A TRANSISTOR DEVICE FOR REMOTE RECORDING OF HEART RATE, RESPIRATION, AND MOVEMENTS

R. V. Unzhin and V. V. Rozenblat

Laboratory of Functional Diagnosis (Director, Candidate of Medical Sciences V. V. Rozenblat), Scientific Research Institute of Workers' Welfare and Industrial Disease (Director, Candidate of Biological Sciences V. A. Mikhailov), and Laboratory of Medical Radio-electronics (Head, A. D. Vorob'ev), Sverdlovsk Medical and Physical Culture Center
(Presented by Active Member AMN SSSR, V. V. Parin)
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 57, No. 2, pp. 117-120, February, 1964
Original article submitted January 19, 1962

By now several trends have developed in the application of biotelemetry to physiology [1, 5, 6, 11], and they include dynamic biotelemetry, whereby investigations may be made of a man moving freely under natural conditions of labor, sport, etc.

For many years we have been developing an apparatus for dynamic biotelemetry for application to the physiological problems involved in labor and sport. Previously we have described the radiopulsophone [4, 5, 7], the transistor radiopneumograph [10], and the contact radiopneumometer [3]. We have now perfected a single channel system which will enable any of three kinds of information to be recorded according to the sensitive element included. The transmitter is a combined radiotelemetric device (CRD). Here we describe a portable transmitting instrument ("patient's instrument") type CRD-3 .

The receiving and recording portion ("operator's instrument") remains practically the same as in previous models, and will be described very briefly.

The "patient's device" satisfies the following requirements.

1. It is a single-channel unit in which the heart rate (principal indication) is recorded in terms of the R wave which is led off from special fluid sucker-electrodes, which we had developed previously for the radiopulsphone [5, 8]; the pneumogram is recorded by means of a carbon-granule element fixed on a belt surrounding the thorax, a unit developed by us previously for the radiopneumograph; it resembles the sensing device of V. E. Busygin [2]; information concerning other indices is obtained by closing of a contact (for example a breathing mask with a contact valve, a contact device for counting the number of movements and the duration of their phases, etc.).

2. The instrument has been made entirely from transistors and miniature components; it weighs 120 g.

3. Power supply is obtained from seven miniature alkaline storage cells type D006 which maintain continuous operation for three hours.

4. For convenience in use controls have been eliminated completely except for a two-pin plug for connection of the power supply. For the same reasons we have incorporated the sound signal which enables discrete events (for example, heart rate, frequency of movements as signalled by closing of a contact) to be heard and measured with a stop watch.

5. When a receiver having a sensitivity of 3-5 μV and a simple stub aerial is used, for graphic recording the direct uninterrupted range is better than 30 m, and for the auditory signal the range is not less than 100 m. For operation at greater ranges provision is made for connection to an external transmitter.

6. The apparatus is adapted for manufacture (no great amount of labor is involved in its assembly, and its characteristics are not greatly dependent upon the transistor characteristics).

The principal components of the CRD-3 unit (Fig. 1, 2) are the amplifier, multivibrator, and radiotransmitter; they have a common power supply.

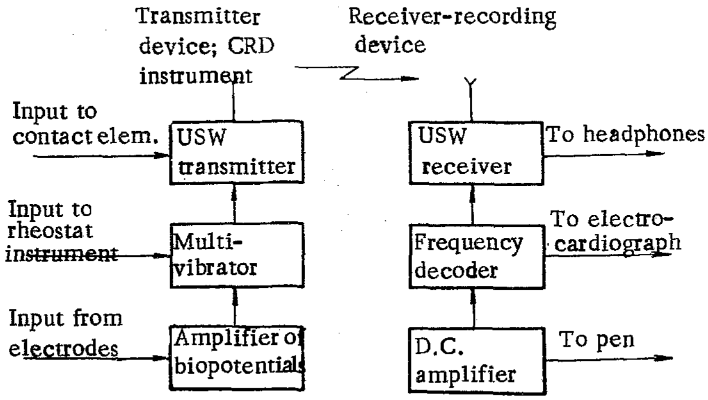


Fig. 1. System of dynamic biotelemetry based on a combined radiotelemetric instrument type CRD. Block diagram.

