Design Heartbeat Monitoring Circuit

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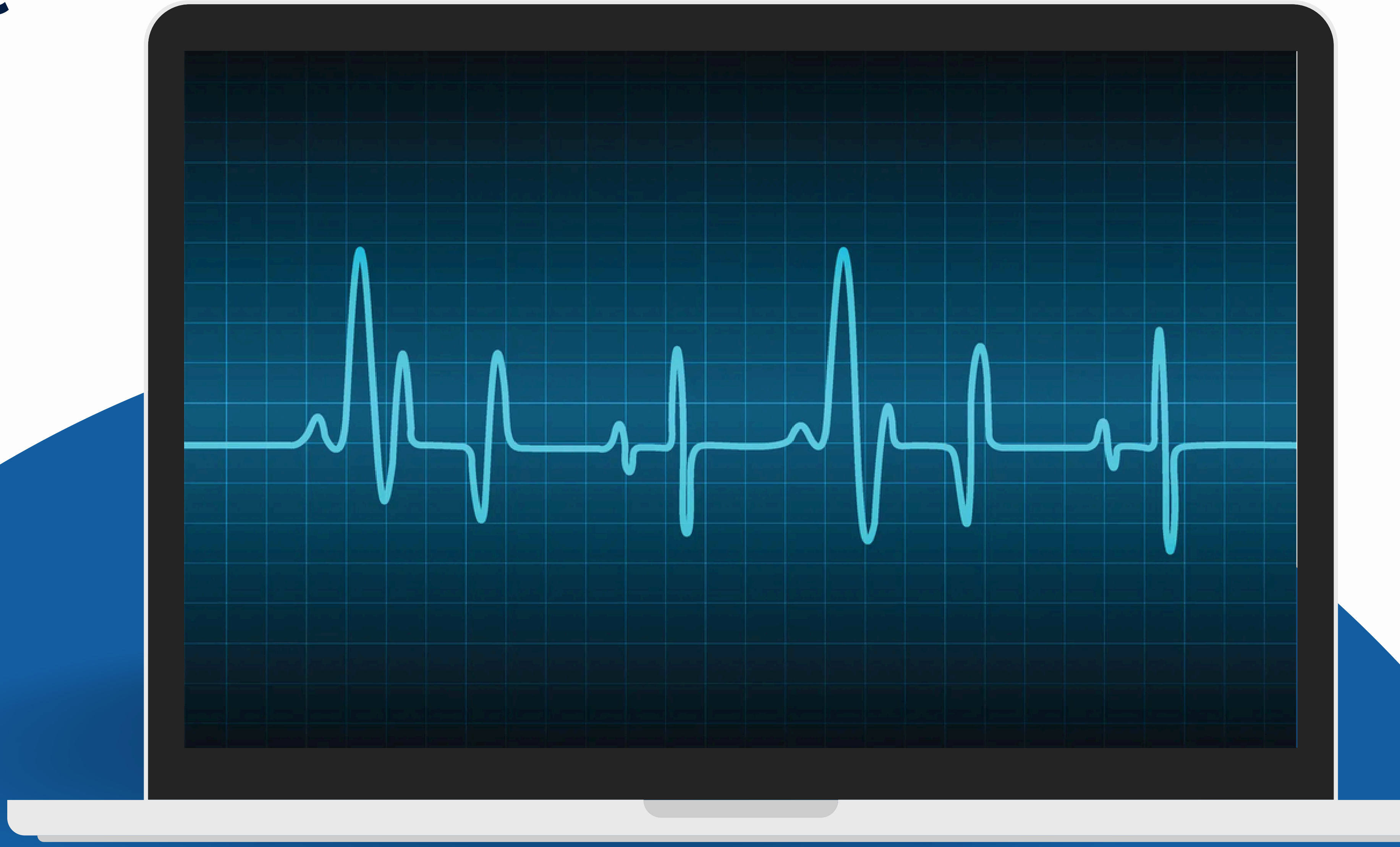


Overview

- Introduction
- Objectives
- Implementation direction

Introduction

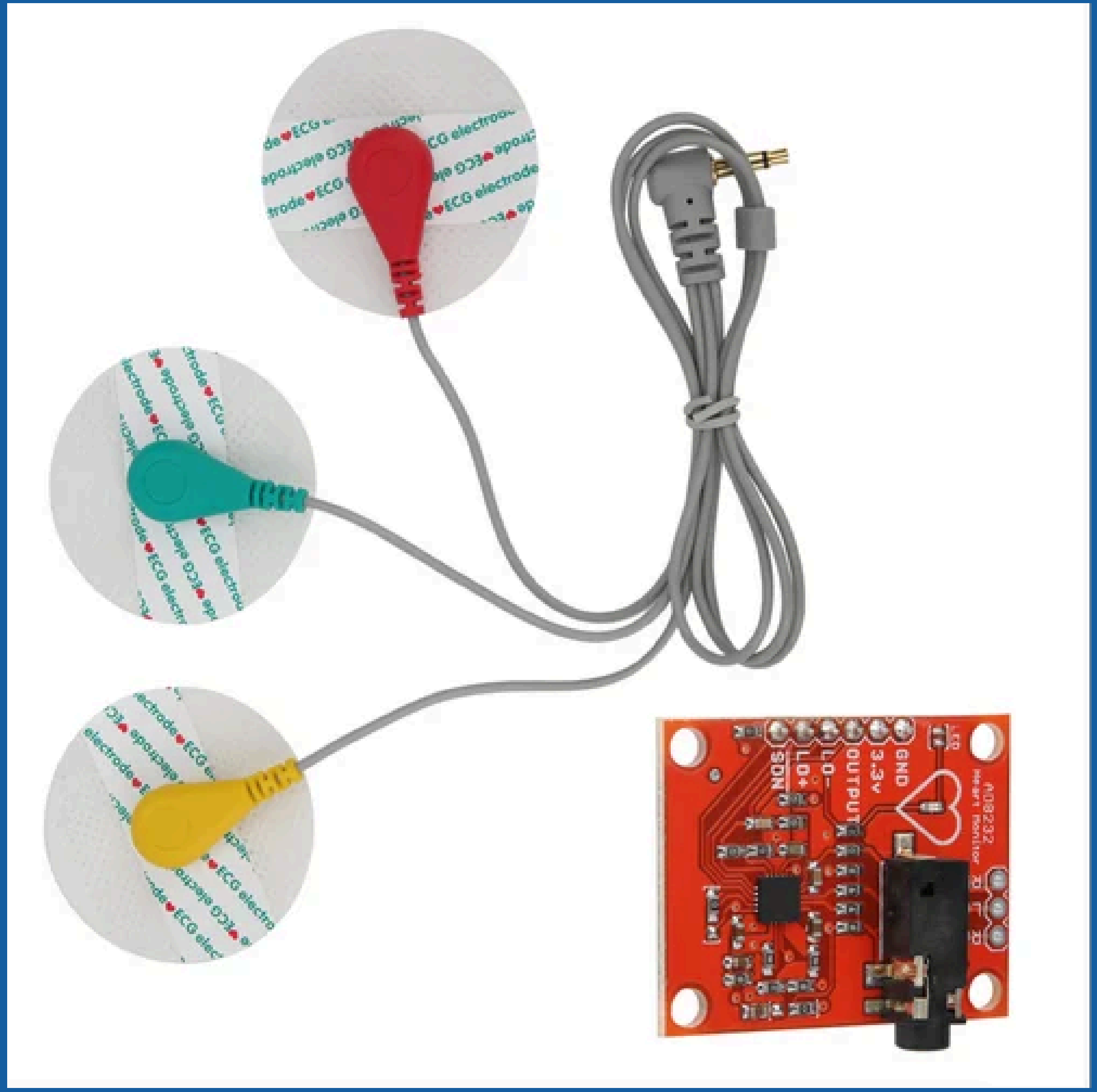
- Heart rate is one of the vital signs that reflects a person's health condition. Regular heart rate monitoring helps detect early signs of heart issues, thereby supporting timely diagnosis and treatment.
- With the rapid advancement of technology, heart rate monitoring devices are increasingly used in healthcare, sports, and wearable technologies. However, not everyone has access to modern and expensive equipment.

Objectives

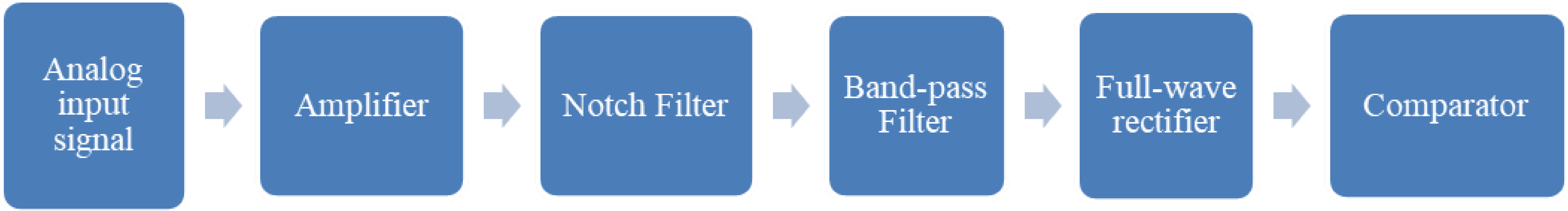
Our group chose the topic with the goal of understanding the operating principles and basic structure of a heart rate measurement circuit, and to build a stable simulated model that can serve as a foundation for future real-world applications.

