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Intrauterine monitor telephone system* †

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A low-cost custom-designed data system using a standard switched telephone line is used to transmit intrauterine physiologic data obtained during human labor.

The purpose of continuous electronic monitoring of fetal heart rate is to determine its relationship to intrauterine pressure during labor. Measures are obtained following rupture of the fetal membranes when a fetal scalp electrode and an intrauterine catheter are introduced through the dilated cervix. The variations in fetal heart frequency, along with changes in uterine pressure, are graphically recorded. During a contraction, the relationship of time form and amplitude of the contraction to the fetal heart-rate variations may be an indicator of the fetal condition. For example, when the fetus is not disturbed by uterine contractions or body movements, fetal heart rate decelerations which are maintained after contractions may be an early warning of fetal distress. These measures provide adjunctive indices on which to base appropriate management decisions. The continuous and simultaneous recording of the fetal electroencephalogram to determine drug effect on the fetal brain (Peltzman, Goldstein, & Battagin, 1973a, b) using fetal scalp bipolar screw electrodes (Peltzman, Goldstein, Battagin, & Markevitch, 1973) is currently considered to be a research tool, but one which holds promise as another useful adjunct to clinical decision making. The goal is to reduce perinatal mortality, improve the quality of survivors, and provide a basis for early management of newborn brain damage (Myers, 1972).

For an adequate understanding of the physiologic basis of fetal monitoring, the attending obstetrical staff and researchers require special training and extended clinical experience in interpreting the relationships among the recorded events. Practitioners and community hospital staff cannot be expected to read volumes of research literature.

On the basis of rising malpractice claims and litigation, practitioners and medical academicians should have the mutual opportunity for training for the conduct of clinical fetal monitoring studies and immediate consultation on a case before the information is outdated and useless. The critical practitioner or community hospital obstetrical staff member should be able to form his own opinion of available records, and he should be able to understand the research worker's interpretation. In response to these needs, a custom-configured data transmission and receiving system consisting of a set of modems (modulator-demodulator), linked between Mercy Hospital, Redding, California, and San Francisco General Hospital, was designed.

DATA ACQUISITION AND TRANSMISSION: MERCY HOSPITAL

Major components of our data acquisition equipment include a fetal monitor system (Corometrics, FMS-101) for obtaining fetal heart rate (FHR) and intrauterine pressure (IUP), and a low-noise, high-gain, differential amplifier (Data, Inc., 1124) with series diode input for patient protection, which is connected to a strip-chart recorder (Gilson, M4P) that provides an ongoing graphic record of the fetal electroencephalogram (FEEG). The differential amplifier high and low 3-dB cutoffs are set at 30 and 1 Hz, respectively. A second strip-chart recorder channel is used as an event marker with a manually initiated dc voltage to denote periods of observations (calibrations, fetal or maternal changes, or clinical manipulations) during monitoring of labor (Fig. 1).

The data transmission modem, with appropriate signal conditioning, transmits the physiologic data acquired during labor via standard, switched, voice-grade telephone lines to San Francisco General Hospital. The modem is basically composed of a set of four voltage-controlled oscillators (VCO) with center frequencies set to fall within the telephone passband. Active filters attenuate high-frequency interference at the model input and the harmonics generated by the VCOs. The VCOs are inputted to a multiplexing amplifier, which, in turn, is inductively coupled to the telephone line. Efforts to acoustically couple the modem to the telephone line were unsuccessful due to harmonics induced in the modem output transducer, telephone handset, and coupler device.

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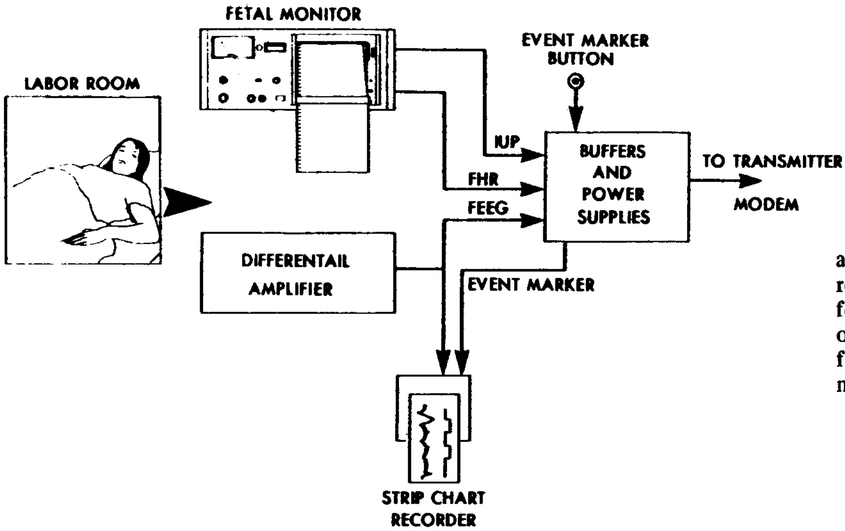

Fig. 1. Schematic illustration of data acquisition equipment located in labor room, Mercy Hospital. Graphic records of fetal heart rate and intrauterine pressure obtained with fetal monitor and amplified fetal electroencephalogram and event markers displayed on strip-chart recorder.

