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TECHNICAL CONTRIBUTION

AN IMPROVED METHOD FOR MEASURING THE GALVANIC SKIN RESPONSE IN SLEEP EXPERIMENTS

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The direct current Wheatstone bridge has for many years been the most popular method for measuring galvanic skin response (GSR) It combines the major advantages of simplicity, accuracy and reliability, but has the fundamental drawback that, in contrast to a c techniques (see, for example, Strong 1970), it allows no distinction to be made between the relative magnitudes of basal skin potential (E) and the skin resistance itself (R) In the context of sleep experiments, however, this shortcoming cannot be ignored because measurements with a c are not compatible with the recording of EEGs

Employing the simple arrangement of Fig 1 for long-term measurements is further complicated by another phenomenon. The conductivity of the skin and the endosomatic voltage are never steady The reason for this lies partly in body movements and partly in slow changes in R and E during the night, as described by Hawkins *et al* 1962, Niimi *et al* 1967, Tart 1967, Koumans *et al* 1968, Craig *et al* 1969 and Bell 1970 This drift, which can exceed the skin response signal by as much as an order of magnitude, means that the bridge has to be frequently calibrated Assuming a typical interval of 10 min after which the bridge has to be rebalanced by adjusting the potentiometer P, it is evident that automatic calibration would facilitate the measurement of GSR in sleep experiments Because the control process is exactly reproducible and takes place at constant intervals, automatic means also make it possible to monitor the behaviour of the drift

A proven circuit is discussed in detail in the following

THE BASIC PRINCIPLE

The principle of the automatic system is illustrated in general terms by the block diagram of Fig 2 For much the greater part of the time the equipment functions as a pure measuring bridge such as shown in Fig 1 Switches Re 1 and Re 2 are open The stepping motor, which here serves to drive the calibrating potentiometer P, does not operate After a pre-set interval, *e g* , 8 min, has elapsed the time marker emits a pulse This starts the program switching device, which first closes Re 1 The variations of potential between A and B caused by GSRs are attenuated by the smoothing capacitor During this phase the recorder shows the mean signal value which, because of drift, is generally not in the centre of the scale of deflection The purpose of the automatic system is to bring the baseline back to the centre, in other words to vary P in such a way that the bridge is balanced To achieve this, Re 2 is closed If the difference in potential between B and C

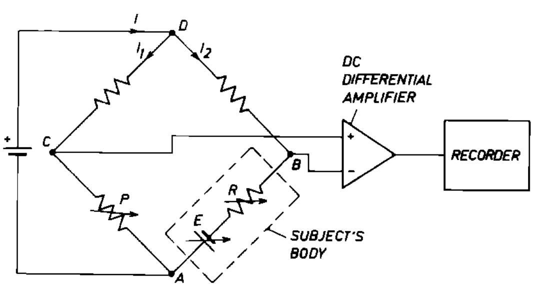

Fig 1 The general d.c bridge method as normally used for measuring galvanic skin response in sleep experiments Since the quantities R and E, apart from skin responses, are never steady the bridge has to be frequently recalibrated This is achieved by manually adjusting P

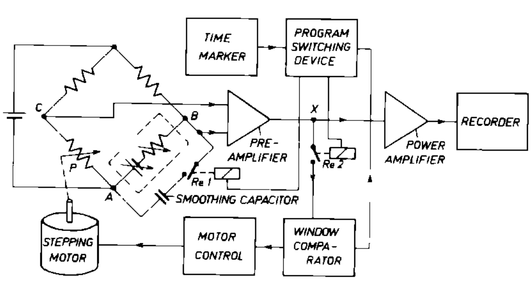

Fig 2 Block diagram of the improved bridge method Potentiometer P is automatically calibrated at pre-set intervals, making measurement much easier Further advantages of this arrangement compared with that of Fig 1 are the reproducibility and that in practice balancing is more accurate

is not sufficiently small, a persistent voltage passes from output X of the pre-amplifier to the window comparator This, via the motor control unit, starts the stepping motor turning in the appropriate direction so that the voltage difference between B and C decreases This regulation process continues until the voltage at point X lies within a tolerance about the zero point As soon as this is achieved, the window comparator returns the program switch to its original position, Re 2 and Re 1 drop back and the bridge operates as before The entire control process normally lasts a few seconds