Operating principle

An ECG sensor works by detecting the electrical signals generated by the heart during each heartbeat. These electrical impulses travel through the body and can be measured using electrodes placed on the skin. The electrodes capture the small voltage signals and send them to an amplifier circuit that boosts the signal strength for further processing. The signal is then filtered to remove noise from the environment and power lines. Finally, the ECG signal is converted and displayed as a waveform, allowing monitoring of heart activity such as heart rate, rhythm, and possible abnormalities. ECG sensors are commonly used in medical devices, wearable health monitors, and electronics projects involving Arduino or Raspberry Pi.



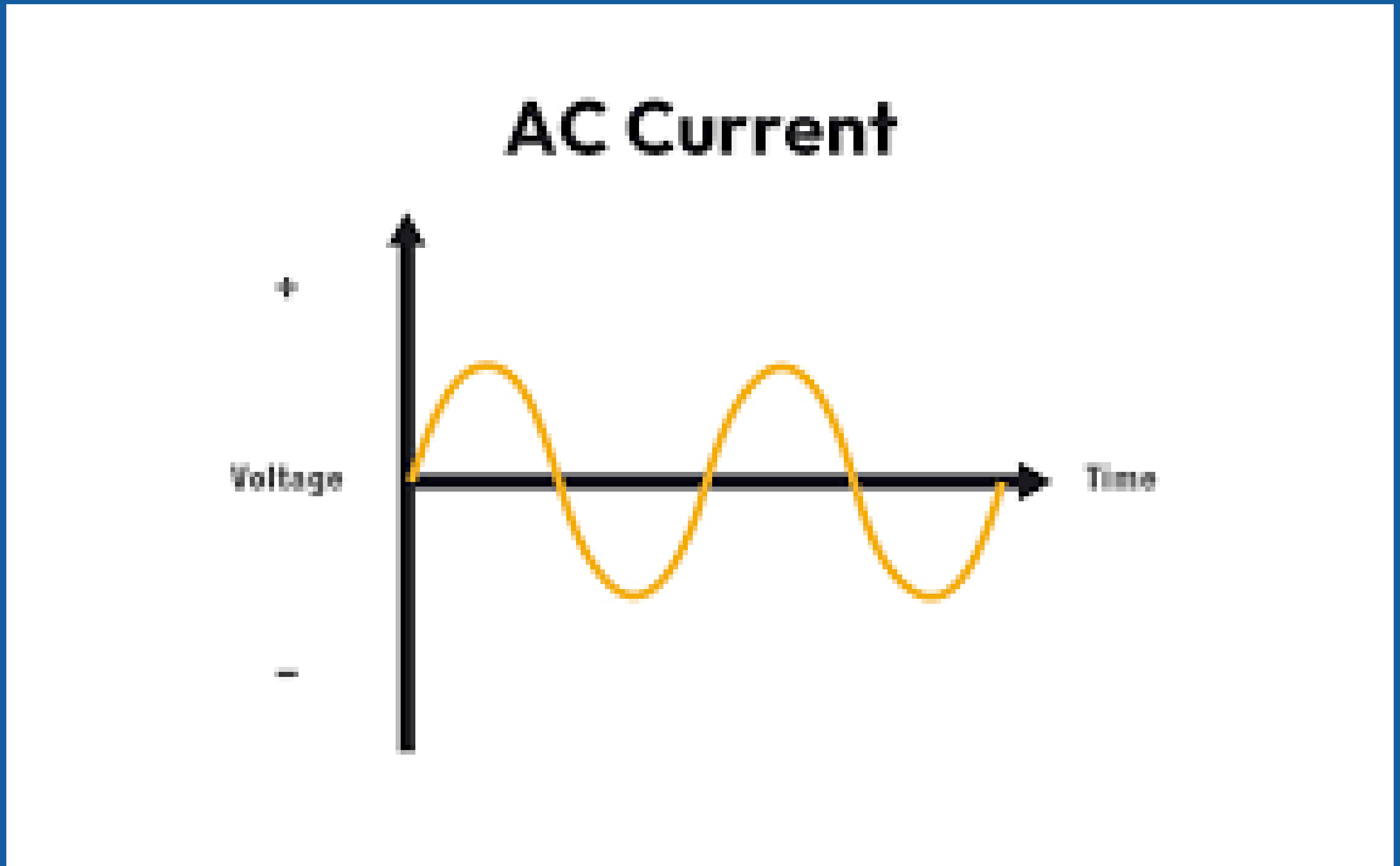
Implementation direction



Block Diagram

Input

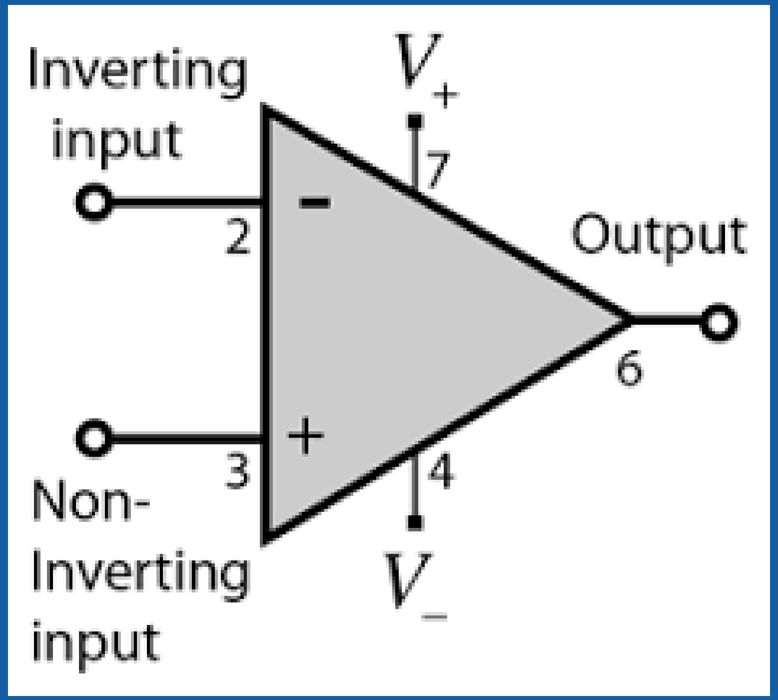
In simulation we don't have EGC signal so we will replace it with sine signal and add noise to check simulation



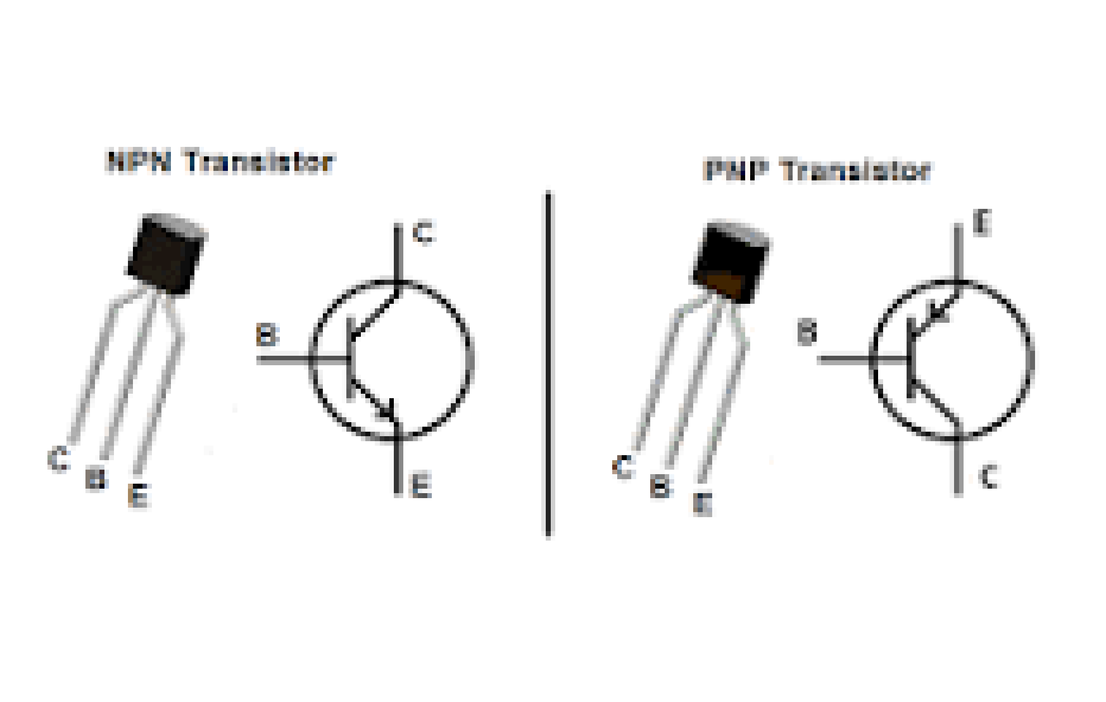
Sine wave

Amplifer

The amplifier increases the small signal to a usable level for further processing. An instrumentation amplifier is used for its high input impedance and excellent common-mode noise rejection, making it suitable for low-amplitude biomedical signals.

