Chapter 47
Design of a Fetal Heartbeat Detector

Nur Sultan Salahuddin, Sri Poernomo Sari, Paulus A. Jambormias and Johan Harlan

Abstract Fetal Doppler is an electronic tool that serves as a standard instrument to assess the health of pregnant mother and her fetus. This tool particularly detects the fetal heartbeat in the womb using ultrasound waves. In this paper, we proposed a prototype of fetal heartbeat detector which can detect fetal heartbeat directly without using ultrasonic waves. This detector uses Chebyshev bandpass filter circuit for passing a frequency of 2–3 Hz.

Keywords Band pass filter · Detector · Fetal heartbeat · Frequency

47.1 Introduction

Fetal Doppler is a tool that utilized ultrasonic waves particularly for detecting fetal heartbeats [1]. Ultrasonic waves are sound waves which have frequencies more than 20 kHz. For detecting the heartbeats the fetal Doppler is attached to lower abdominal skin, which lies near the fetal heart, using a transducer probe. The crystals in the transducer will capture reflections of the waves sent out by the transducer. Reflective waves to be captured are still in the form of ultrasonic waves, hence the crystals will convert the waves into electronic ones. The sound waves can penetrate the body and the boundaries between human tissues, e.g. those among body fluid, blood, muscles, and bones. Normal fetal heart rate ranges from 120 to 140 beats per minute. Fetal Doppler is often used in maternity clinics or for pregnant mothers who want to hear the heartbeat of their babies in the uterus [2].

Fetal heartbeats can be heard by amplifying signals from the fetal heart, using a microphone. Inside the womb, beside the fetal heart, there is also a maternal heart that produces heartbeats although with different frequencies. Fetal hearts' rate have

N.S. Salahuddin (✉) · S.P. Sari · P.A. Jambormias · J. Harlan
Gunadarma University, Jl. Margonda Raya 100, Pondok Cina Depok 1642, West Java, Indonesia
e-mail: sultan@staff.gunadarma.ac.id

F. Pasila et al. (eds.), *Proceedings of Second International Conference on Electrical Systems, Technology and Information 2015 (ICESTI 2015)*, Lecture Notes in Electrical Engineering 365, DOI 10.1007/978-981-287-988-2_47

a range from 120 to 140 beats per minute (about 2–2.33 Hz), while maternal heart rate have a range around 80–90 beats per minute (approximately 1.3–1.5 Hz) [3]. Those two types of waves are simultaneously captured by that tool. Therefore for hearing the pure fetal heartbeat, the maternal heartbeat should be separated from the fetal one. This can be done by applying several filtering techniques.

In this study we proposed a fetal heartbeat detector that functions exactly the same as the fetal Doppler in general, nevertheless by using the simple principles of analog electronics. Detection of fetal heartbeat is performed directly without using ultrasonic sensors as that in the fetal Doppler. The purpose of this study is to design and create a prototype of fetal heartbeat detector that can detect fetal heartbeat with the frequency of 2–3 Hz, without using ultrasonic waves.

47.2 The Design of Heartbeat Detector

The design of the fetal heartbeat detectors can be seen in Fig. 47.1 [3].

The working principle of the detector is based upon the electrical signals produced by the mic. The signals are further processed in pre-amplifier circuit, consisting of a parallel voltage feedback amplifier circuit and common emitter amplifier. Pre-amplifier circuit can increase the sensitivity of the sensor. Moreover, the produced sound is free from noise, and can easily set the sensitivity [3]. In the next procedure, we filtered the captured signals using Chebyshev bandpass filter