The amplifier has three-balanced stages incorporating P-13 transistors. As compared with other transistor amplifiers [12, 13, 14] the special features are the elimination in the first stage of the emitter repeater (some increase of the input resistance to match the interelectrode resistance of the patient is achieved by use of a 6.8 kΩ resistance in the base of the first-stage triode), and satisfactory operation is given without use of a third electrode on the subject. At a frequency of 20 cps the amplification factor is 400-600. The frequency characteristic of the amplifier in conjunction with the input filter and the values of the coupling capacitors selected results in preferential amplification of the R wave of the electrocardiogram, and less amplification of the high-frequency components from the muscles and the low-frequency components from other parts of the electrocardiogram (T and P waves). The result is a stable recording of the cardiac contractions under conditions of vigorous muscular activity.

The amplified R-wave signal is fed to a multivibrator built of P-14 transistors, and modulates its frequency. The frequency is in the audio range, varying between 500 and 3,000 cps according to the model; V. M. Forshtadt has worked out a modified circuit, the CRD-2 device (Fig. 3), in which the multivibrator is arranged as a trigger circuit (amplified R waves cause either onset or cessation of oscillation). Choice of continuous oscillation or various trigger arrangements may be selected by potentiometer R_{15}.

The rheostat element of the pneumogram is connected directly to the multivibrator and also modulates the frequency. The contact may be included in place of the rheostat, in which case closing or opening cause alterations in the multivibrator frequency; alternatively, it may be connected so as to break the supply to the transmitter (opening the contacts switches off the transmitter, closing of the contacts switches it on). We have used a face mask with a valve contact [3]. and a contact pedometer (developed together with G. L. Karmanov).

The transmitter consisted of a two-stage circuit with self-excitation assembled out of P-403 transistors operating at a frequency of 39 Mcps.* The transmitter is amplitude-modulated by the multivibrator.

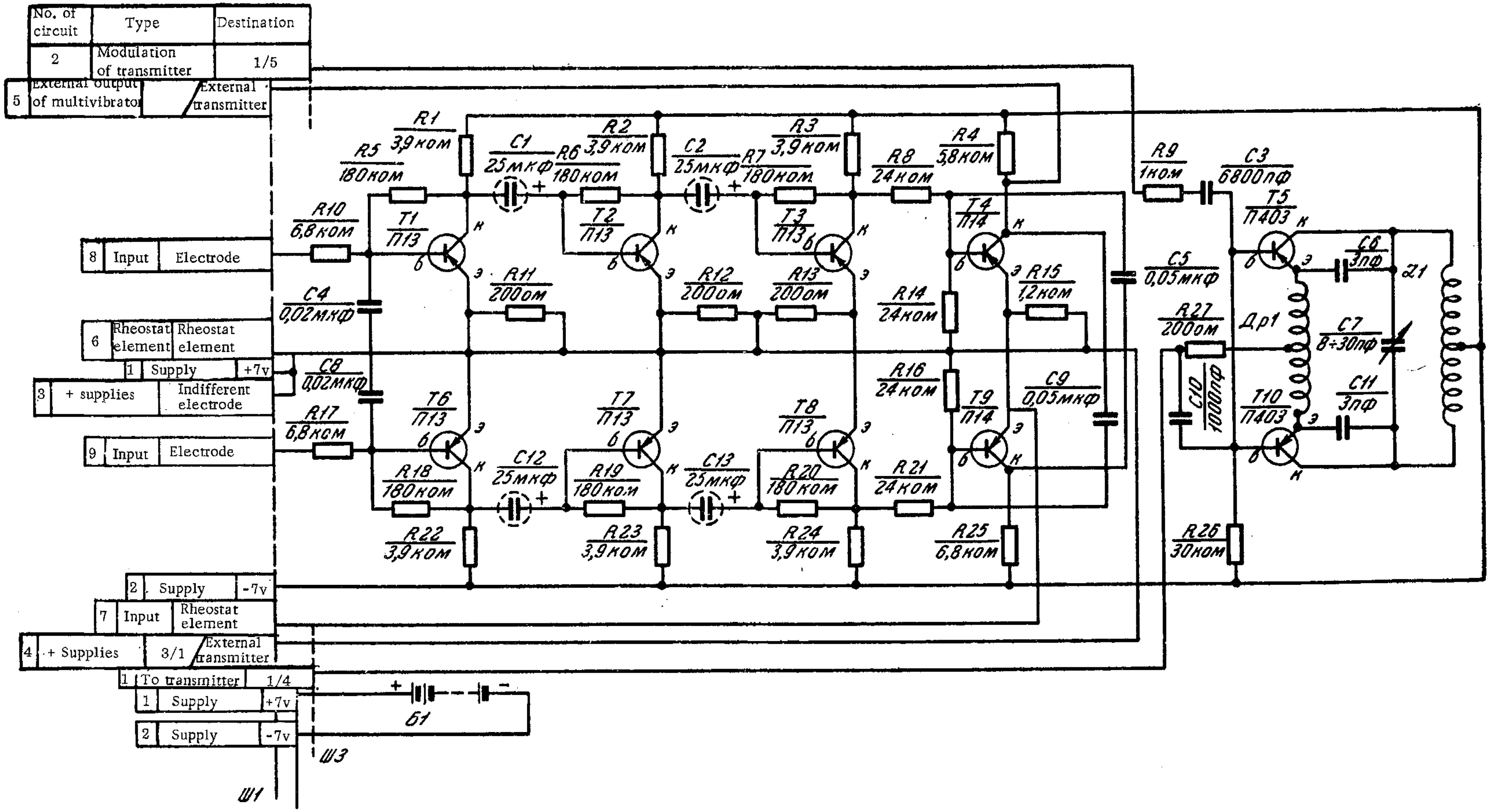
We thus use a FM-AM frequency for transmission of the information, i.e., the carrier frequency generated by the multivibrator and lying in the audio range is frequency-modulated, while the ultra short carrier wave is amplitude-modulated.