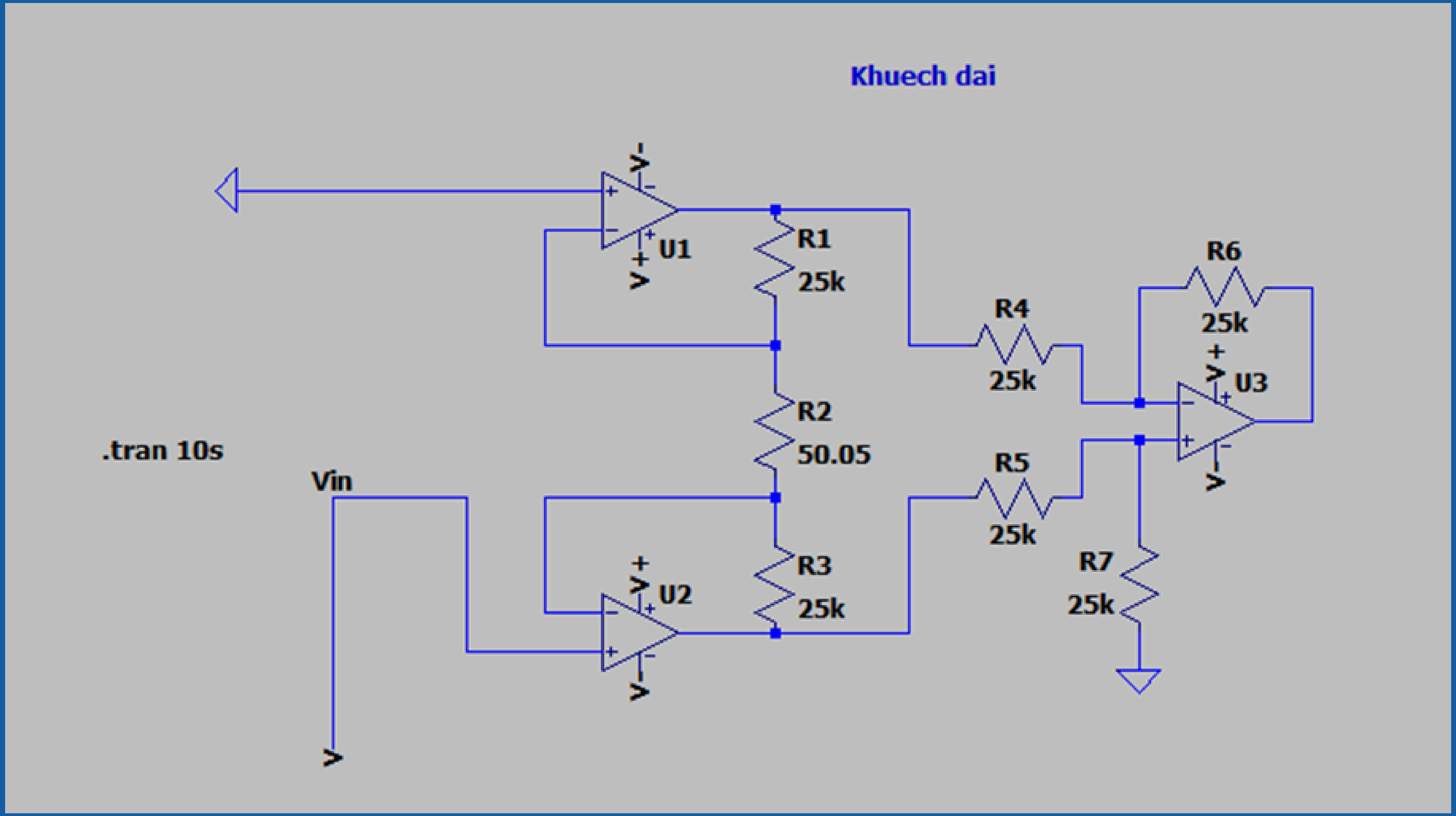


Op-amp



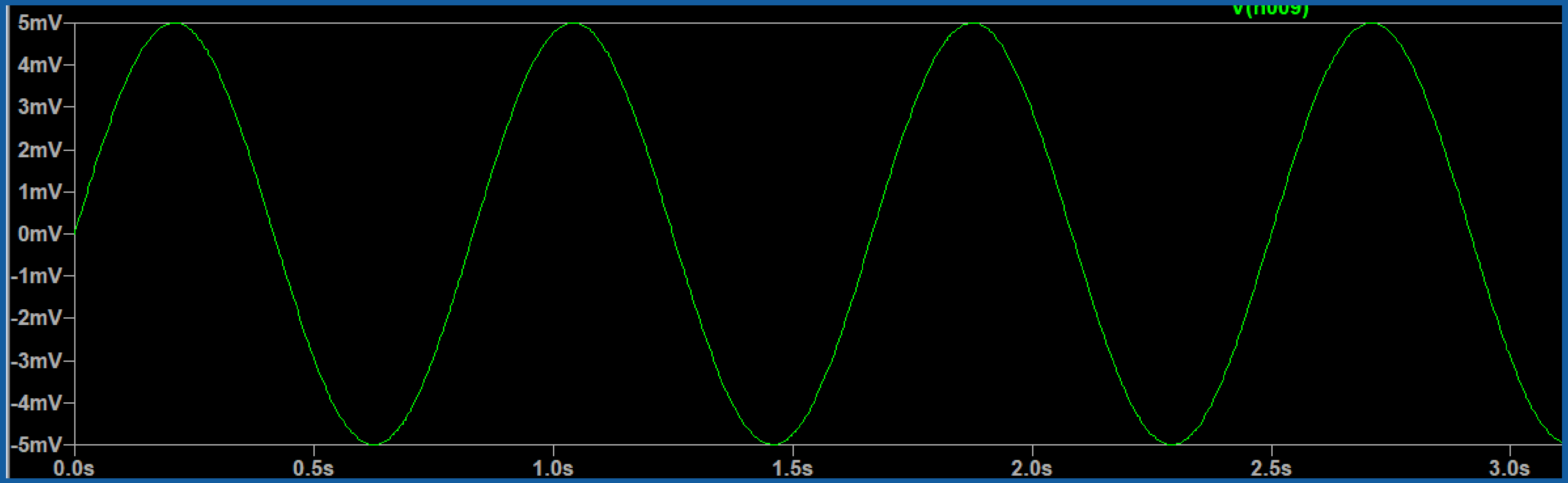
Transistor

Amplifer

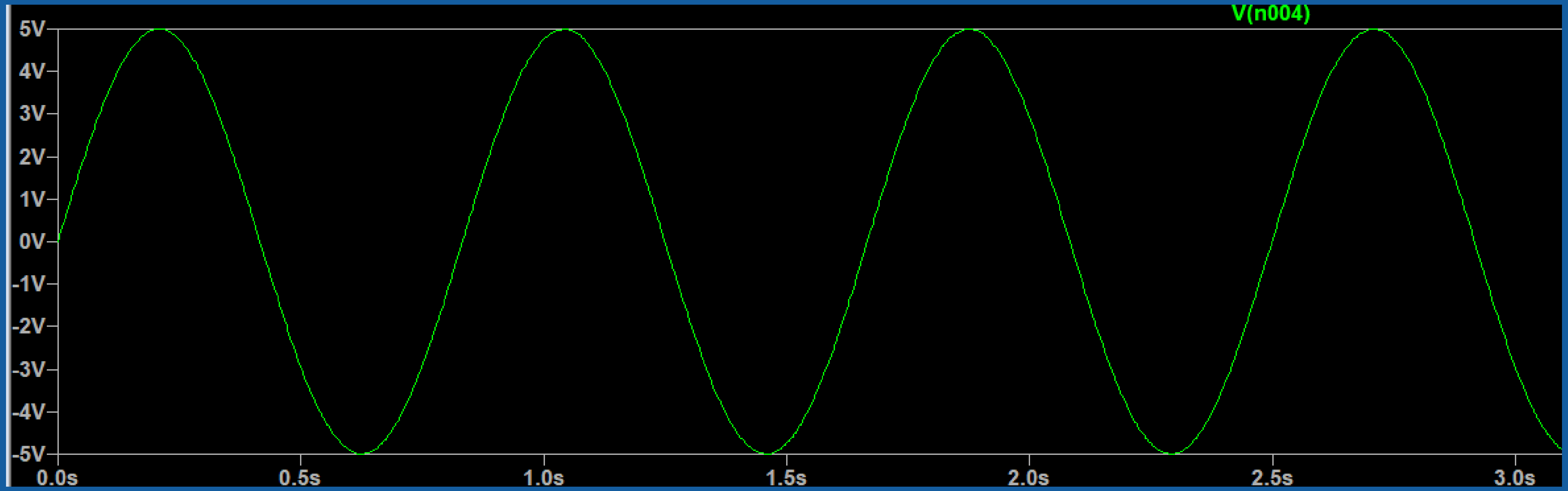


Amplifer circuit simulation

Amplifer



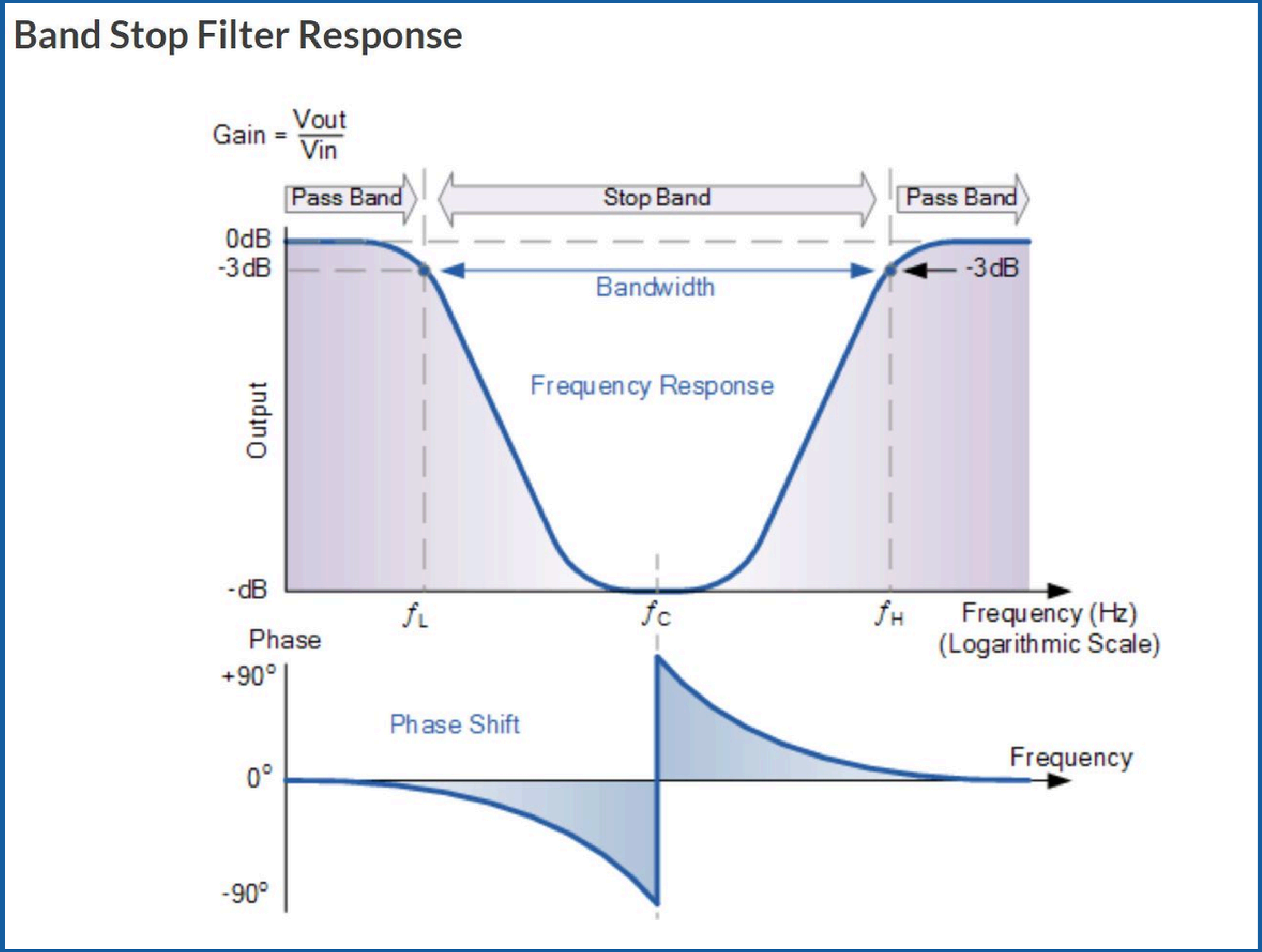
Before Amplifer



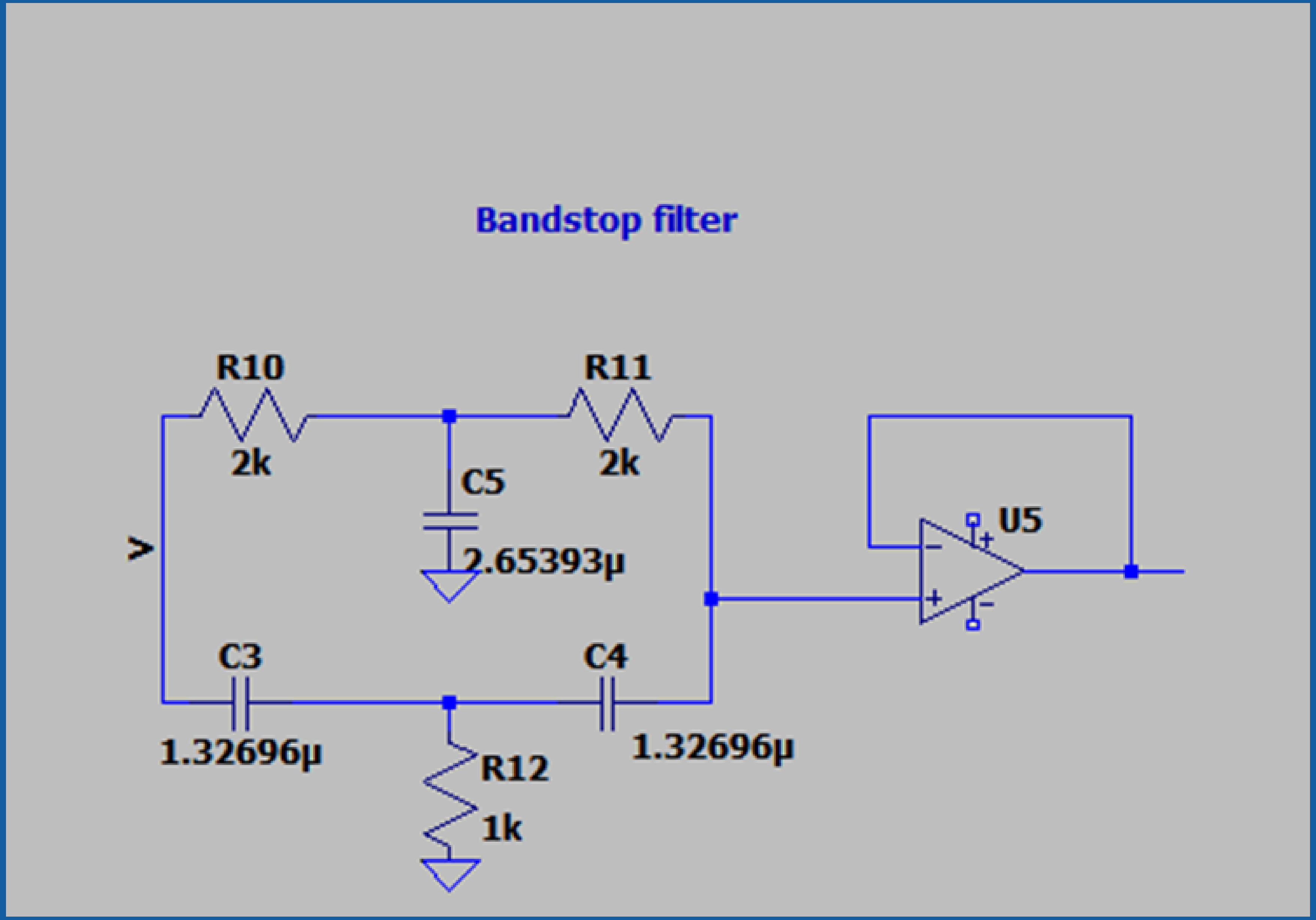
After Amplifer

Filter block
Band stop filter

- As we know, the ECG signal is a very weak physiological signal that is highly susceptible to various types of noise. Among these, the most common and troublesome is the 50 Hz or 60 Hz power line interference, depending on the region.
- To solve this problem, we use a special type of filter called a Band Stop Filter, also known as a Notch Filter. This filter is designed to eliminate a specific narrow range of frequencies — in this case, the 50 Hz frequency — while allowing all other frequencies to pass through unaffected.
- By using this filter in ECG circuits, we can significantly reduce the power line noise, which helps make the ECG waveform clearer and more accurate. This is crucial for identifying important features such as the P wave, QRS complex, and T wave.