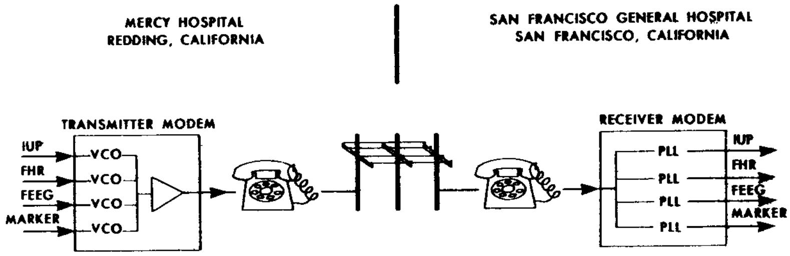

Fig. 2. Schematic illustration of telephone data transmission and receiving system which connects Mercy Hospital to San Francisco General Hospital. Four channels of physiologic data include intrauterine pressure (IUP), fetal heart rate (FHR), fetal electroencephalograph (FEEG), and event markers.

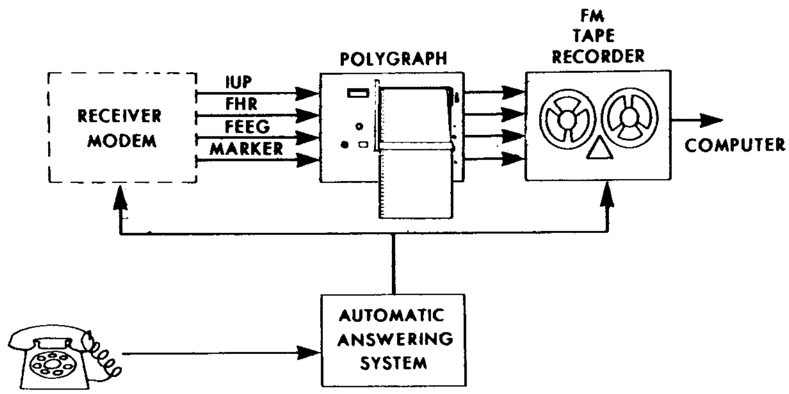

Fig. 3. Schematic illustration of receiving terminal at San Francisco General Hospital. Physiologic data is displayed graphically and stored on magnetic tape for subsequent computer analysis.

DATA RECEIVING AND STORAGE: SAN FRANCISCO GENERAL HOSPITAL

At the receiving terminal, the demodulating modem is similarly inductively coupled to the telephone line. The signal, composed of four frequency-modulated tones, is passed through a series of active filters to discriminate between tones and then through four phase-locked loops (PLL) to recover the original voltages generated at the transmitting station. The overall transmitting-receiver system has a dc to 27-Hz response range, down 3 dB at 27 Hz referred to dc, a 40-dB signal-to-noise ratio, and low drift following initial warm-up. Linearity is 1% or better (Fig. 2).

To receive data, San Francisco General Hospital contains a specially constructed automatic answering device. This unit detects a ringing voltage on the telephone line, and, after a predetermined number of rings, outputs are transferred to end devices, which include a four-channel polygraph (Grass Instruments, P7) and an FM tape recorder (Ampex, FR-100B) (Fig. 3) for subsequent data analysis by a computer. Transmission instructions are to dial the receiving station, wait for the phone to stop ringing, turn on the transmitting modem (automatically coupling it to the line), and hang up the handset. The final telephone ring interconnects the modem coupling inductor to the line, thereby effectively "answering" the phone and rendering the system ready to accept data. The two modems are thus in direct communication without acoustic couplers, and the telephone handsets are in the cradles to prevent environmental noise from contaminating the data.

