An Amplifier for Fetal Electrocardiography

J. D. Sherwood, B.Sc. in Engineering Physics
Department of Physiology and Biophysics, Dalhousie University, Halifax, Nova Scotia

An amplifier is described which uses several novel techniques to reduce noise and interference during recordings of fetal ECG from the mother's abdomen. Emphasis in the design has been placed on patient safety.

The preamplifier section is powered by rechargeable batteries and isolated from the main unit by GaAs photo-diode pairs. FET-input amplifiers reduce electrode artifacts by increasing input impedance and reducing bias current. A voltage clamp is used to simulate a differential input, resulting in a high common-mode rejection ratio and a simplification of circuitry.

At present the interpretation of the fetal electrocardiogram is hampered by poor signals and high noise content. Special electrode designs have resulted in acceptable recordings, but only under special conditions (1). Recordings of the FECG under normal circumstances leave much to be desired.

The amplifier described here had two design goals:

1. to provide maximum patient safety
2. to hold noise to as low a level as possible

In order to further both these ends the amplifier is divided into two parts, one line powered and the other powered by rechargeable nickle-cadmium batteries, coupled by gallium-arsinide photo-diode pairs. The battery powered section is completely isolated from ground with a leakage resistance in the order of 10^{10} ohms and a breakdown potential in excess of 600 volts. Since this section, containing all the preamplifier stages, is isolated and battery powered, line noise is a a minimum.

The preamplifier consists of two single-ended FET input stages, a single differential input stage and a voltage clamp.

The design criteria for the single-ended input stages were high input impedance and low bias current. A high bias current causes anamolus changes in the input potential if the electrode-skin impedance should vary. Since the skin on the mother's abdomen is subject to large stresses during the contractions of labour, the impedance changes can be quite drastic if the electrodes are not applied with more care than can reasonably be expected in routine clinical practice; thus the bias current must be kept low, preferably below 1 na. A high input impedance is desirable in order to prevent loading the electrodes, although this is not as essential in this design as for a differential input amplifier. Both these criteria are met with a field-effect transistor input stage, at the expense of a small increase in amplifier noise over that obtainable with bipolar transistors. It was felt, however, that the increase in noise would be more than offset by the decreased sensivity to electrode artifacts. Input impedance is further increased by driving the shield of the input cable to a potential equal to that of the center conductor. This decreases the capacitive loading on the electrodes by long lengths of cable.

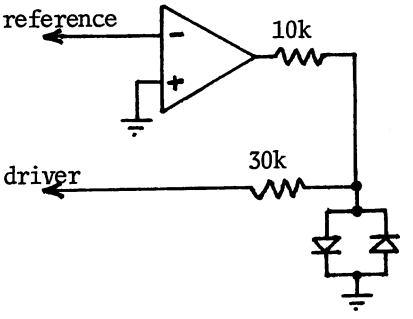

figure 1. Voltage clamp.

The voltage clamp circuit is used to simulate a differential input to the various amplifiers. A high gain, FET-input, inverting amplifier is connected to the subject as in fig. 1. Any tendency for the potential at the reference electrode to vary from ground is counteracted by the output of the amplifier feeding into the driving electrode. Since "ground" here refers to the ground of the isolated battery powered section, and since only the driving electrode is capable of passing current, and since the output of the amplifier is limited to 30μa, there is no possibility of shock-hazard from this configuration. It offers the advantage that all amplifiers can be designed single-ended, thus eliminating the necessity of trying to balance out common-mode signals.

A single differential input amplifier is used to obtain a signal containing only maternal ECG (standard lead I) by recording from points distant from the fetus. This signal is used during computer processing in anti-coincidence logic to eliminate the influence of maternal ECG from the fetal signals.

A multivibrator using a zener diode reference provides a 200μV calibration signal to the input of each of the amplifiers.

The line powered section of the amplifier contains receivers for the photo-diode pair and line drivers. A charging circuit for the batteries is also provided. Before this charger can be connected to the batteries, the patient cable must be disconnected from the amplifier. Thus the subject is not hooked up during the only time when the preamplifier section has any con-

nection with line voltages.

A typical recording is shown in fig. 2. The FECG (negative spikes) are quite prominent. The main interference can be seen to come from the mother's ECG (positive spikes) and low frequency baseline noise. Processing techniques such as averaging and the anti-coincidence logic mentioned above can be used to eliminate each of these to give a clean FECG.

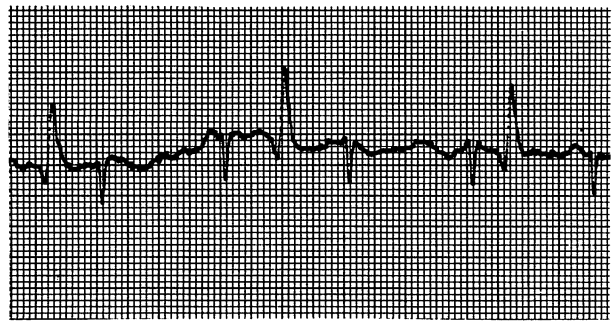

figure 2. A typical signal showing mixed fetal and maternal ECG complexes.

Bibliography

1. Hon, E. H. "A Fetal Electrocardiographic Electrode". The Yale Journal of Biology and Medicine, V. 39, no. 1, August, 1966.

The author would like to thank Dr. H. K. Wolf for his assistance both in the design of this instrument and the preparation of this manuscript.