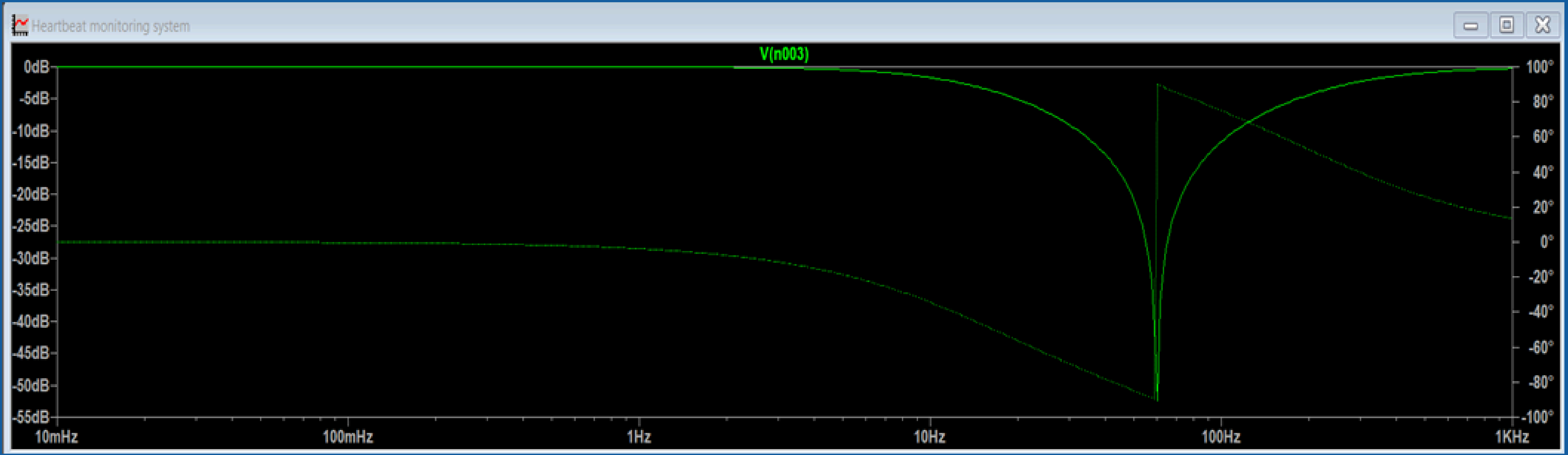


Filter block
Band stop filter



Bandstop filter circuit simulation

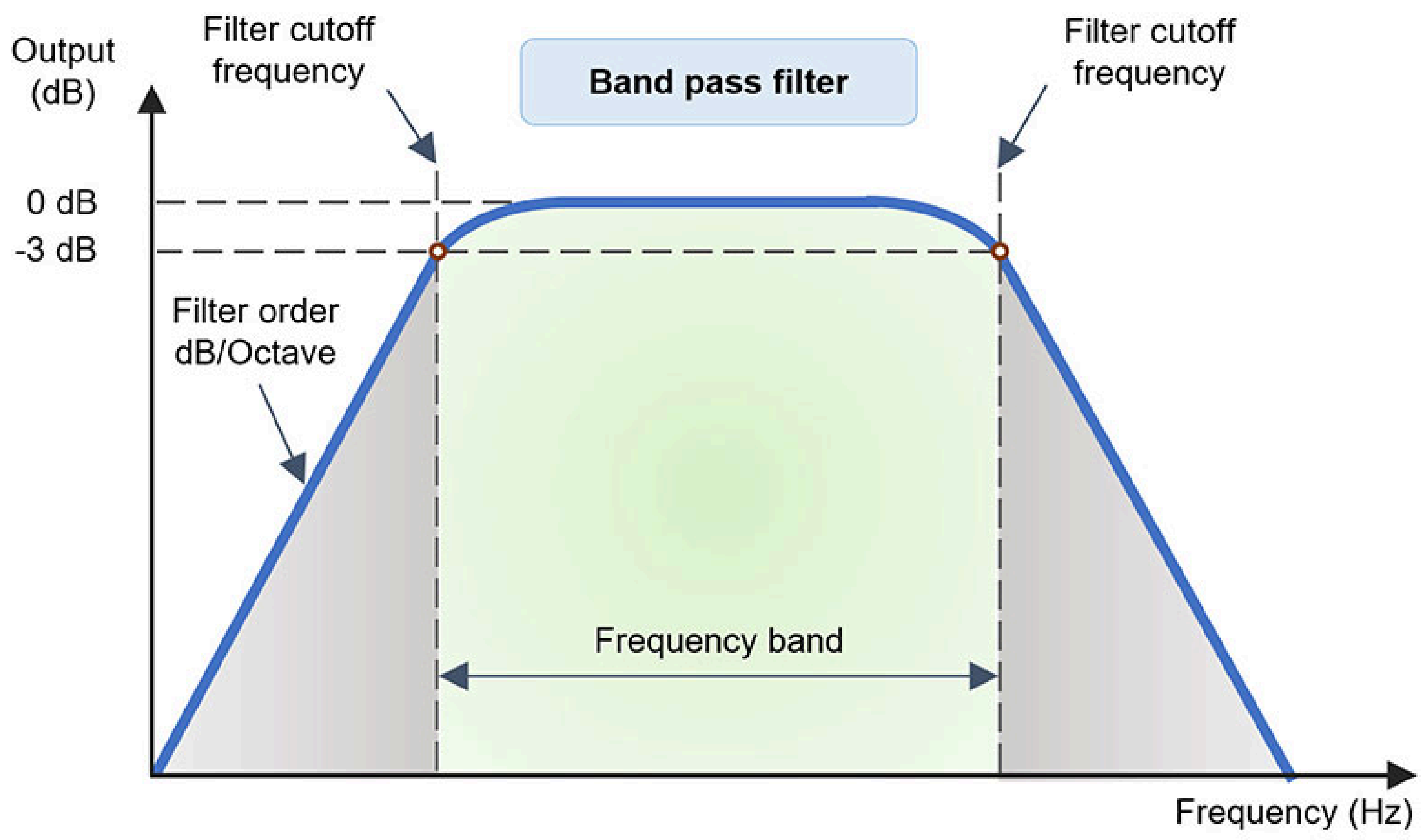
Filter block
Band stop filter



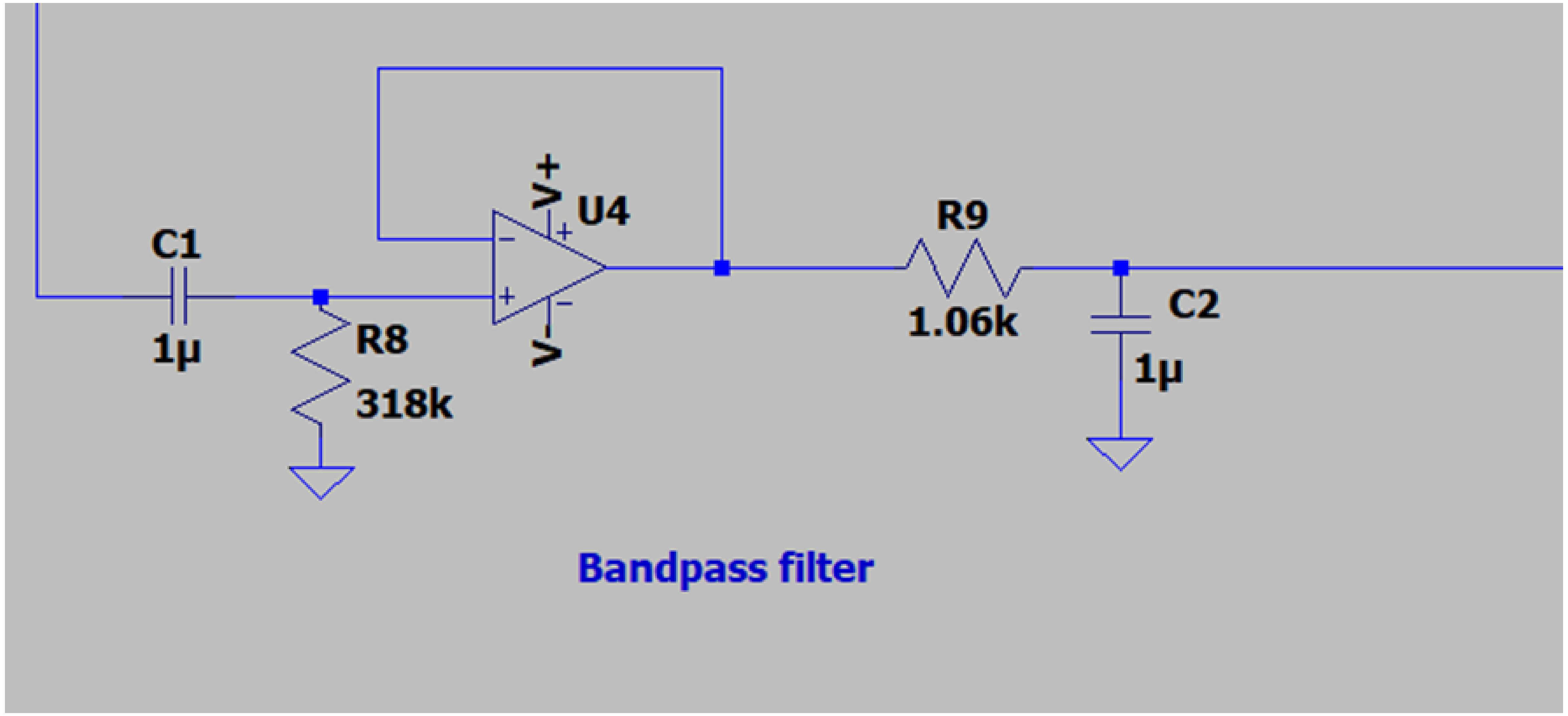
Bandstop filter result

Filter block
Band-pass filter

- When we measure ECG signals, we often face the problem of unwanted noise. This includes low-frequency noise, such as motion artifacts from body movement, and high-frequency noise, like interference from electrical devices or muscle activity.
- To solve this, we use a band-pass filter, which allows only signals within a specific frequency range to pass, while filtering out frequencies that are too low or too high.
- In ECG systems, the important frequency components of the heart signal typically lie between 0 Hz and 150 Hz. Therefore, the band-pass filter is designed to allow signals only within this 0–150 Hz range, and suppress any noise outside of it.
- and operational amplifiers, or in digital form, using microcontrollers and digital signal processing.