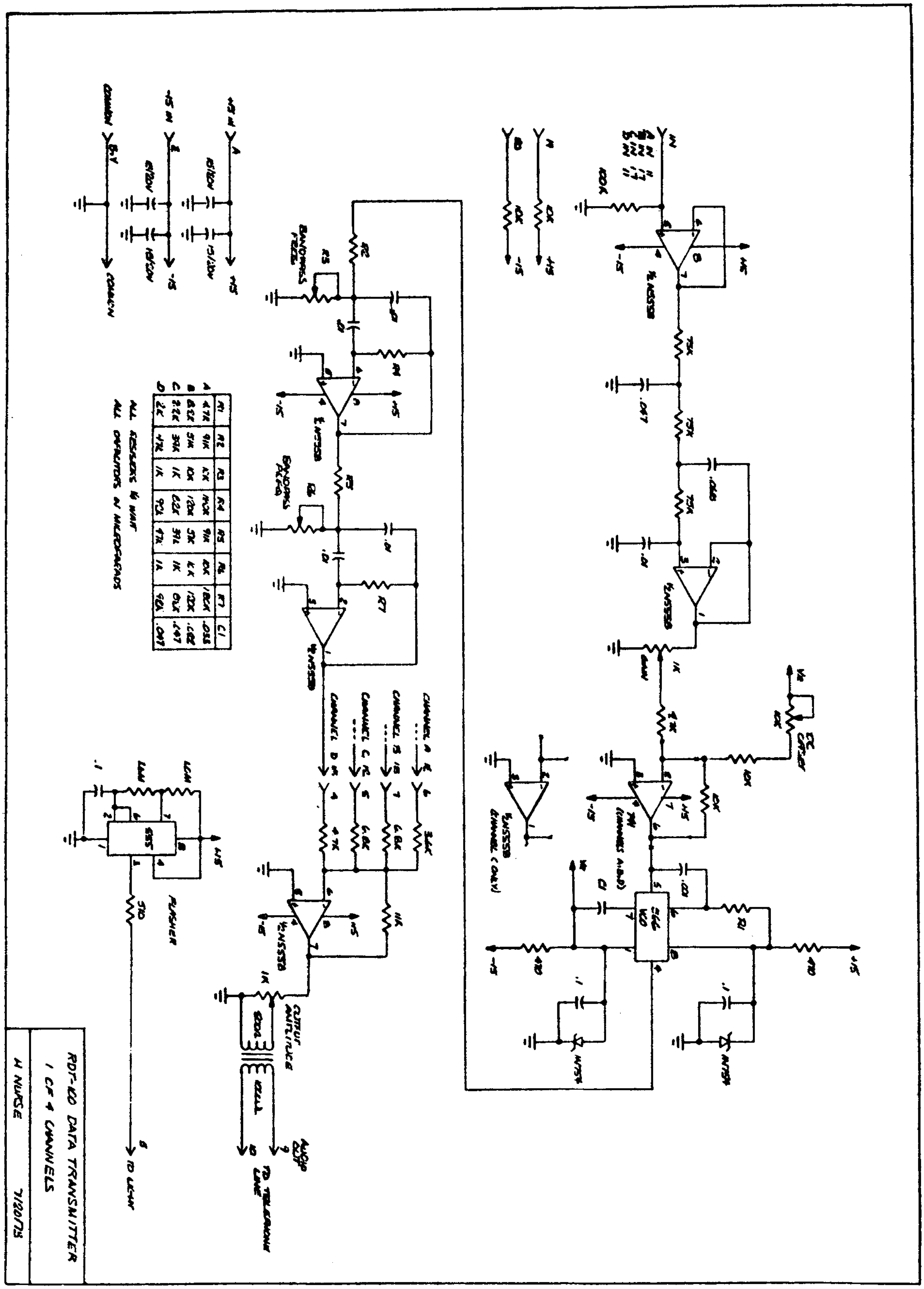

Fig. 4. Schematic diagram of transmitter modem (one of four channels).

