polarized relay (R_1) and the contacts KP are closed. As a result of this, a large negative potential reaches the grid of the left half of L_3 and it is reliably wiped out. The measurement period is ended and the period of indication begins. Opening the contacts KP and removing the negative potential from the grid of L_3 take place at the time when the current appears in the circuit of the 9th cathode, to which the second winding of the polarized relay (R_2) is connected.

One time marker ahead of this moment, on the arrival of the current in the circuit 8 of cathode L_9, the system of automatic discharge of the counter-indicator unit constructed on the thyratron L_{10} operates. This brings the cycle of work to an end and the instrument is ready for the next measurement.

The counting circuit works reliably, because the chosen frequency of infilling (1000 cps) is much below the limit of resolving power of the counting decatrons of type OG-4 used in the circuit. Meanwhile the resolving power of counting of the instrument as a whole, with a cycle of 10 sec, is about 3000 pulses/min, and for a cycle of 20 sec, about 6000 pulses/min, which is much higher than the upper limit of possible pulse rate for any animal. With a heart rate of about 200/min, in the first mode of operation an accuracy of about ± 3% is achieved, and with the second, ± 1.5%.

LITERATURE CITED

1. V. P. Lebedev and M. A. Sokolov, Fiziol. Zh. SSR, No. 7, 889 (1963).
2. V. P. Lebedev, A. G. Lazarevich, and M. A. Sokolov, Radio, No. 11, 54 (1964).
3. W. E. Boyd et al., Electron. Engng., 1954, v. 26, p. 330.
4. L. D. Kitchen, Ibid., v. 31, p. 44 (1959).