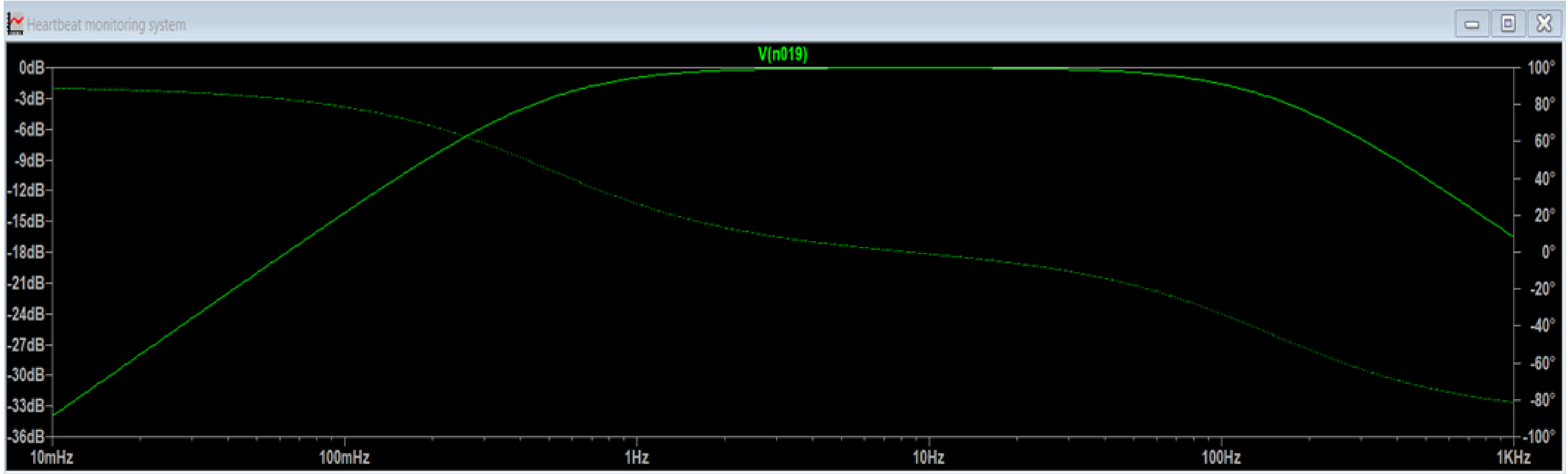


Filter block
Band-pass filter



Bandpass filter circuit simulation

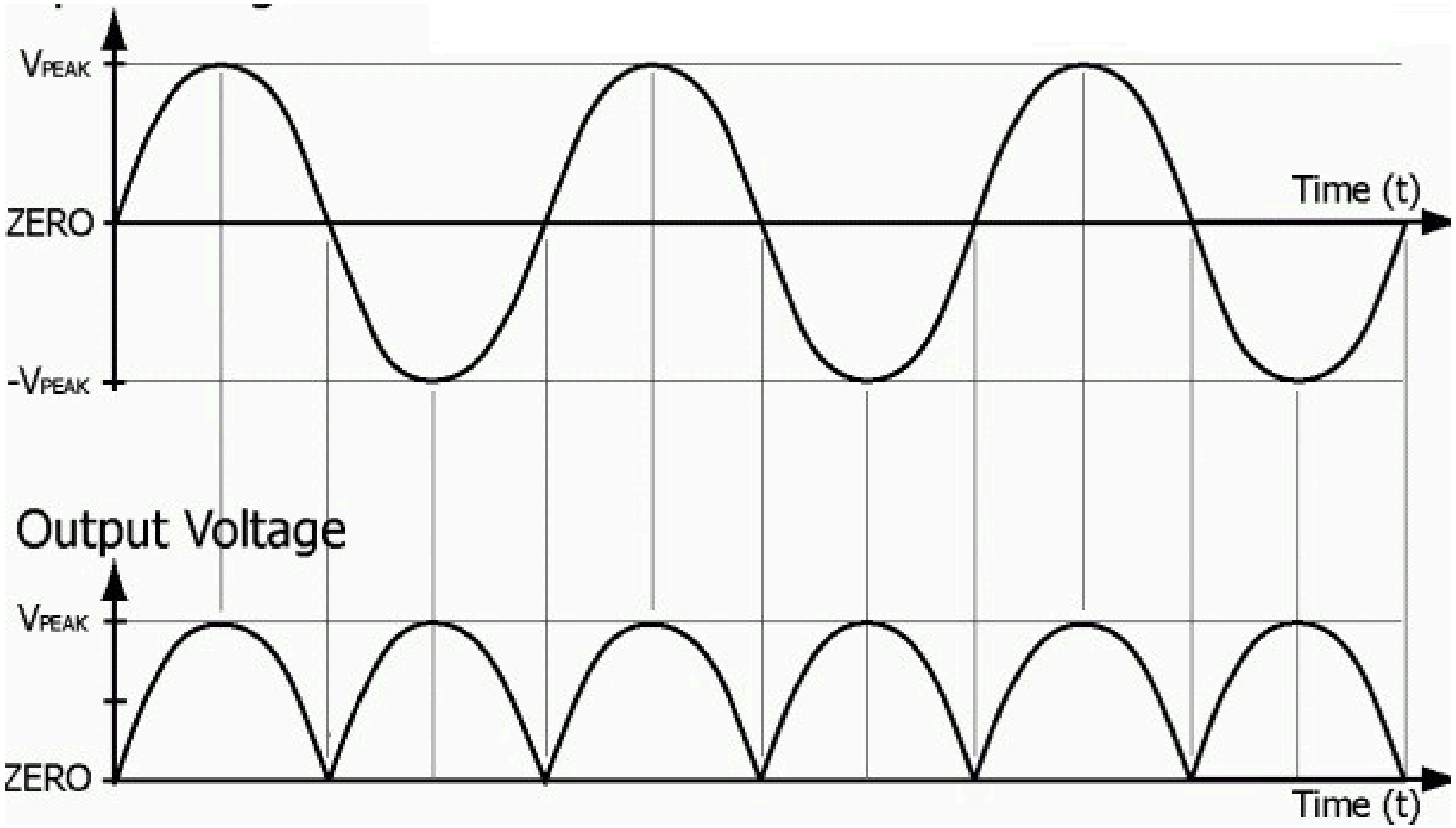
Filter block
Band-pass filter



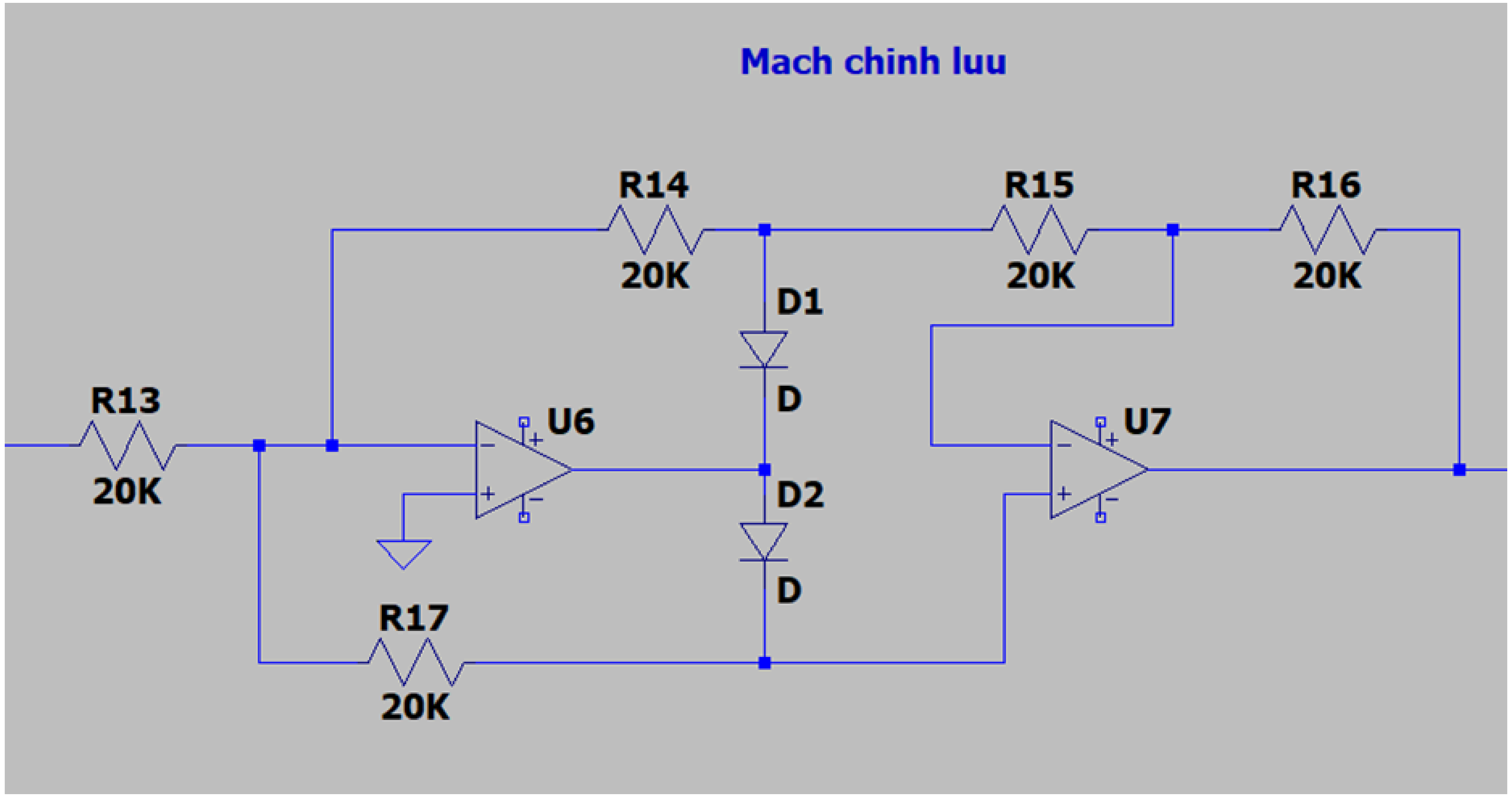
Bandpass filter result

Full-wave rectifier circuit

In heart rate measurement systems using optical sensors, the signal obtained is typically a small-amplitude alternating current voltage signal that fluctuates around 0V. Direct processing of this signal is challenging due to its low amplitude and the presence of both positive and negative half-cycles. Therefore, a precision rectifier circuit is used to convert the small AC signal into a unidirectional (DC-pulsed) signal that is easier to process in later stages.