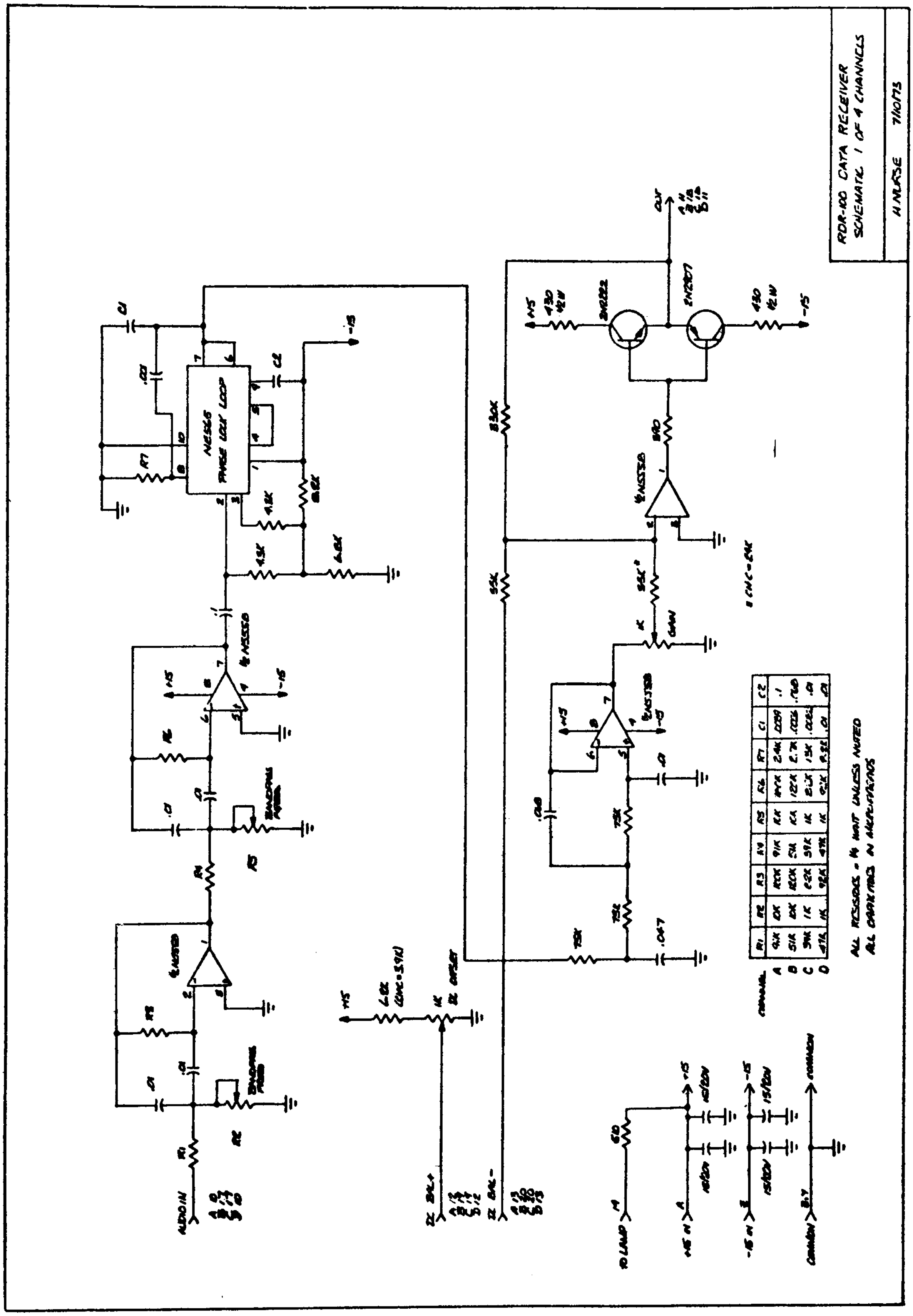

Fig. 5. Schematic diagram of receiver modem (one of four channels).

Interfacing buffer amplifiers provide proper amplification and dc offsets.

Data transmission may be terminated by any one of several alternate methods. Should the transmitting modem be switched off manually, a tone detector at the receiving station, failing to receive the transmitter's communicating tones, will automatically turn off the receiving and storage equipment and automatically reset the system to accept another call. Also, personnel at the receiving station may switch the system off by manually activating a reset switch. The final option involves a 0-5-h timer, which will automatically reset the system after a predetermined time interval has elapsed should other methods not be utilized. Provision exists to bypass the timer for extended periods of data transmission. The cost to produce the transmission-receiver system and timer is less than $400. The transmitter and receiver modems contain some common circuitry. The low-pass filters, bandpass filters, and power supplies are identical in both units. Figures 4 and 5 are schematic diagrams of the transmitter and receiver modems, respectively.

A regular telephone line located at the transmitting and receiving stations allows personnel to converse and take appropriate action, if required, during data transmission.

In work of this kind, the eye must be trained to pick out the characteristic patterns and features which are of diagnostic significance. The prime benefit of the telephone transmission system at this time is that it allows the consultant at the receiving station an instantaneous visual impression of the signals, which is often a better key to understanding of biologic phenomena than a verbal explanation. It is conceivable that the transmission could be linked "on-line" to a computer for alarm surveillance.

The analog data transmitter-receiver system is ideally suited for communicating low-frequency data such as physiologic events, remote meter outputs, or a variety of transducer signals. The internal circuitry can be adjusted to accept either bipolar or unipolar input signals with peak-to-peak amplitudes ranging from 2 to 10 V.

Obstetric events as determined by fetal monitoring can yield indications of fetal head or brain compression which may have some direct bearing on neonatal neurological problems, and can be used in the earliest identification of aberrations in development and maturation of the infant. The experimental data imply that poor fetal oxygenation, for example, is associated with neurologic handicap later in development (Myers, 1972). The current effort, therefore, is to conduct longitudinal studies using averaged evoked auditory and visual EEG potentials (AEPs) (Peltzman, Ostwald, Yeager, & Manchester, 1970) with monitored normal infants and infants who showed fetal stress, in order to ascertain early sensory sequelae and attempt to relate these measurements to the intrauterine data. Attention is also directed toward inexpensively extending the AEP capability to places separated by an inconvenient distance from the relatively well-instrumented laboratory.

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