DESCRIPTION OF FULL CIRCUIT DIAGRAM

We have fitted the control circuit, including the bridge, into the coupler housing of a Beckman type R Dynograph recorder The pre-amplifier, power amplifier and recorder are basic parts of the equipment A compact construction was made possible through extensive use of integrated circuits, as can be seen in Fig 4

The circuit is shown in detail in Fig 3 The arrangement of the functional units corresponds roughly to that in the block diagram of Fig 2 The subject is connected to the bridge circuit by plug P 1, the smoothing capacitor of 1 μF being connected in parallel with the subject if only Re 1 is closed The value of 1 μF was determined empirically On the one hand, the capacitance should be as high as possible in order to smooth the GSRs well, while on the other it must not be too high in order to keep the control process as short as possible For Re 2 must not pull in until the smoothing capacitor has become charged up to the mean voltage across the subject The output of the measuring bridge passes to P 2, the plug connector to the Beckman pre-amplifier The output X of this can also be tapped at P 2 However, the signal is too small and the output impedance too high to allow the Motorola differential comparator MC 1710 C to be driven direct An operational amplifier MC 1741 C is therefore inserted to act as amplifier and impedance transformer The tolerance of the comparator can be adapted to requirements by making small modifications to resistance network N The Dual JK flipflop MC 853 P controls the Philips stepping motor type AU 5053 by way of transistors T 1, the motor being connected to the 10-turn 100 kΩ potentiometer through a 1 10 reduction and a rubber coupling The speed of the stepping motor is determined by the frequency of a unijunction oscillator T 3, T 1 The clock of the system is at top left of the diagram A unijunction oscillator emits pulses at 2 c/min which are binarily reduced by a train of Raytheon JK flipflops RC 251 G The interval between calibrations can be chosen between 1 and 64 min by means of a selector switch In addition, the automatic control procedure can be initiated at any time with button S 3

