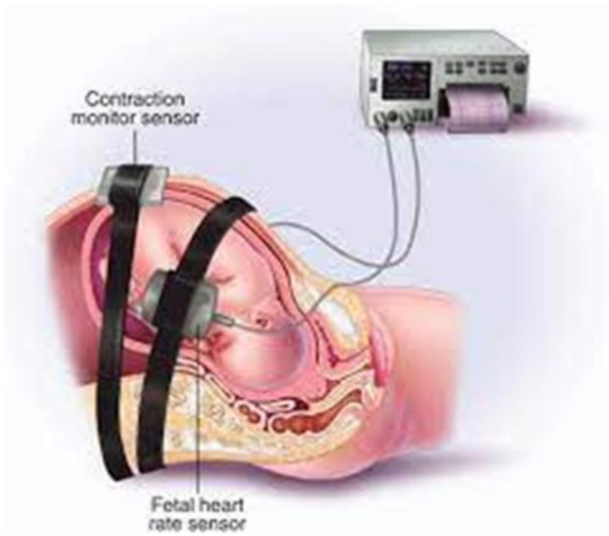
Gynecology Inst. And Ultrasonic assisting device.

Fetal Heart Rate (FHR) & Labor monitoring Devices

FHR & Labour monitoring Devices

Introduction:

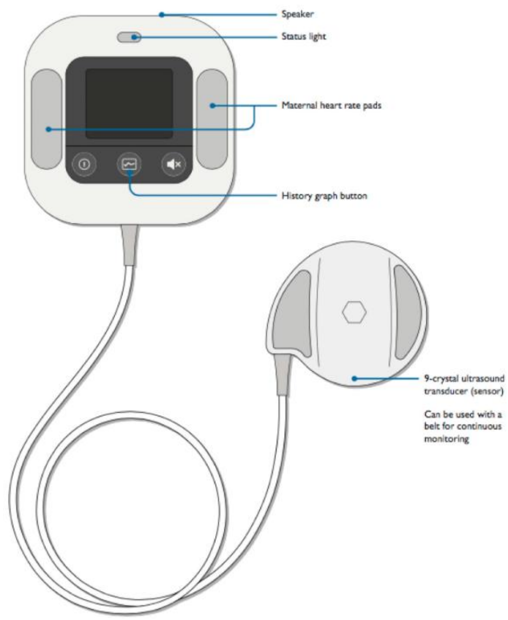
An important clinical instrument for obstetric applications which makes use of the Doppler shift principle is fetus blood flow detector. The technique is extended to derive an integrated rate of the fetus heart from blood flow signals and to display it on a suitable display system. In obstetric applications, the site of investigation varies from 5 to 20 cm below the surface of the abdomen.



This depends upon the patient and the stage of pregnancy. For obstetric studies, ultrasonic frequency of about 2 to 2.5 MHz is usually employed, whereas in the study of blood flow in arteries and superficial blood vessels frequencies around 5-10MHz is preferred. The level of ultrasonic energy transmitted into the body is generally kept between 10-15 mW/cm^2. Assuming a maximum of 50% conversion efficiency, this would mean that the transducer should be powered with an electrical energy below 30 mW/cm^2.

Fetal blood flow detector

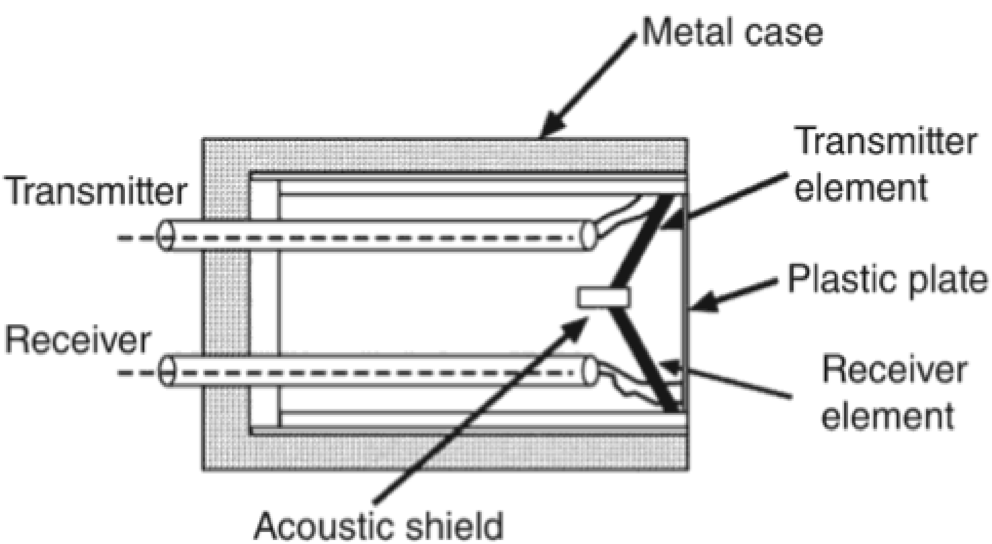
- The Doppler-shift based ultrasound fetal blood flow detectors use hand-held probes which may be either pencil-shaped or flat and contain two piezo-electric crystals.
- The probe is coupled to the patient's skin by means of an acoustic gel. This is done to exclude any air from the interface. The presence of air severely attenuates ultrasound.
- The transmitting crystal emits ultrasound (2-2.5 MHz) and the backscattered ultrasound is detected by receiving crystal. The back-scattered ultrasound frequency would be unchanged if the reflecting object is stationary.