The function of the aerial is performed by a coil fixed in the outer part of the device just beneath the case.

Provision is made for connection of the three sensitive elements described. Contacts are also provided from the internal storage cells for charging and for connection to a plug; (when necessary an external power supply may be used and the internal storage cells disconnected). Also a special connection is available for the transmitter (power supply and modulation signal), so that if necessary the transmitter may be switched off and the carrier frequency oscillations may be taken to the modulator of an external, more powerful transmitter.

To avoid interference when the apparatus is severely shaken all the contacts are spring-loaded. In the first stages of the work we used screw connections, and the plugs as a rule made two connections, one with a pin and the other with a socket so as to avoid the possibility of misconnection.

* At the present time frequencies of 39 and 145 Mcps are used in the USSR for medical radiotelemetry.



Some of the following Russian abbreviations may be found in the figure: $Л$ = tube, $Д$ = diode, $Тр$ = transformer, $Др$ or $др$ = choke, $Вк$ = switch, $в$ = V, $М$ = MΩ, $к$ = kΩ, $мк$ = μF or μH, $п$ = pF or pH, and $н$ = nF or nH.

Fig. 2. Distinguishing instrument type CRD-2.

The instrument was housed in a plastic case 1 mm thick; it measured 110 × 70 × 25 mm.

The receiving and recording unit ("investigator's apparatus") included (see Fig. 1): 1) USW short-wave amplitude-modulated signals covering the band from 38 to 40 Mcps; 2) headphones for listening; 3) a decoder in the form of a diode-capacitor frequency meter; 4) a heart-rate recorder (an electrocardiograph connected to the output of the frequency meter); 5) a pneumogram recorder (a dc amplifier and recording unit, type N-370).

It must be emphasized that such an elementary transmitting system consisting of a single-stage AM transmitter with self-excitation cannot give impeccable stability for the graphic recording of biological potentials or other functions because of the impossibility of screening the transmitter from the action of the surrounding mass present in biotelemetry (and the frequency may therefore change); the receiver-recorder apparatus must be accurately constructed, which makes the work difficult for the nonspecialist. We think the device is completely efficient first of all for recording pulse and respiration rates via the headphones, so that the physiologist or medical man may easily gather extensive material. For these purposes the use of a portable super-regenerative receiver based on transistors is fully justified; É. I. Rimskikh developed the receiver for us.