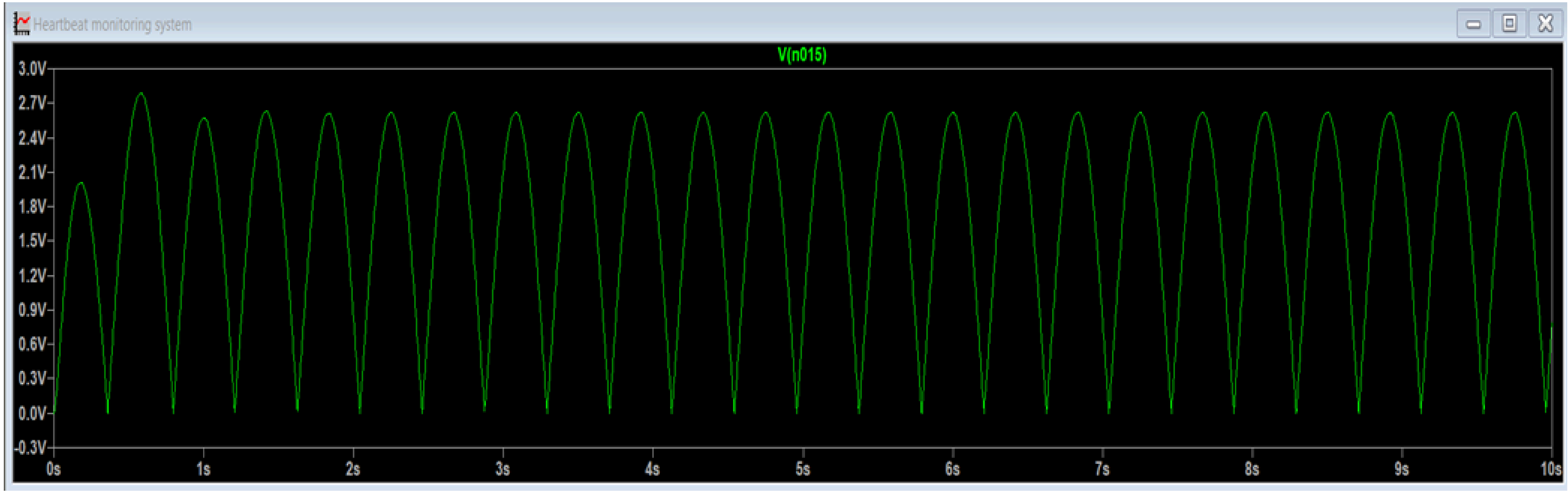


Full-wave rectifier circuit



Full-wave rectifier circuit simulation

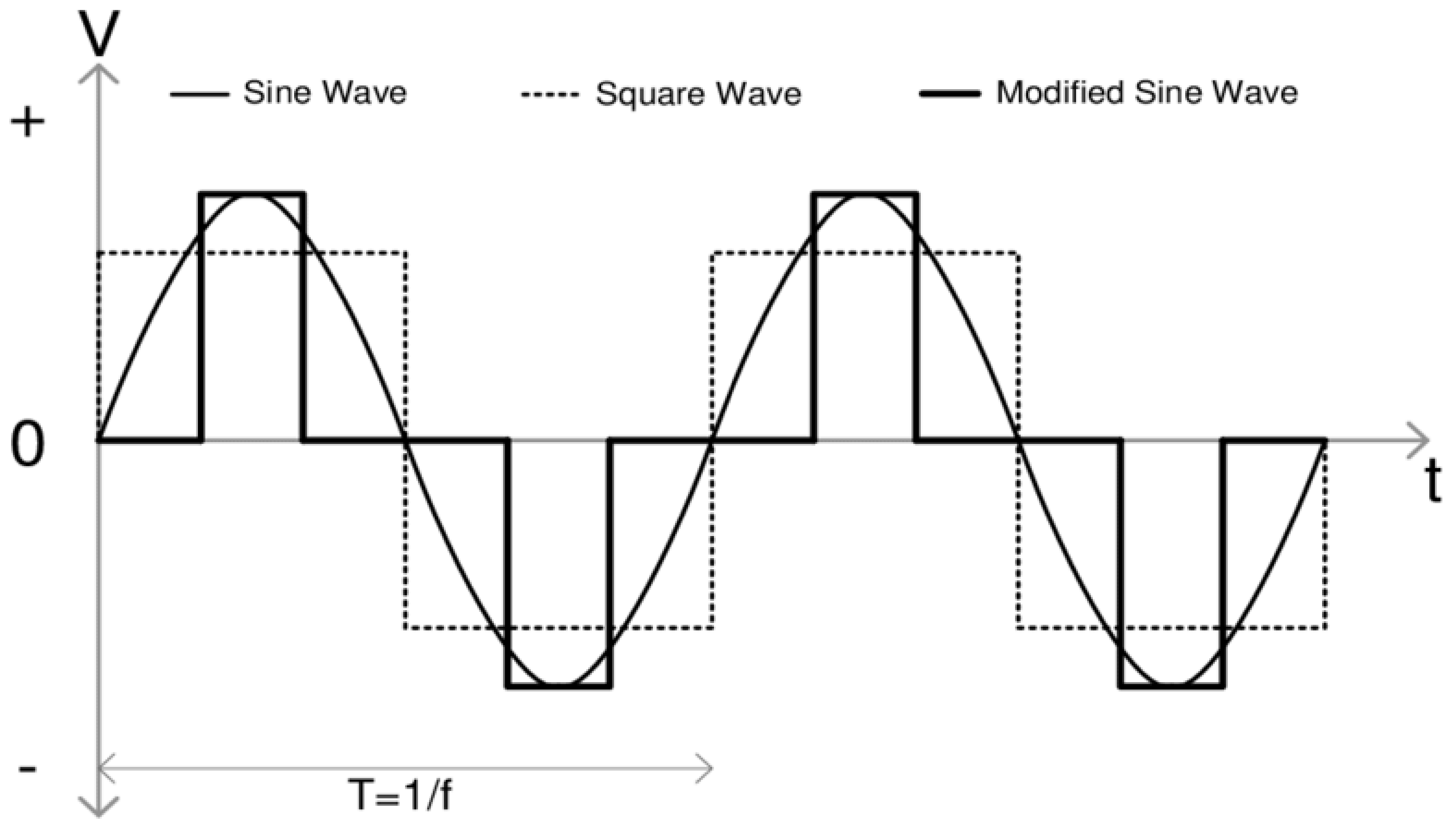
Full-wave rectifier circuit



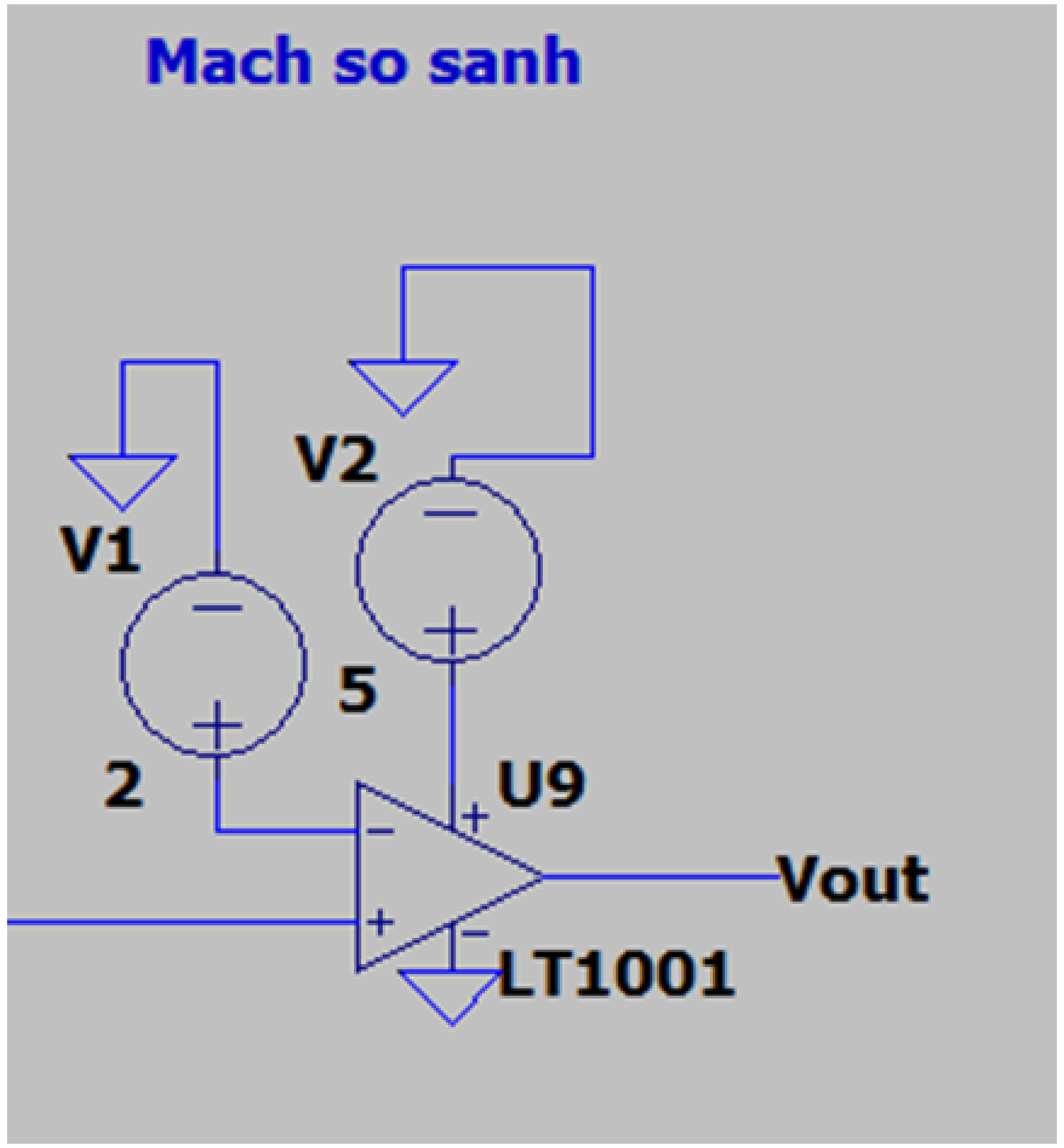
Full-wave rectifier result

Comparator circuit

A comparator plays a crucial role in converting analog signals, such as sine waves, into digital square waves. When a sine wave is fed into the input of a comparator, the circuit continuously compares the instantaneous voltage of the signal to a fixed reference level (usually 0V or another threshold). When the input voltage rises above the reference, the output of the comparator switches to a high level (logic 1), and when it falls below the