- If the reflecting object is moving, as would be the fetal heart blood vessels, then the back scattered frequency is higher as the blood cells is approaching the probe, and lower if it is moving away from the probe. The magnitude of the frequency shift (Δf) varies according to the following formula:

$$\Delta f = (2\, f_o u \cos\ \theta) / c$$

where f_o represents the transmitted frequency, u is the blood velocity, cosθ is the cosine of the angle of the sound beam and the object's direction, and c denotes the velocity of the sound wave in the tissue.



Constructional details of an ultrasonic Doppler transducer used for fetal heart studies.

The ultrasound Doppler shift method is more practical and easier to use during labor. It is currently the most reliable method for detecting the fetal heart rate (FHR) pattern that is interpretable. Signal processing for FHR determination can be based either on detecting the fetal heart valve motion or on detecting the heart wall motion. The heart valve motion detection technique is based on the small heart valves involving a longer search period and frequent repositioning of the transducer. Therefore, it is not preferred for continuous monitoring applications. Movements of the fetal heart wall are slower as compared to valve movements and, therefore, produce a smaller frequency shift. This signal is less precise than the heart valve signal and tends to produce more jitter on the FHR trace often , they are better suited for continues monitoring, in order to reduce jitter on the trace, the usual practice is to incorporate a signal smoothing circuit with an averaging time constant over a window of approximately three heart periods.

Transducers

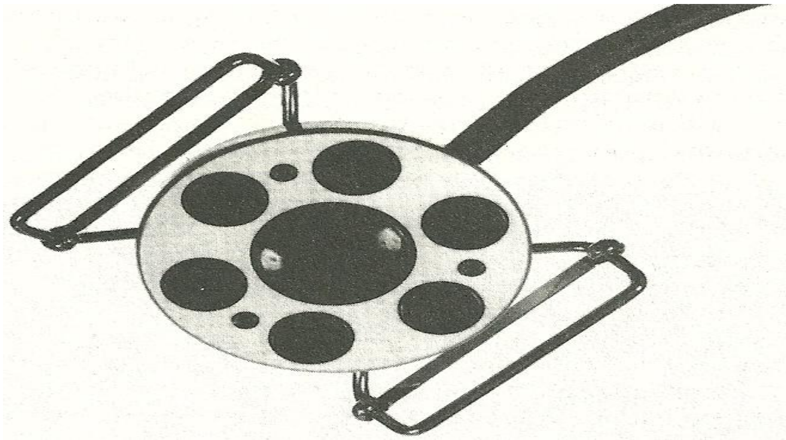
Two types of ultrasonic transducers for FHR measurement are commonly use. They are the narrow beam and the wide-angle beam types. The narrow beam transducer used a single ultrasound transmitter/receiver piezo-electric crystal pair. The maximum ultrasound intensity is generally kept below 25 mw/cm^2. The typical transducer diameter is 25 mm. The narrow beam transducer is very sensitive and produces a good trigger signal for instantaneous heart rate determination.

However, it takes time to detect a good signal and, therefore, frequent transducer repositioning is necessary. The broad beam transducers are available in many configurations. The transducers comprise a number of piezo-electric crystals mounted in such a way as to be able to detect fetal heart movements over a wider area. In one arrangement, the ultrasonic transducer is arranged in the shape of a clover-leaf so that it provides a large area of ultrasonic illumination which allows the monitoring considerable lateral and descending fetal motion before requiring repositioning.

The transducer housing is flexible to permit it to follow the contour of the abdomen regardless of the shape changes with contractions. The traducer has three crystals on the other side acting as a transmitter whereas the crystal placed at the center acts as a receiver. An alternative arrangement is the array transducer which has one transmitter and six peripheral ceramic receiving crystals as in figure below.