The CRD-3 apparatus has been successfully used for radio telemetric observations in the physiology of labor and sport.

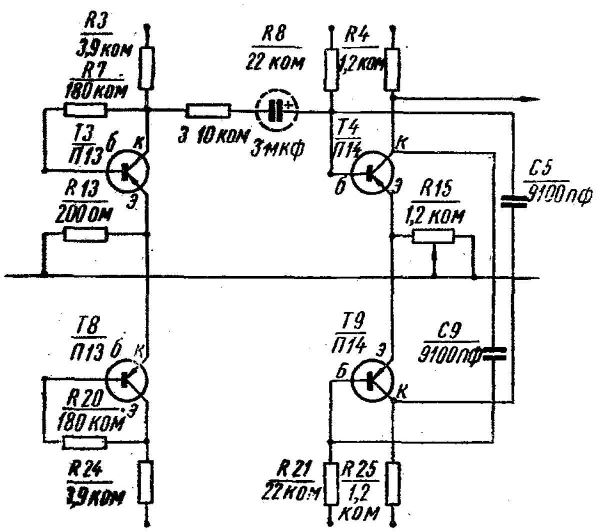


Fig. 3. Another arrangement of the circuit for unsymmetrical connection of the amplifier to the multivibrator (portion of the circuit, distinguishing instrument type CRD-2).

For stable graphical recording we have developed frequency-modulation transmitters and receivers which will be described separately.

We think that the production which has been undertaken of the first industrial instrument for dynamic biotelemetry in physiology – the tele-electrocardiograph VNII MIiO [8] will lead to the rapid introduction of radiotelemetry in scientific investigations, and will lead to a demand for the development of new miniature instruments. One such instrument is the transistor device described here.

SUMMARY

A description is given of a single-channel transistorized instrument, type CRD-3; it provides for separate radio recording of various physiological quantities, according to the sensitive elements used. Records which may be made from an individual moving freely include: heart rate (from the R wave of the electrocardiograph led off from the skin of the chest) pneumogram of the chest (by means of a rheostat element), the frequency and duration of the different phases of the respiratory movements (recorded through the closing of contacts). The instrument includes an amplifier, a multivibrator, and a transmitter all powered from miniature storage cells. We have demonstrated the usefulness of multipurpose instruments allowing transmission of different sorts of information over a single channel.

LITERATURE CITED

1. R. M. Baevskii, Foreign Radioelectronics (1961), 1, p. 82.
2. V. E. Busygin, Byull. éksper. biol. (1955), 6, p. 71.
3. B. A. Katsnel'son, B. D. Kedrov, and V. V. Rozenblat, Gig. i san. (1961), 11, p. 61.
4. V. V. Rozenblat and L. S. Dombrovskii, Contributions to the 2nd Scientific and Practical Conference on Problems of Medical Control and Therapeutic Physical Culture, Sverdlovsk (1957), p. 112.
5. V. V. Rozenblat and L. S. Dombrovskii, Fiziol. zh. SSSR (1959), 6, p.718.
6. V. V. Rozenblat, Contributions to the 3rd (Zonal) Scientific and Practical Conference on Medical Control and Therapeutic Physical Culture (1959), 2, p. 73.
7. V. V. Rozenblat, Problems of Fatigue [in Russian], Moscow (1961), V. V. Rozenblat and A. T. Vorob'ev, Byull. éksper. biol. (1961), 10, p. 119.

8. T. E. Timofeeva and V. A. Antselevich, Novsti med. tekhniki (1960), 3, p. 27.
9. R. V. Unzhin and V. V. Rozenblat, Contributions to the 3rd (Zonal) Scientific and Practical Conference on Medical Control and Therapeutic Physical Culture, Sverdlovsk (1959), 2, p. 102.
10. L. P. Shuvatov, Miniature Apparatus for Recording Certain Physiological Functions by Radio [in Russian], Moscow (1959).
11. H. G. Beenken and F. L. Dunn, IRE Trans. med. Electronics (1958), 12, p. 53.
12. E. F. Macnichol and T. Bicart, IRE Trans. med. Electronics (1958), 10, p. 15.
13. L. Molyneux, Electron. Eng. (1957), 3, p. 125.

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.