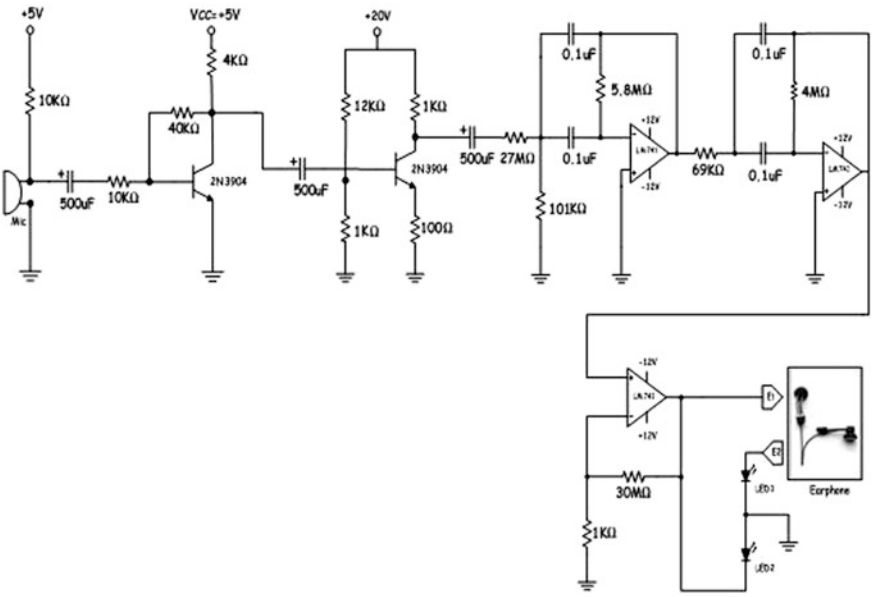

Fig. 47.1 Detector circuits

circuit for filtering the maternal heartbeat to the fetal one. Additionally, a non-inverting amplifier circuit is used to amplify the signals so the captured fetal heart beats can be heard by human ears using the Earphone. In this proposed device, the detector is also equipped with two LEDs. There two LED will flare alternately, that flare correspond to the detected the frequencies of the captured fetal heartbeat.

47.2.1 Chebyshev Band Pass Filter

The design of a Chebyshev Bandpass, which is used in this study, is Delyiannis & Friends circuit [4, 5]. This design is able for filtering frequencies 2–3 Hz using a 0.1 μF, wherein the circuit component values were obtained from the calculation of previous studies in Ref. [6] (Fig. 47.2).

47.3 Testing and Results

Figure 47.3 shows the proposed prototype of fetal heartbeat detector.

We performed two types of tests, for testing the performance of the proposed detector. The first one is the laboratory test using a gauge and the second one is the direct test on the pregnant mothers. The results are explained in the following subsections.

47.3.1 Testing with a Gauge

The tests were carried out at the Laboratory of Electrical Engineering, Gunadarma University. They are aimed to determine whether the equipment functions properly

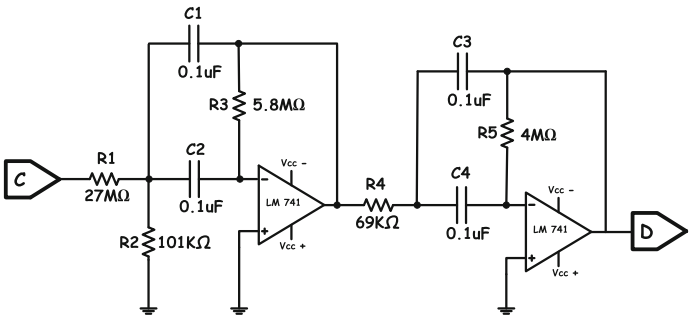

Fig. 47.2 Chebyshev band pass filter

Fig. 47.3 Fetal heartbeat detector prototype

or not. The devices for performing the tests are function generator and oscilloscope. The output measurement was further processed using Eq. (47.1):

$$V_{out} = \text{number of peak} - \text{to} - \text{peak}\, x\, \frac{Volt}{Div} \text{scala (in Oscilloscope)} \tag{47.1}$$

Equation (47.2) was used to calculate the frequency:

$$\text{f} = \frac{1}{\text{T}} \left(\text{number of peak} - \text{to} - \text{peak x } \frac{\text{Volt}}{\text{Div}} \text{scala (in Oscilloscope)} \right) \tag{47.2}$$

To calculate the gain, we used Eq. (47.3):

$$A_{dB} = 20 \log \frac{Vout}{Vin} \tag{47.3}$$

The percentage error (% error) of the test was obtained using Eq. (47.4):

$$\text{Error percentage} = \left| \frac{\text{Calculated data} - \text{Test data}}{\text{Calculated data}} \right| \times 100\,\% \tag{47.4}$$

From the results shown in Table 47.1, it is concluded that the parallel voltage feedback amplifier circuit works as expectedly.

From the results shown in Table 47.2, it is concluded that the common emitter amplifier circuit works as expectedly, indicated by its small values of error percentages.