The transmitting crystal emits a 40° divergent beam so that at 10 cm from the skin surface the beam covers an area of approximately 10 cm from the skin diameter.

This construction ensures continuous recording of the fetal heart activity without the need to reposition the transducer which is otherwise necessitated due to normal fetal movement. The transducer has a diameter of 6 cm and can be held in place either by a simple buckle or a stretch belt.



Multi-receiver transducer

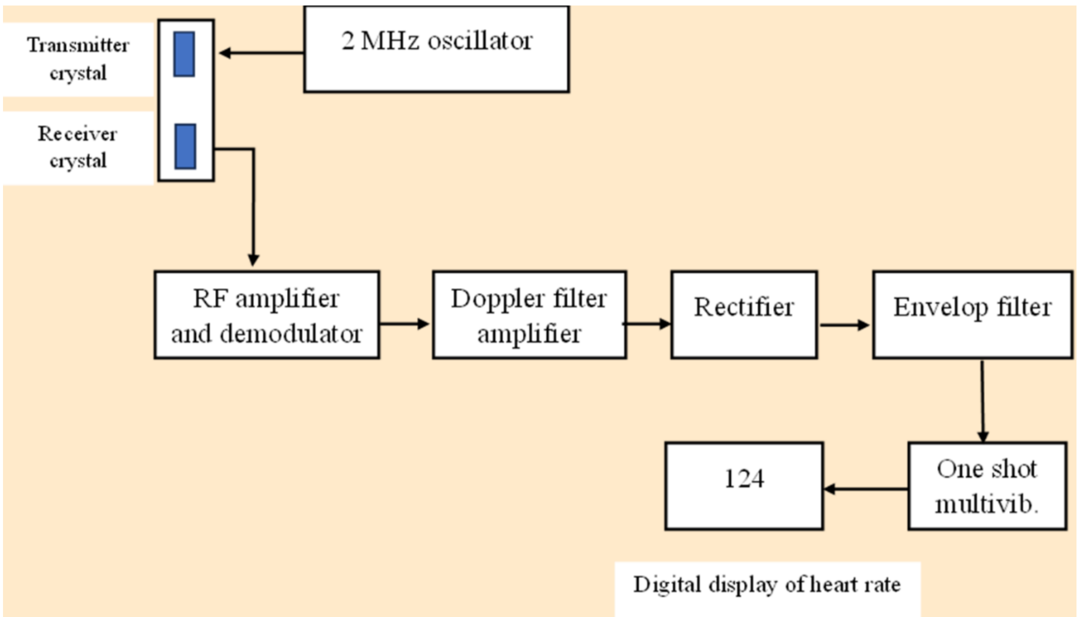
Analysis of ultrasonic Doppler signals using a speech spectrograph shows that frequency components in the range of 100-1000 Hz tended to be more distinctly related to the fetal heart cycle than components lying outside this frequency range. The band pass filter, therefore, enhances the signal/noise ratio-the noise in this context banning, for example, fetal movements at low frequencies and maternal placental blood flow at high frequencies.

With ultrasonic Doppler signals, there remains the possibility of more than one burst in each cardiac cycle being detected. In some instruments, this difficulty is overcome by the dead-time generator, which inactivates the detector for a period of 0.3 sec after an amplitude burst has been detected. This dead time is chosen on a compromise basis: it defines a maximum heart rate (200bpm) that can be detected while at rates which are less than half this maximum, i.e. 100 bpm, it is conceivable to double –count the signal, although the total signal processing in many instruments goes far in minimizing this frequency-doubling possibility, the effect remains a fundamental limitation of using the fetal ultrasonic Doppler signal for recording heart rate.

FHR block diagram:

The principle of ultrasonic Doppler-shift based FHR measuring circuit is shown in the block diagram. This arrangement can be used both with a wide-angle beam as well as a narrow beam transducer. The transmitted signal that leaks into the receiving path serves as a local-oscillator signal for the mixing diodes in the demodulator. The output of the demodulator is dc except for the presence of a Doppler-shift frequency. The reflected signal is some 90 to 130 dB lower in amplitude than the transmitted signal.

The high overall gain in the receiving channel (+110 dB) requires special measures to minimize the effects of interference. One measure used is a low noise, low distortion oscillator for the transmitter. This reduces interference caused by oscillator harmonics beating with radio and TV signals. Other measures involve filters in the transducer connected for attenuating high-intensity high frequency radiation that could drive the amplifiers into a non-linear operating region. The high frequency section of the circuits is surrounded by both magnetic and electrical shields.