reference, the output switches to a low level (logic 0). As a result, the smooth sine wave is transformed into a square wave that reflects the original frequency. This process is essential in applications like frequency measurement, pulse counting, digital signal processing, and generating control signals for microcontrollers.

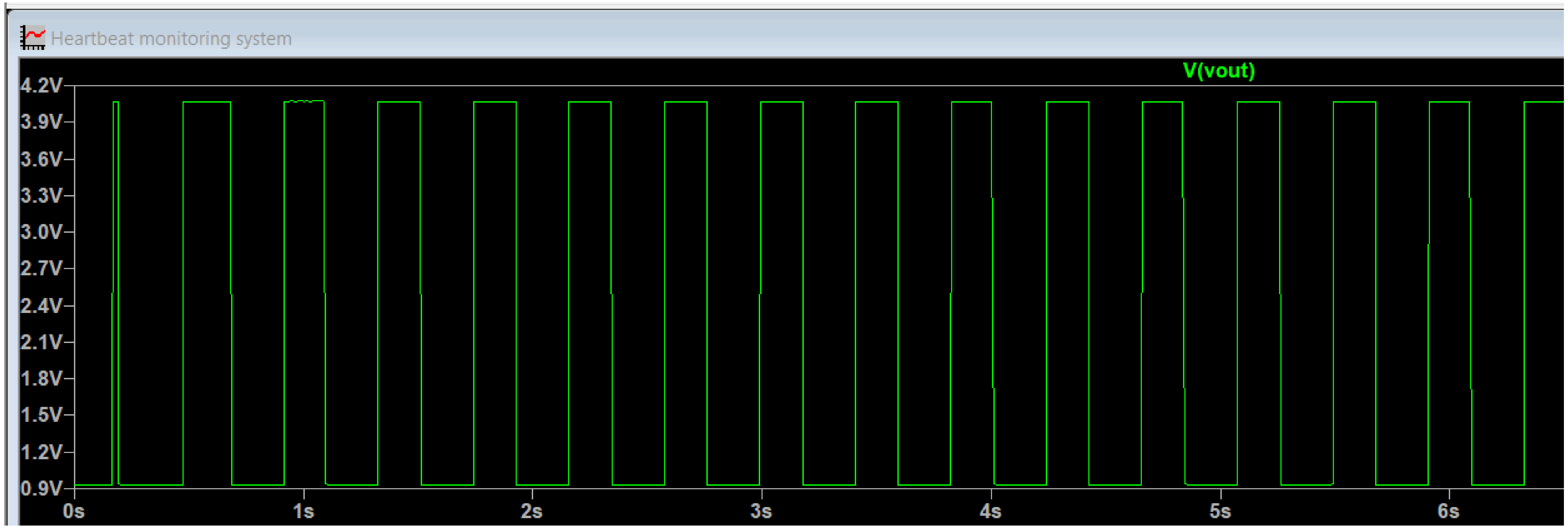


Comparator circuit



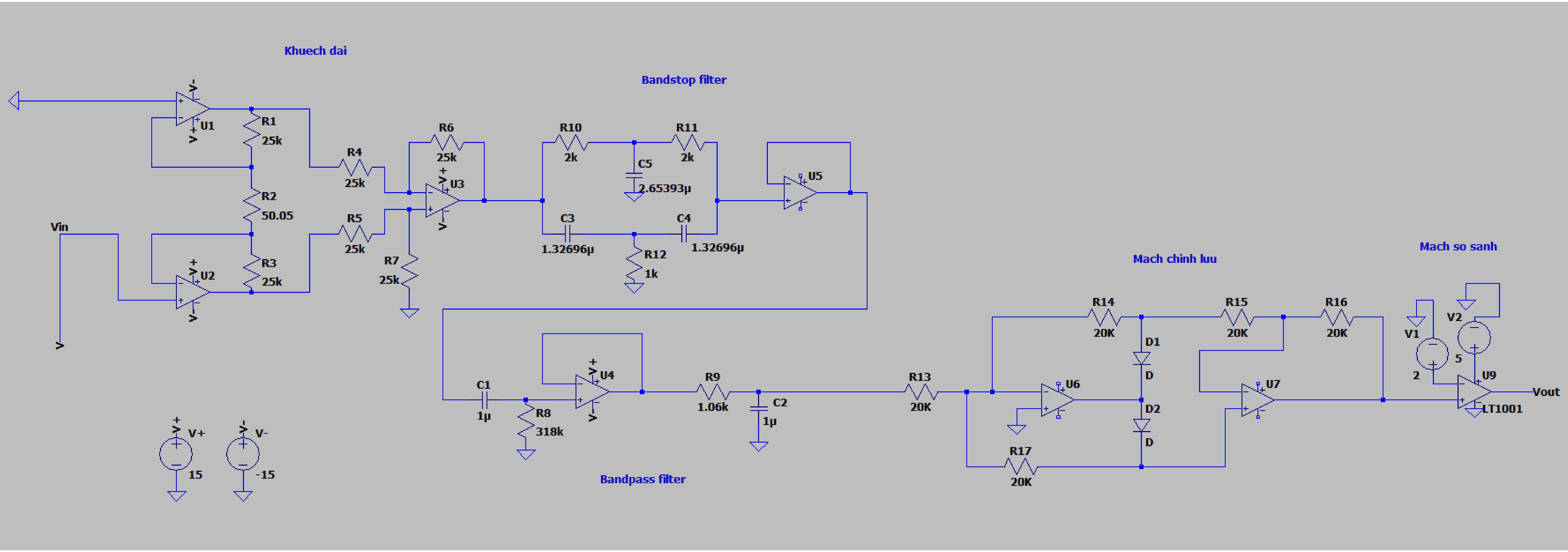
Comparator circuit simulation

Comparator circuit

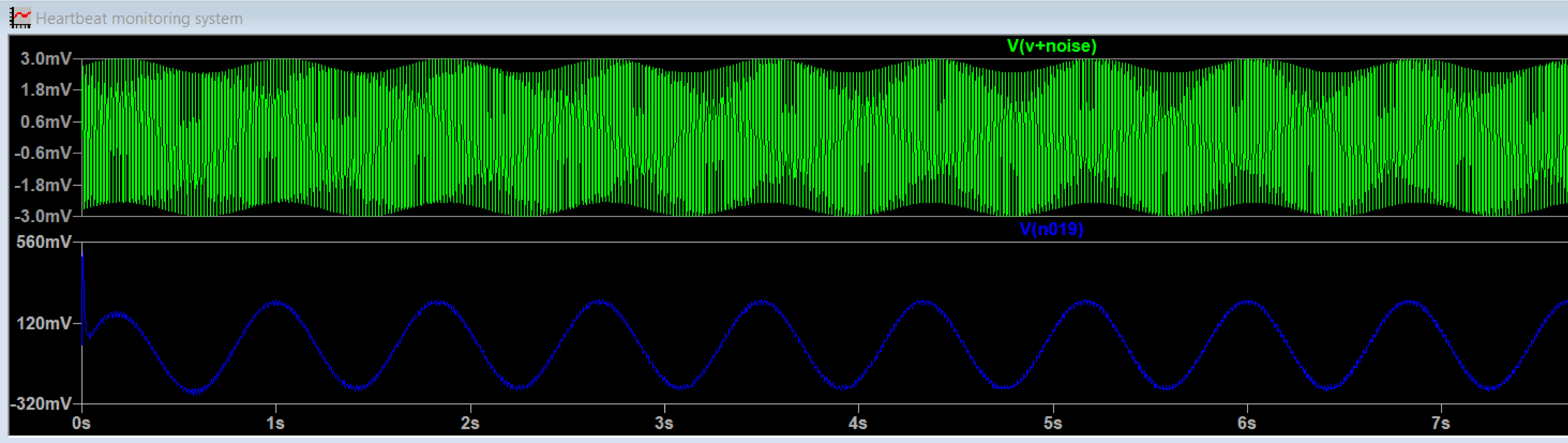


Comparator circuit result

Full circuit



Testing


Heartbeat monitoring system
V(v+noise)
3.0mV
1.8mV
0.6mV
-0.6mV
-1.8mV
-3.0mV
V(n019)
560mV
120mV
-320mV
0s
1s
2s
3s
4s
5s
6s
7s

THANK YOU FOR WATCHING