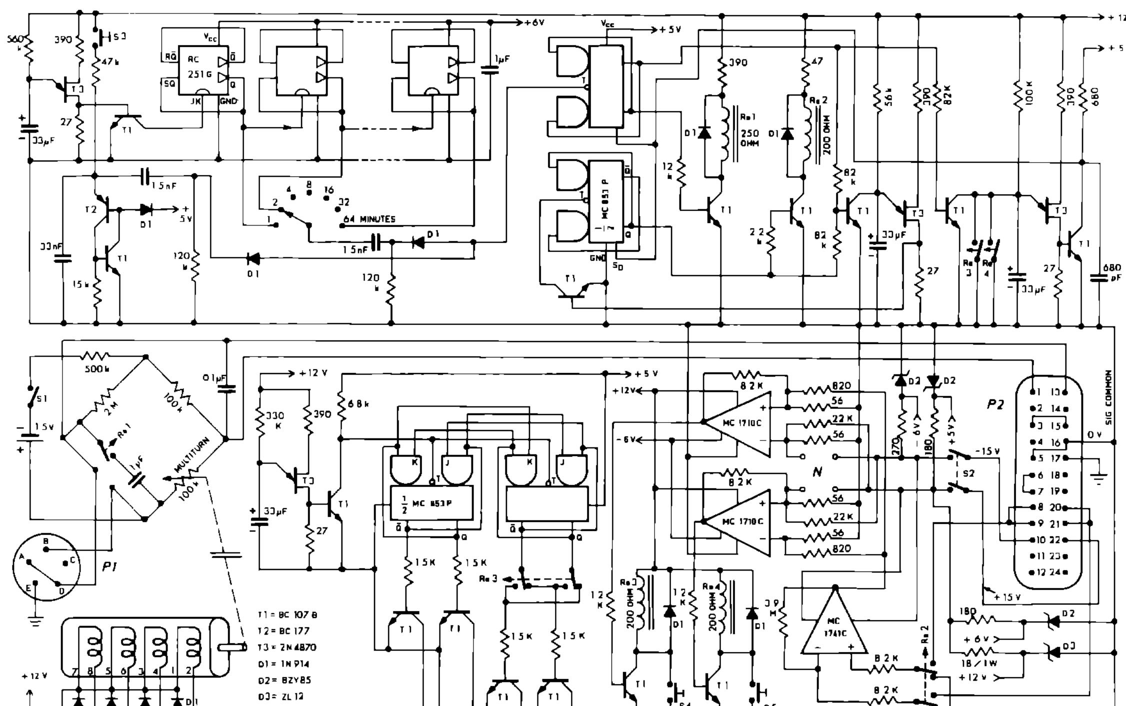

Fig 3 The full circuit diagram of the automatically balancing Wheatstone bridge of Fig 2 The system shown is the first element, termed the coupler, of a Beckman type R Dynograph recorder The skin electrodes are connected at plug P 1 and P2 leads to the Beckman pre-amplifier

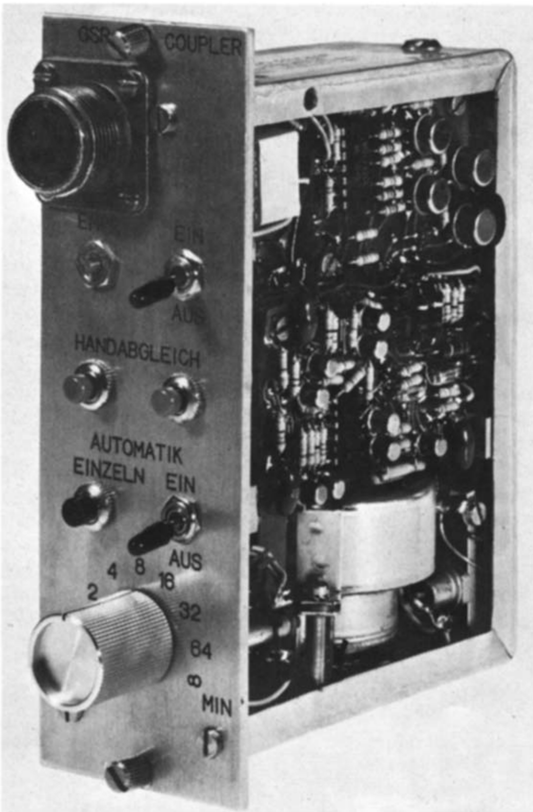

Fig 4 The complete unit Compact construction and extensive use of integrated circuits allow all the parts shown schematically in Fig 3 to be fitted in a small Beckman coupler housing At top left can be seen the plug P 1, while at the rear end is P 2, the 24-pole plug connector to the rest of the equipment The system has been in use for one year and has performed well

A Dual JK flipflop MC 853 P and two unijunction pulse-retarders form the program switching device, the purpose of which is to ensure the correct sequence of the control process The automatic system can be switched off with S 2 The bridge can also be balanced manually by means of buttons S 4 and S 5, which act direct on the motor control unit

SUMMARY

An improvement on the traditional direct current method of measuring galvanic skin response is reported The drift of electrical conditions in the subject during the course of sleep experiments necessitates frequent and inconvenient adjustment of the bridge A proven circuit which carries out this procedure automatically is presented in detail

RESUME

UNE METHODE AMELIOREE POUR MESURE DE LA REPONSE GALVANIQUE DE LA PEAU PENDANT LE SOMMEIL

Cet exposé montre comment on peut améliorer la méthode du pont à courant continu classique pour mesure de la réponse galvanique de la peau La variation des conditions électriques dans la personne soumise à l'essai pendant le sommeil exige un rééquilibrage fréquent et pénible du pont Un montage éprouvé est décrit en détail, lequel effectue ce processus automatiquement

I wish to express my gratitude to Prof C A Meier, M D for his constant interest and help

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