Ultrasound Doppler-shift based FHR block diagram

Depending upon the transducer used, i.e. array or narrow beam, the filter circuit can be selected to match the Doppler-shifted frequency components. A band pass filter centered on 265 Hz isolates the Doppler frequencies resulting from the movement of the heart walls. The array transducer used with this circuit gives a broad ultrasonic beam that does not require careful positioning to obtain a strong Doppler return from the relatively large heart walls.

- Figure shows the circuit diagram of the ultrasonic transmitter.
- It consists of an oscillator (X1) that generates an ultrasound frequency followed by an amplifier (U2) to condition the sine waveform. This waveform is applied to the transmitter transducer to generate and send ultrasound vibrations through the body, which get reflected back when the density of the medium changes.
- In the transmitter circuit, the resistor R3 limits the current to transformer T1.

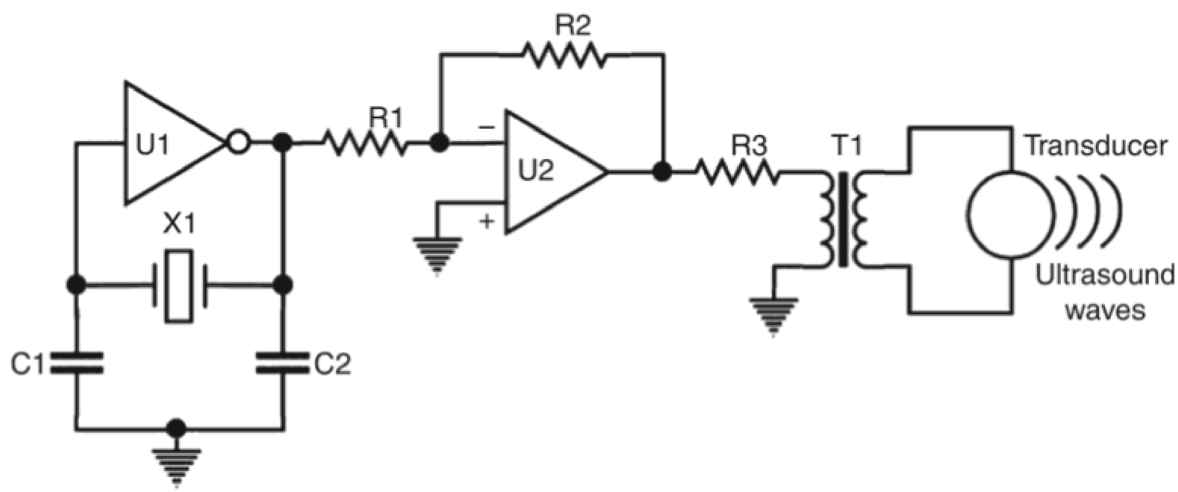


Figure: Block diagram of ultrasound transmitter circuit.

Figure below shows the block diagram of the ultrasound receiver.

Transformer T2 provides isolation between the circuit and the patient's body.

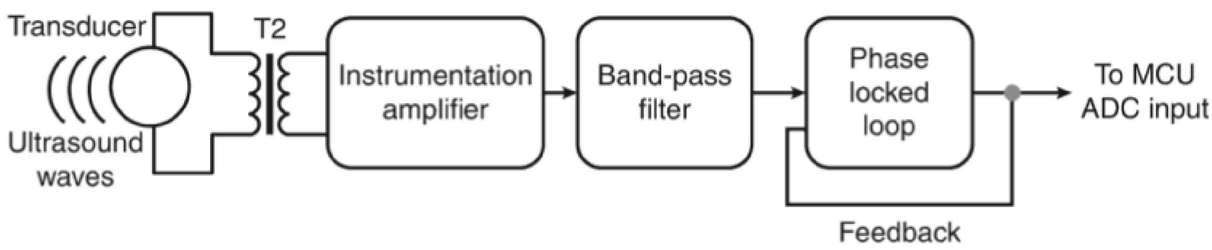
The received reflected ultrasound is converted into electrical signal by the receiving transducer.

This signal is amplified using an instrumental amplifier and is sent to a bandpass filter.

The filtered signal is sent to a phase-locked loop to generate a voltage signal, which depends on the frequency applied.

The reflected ultrasound signal is mixed with the transmitted wave, and the beat frequencies are produced when there is a Doppler shift.

The beat frequency voltage signal is given to an analog-to-digital converter (ADC) and microcontroller for processing the information and displaying the audio signal on a speaker, digital heart rate on LCD screen, and for wireless communication.



Block diagram of ultrasound receiver circuit