In Table 47.3, it is seen that the highest output voltage is generated at the input frequency of 2 Hz, i.e. 0.8 Vpp, while at the input frequency of 3 Hz, the output is 0.4 Vpp. It is concluded that the value of frequency response of the test results is close to the desired frequency response.

Table 47.1 Test results of amplifier circuit of parallel feedback

Input frequency (Hz)	Calculation of gain		Gain testing		Error (%)	
	A_V	A_{dB}	A_V	A_{dB}	A_V	A_{dB}
1	3.58	11.07	2	6.02	39.66	45.65
2	3.58	11.07	3.75	11.48	4.74	3.63
3	3.58	11.07	3.43	10.72	3.98	3.18
4	3.58	11.07	2.75	8.78	23.18	20.68
5	3.58	11.07	2	6.02	44.13	45.65
6	3.58	11.07	2.33	7.35	34.82	30.56
7	3.58	11.07	2	6.02	44.13	45.65
8	3.58	11.07	2.5	7.95	30.16	28.15
9	3.58	11.07	2.25	7.04	37.15	36.41
10	3.58	11.07	3.09	9.81	13.54	11.4

Tabel 47.2 Test results of common emitter amplifier circuit

Input frequency (Hz)	Calculation of gain		Gain testing		Error (%)	
	A_V	A_{dB}	A_V	A_{dB}	A_V	A_{dB}
1	7.5	17.5	10	20	25	12.49
2	8.33	18.41	10	20	16.66	7.91
3	9.09	19.17	10	20	9.09	4.13
4	8.72	18.81	10	20	12.72	5.91
5	10	20	10	20	0	0
6	8.57	18.66	10	20	14.28	6.69
7	9.37	19.43	10	20	6.25	2.8
8	8.88	18.97	10	20	11.11	5.11
9	10	20	10	20	0	0
10	9.23	19.3	10	20	7.69	3.47

Tabel 47.3 Test results of chebyshev band pass circuit

Input frequency (Hz)	Output Voltage (Vpp)
1	0.06
2	0.8
3	0.4
4	0.16
5	0.08
6	0.06
7	0.04
8	0.04
9	0.04
10	0.04

Fig. 47.4 Detector testing by doctor, accompanied by midwifery lectures and students

47.4 Testing on Pregnant Women

After laboratory tests with a gauge gave good results, i.e. the detector can detect the frequency of 2–3 Hz, the second test is then performed directly on pregnant women. The tests were conducted at the clinic of Gunadarma University which is located in the area Salemba Raya, Jakarta Indonesia by medical doctors, accompanied by midwifery lecturers and students (Fig. 47.4).

As the results, we found that the detector can detect the fetal heartbeat at the frequency of 2–3 Hz. However, there is still instability of the prototype performance in detecting fetal heartbeat. The instability happened especially because the electret condenser microphone is very sensitive to movement. During the test, the pregnant mother should be assured for not moving the body very much, because it will affect the test results.

47.5 Conclusion

In general the prototype working good. However, it has a drawback due to instability that occurred when the tested mothers are moved during the tests. In further research, a circuit detector is designed in a single integrated circuit using mentor graphics tools. Additionally, a screen is added to show which frequencies are detected in the range of 2–3 Hz.

References

1. Nuryati, V.: Design build tool detector and counters fetal heart rate with doppler principle (in Bahasa Indonesia). Thesis, Faculty of Engineering, University of Indonesia (2010)
2. Kristyawati, D., Siswono, H.: Analysis, Simulation, and Design of Bandpass Filters Using PSPICE for Fetal Doppler, Thesis (2009)
3. Salahuddin, N.S., Triawati, E., Jambormias, P.: Mini Doppler detector circuit design (in Indonesia). Proceedings KOMMIT **7**, 311–316 (2012)
4. Tomlison, G.H: Electrical Networks and Filters Theory and Design. Prentice Hall Europe, New York (1991)
5. Coughlin, R.F., Driscoll, F.F.: Operational Amplifiers and Linear Integrated Circuits. Prentice-Hall, New Jersey (2001)
6. Kristyawati, D., Nur'ainingsih, D.: Analysis and simulation Chebyshev bandpass filter for fetal doppler use tools mentor (in Bahasa Indonesia), Konferensi Nasional Sistem Informasi 2012, STMIK–STIKOM Bali 23–25 February 2012. http:// repository.gunadarma.ac.id/ bitstream/123456789/2481/1/095.pdf