Pacemaker: Narrow Pulses Generation for Design and Sensitivity Test

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Abstract—A pacemaker is a small device that helps the heart to beat more regularly and properly. It does this with a small electric stimulation that controls the heartbeat. This paper outlines pulse generation and sensitivity test of a pacemaker. Designers require a generated signal to simulate the real pacemaker pulse signal to use for sensitivity testing of the pacemaker. Next generation of function generators offer the best signal generators that can simulated a pulse signal as narrow as 1usec pulse width and arbitrary cardiac signal. The new digital or mixed signal oscilloscope, with its high resolutions acquisition, allows designers to analyze both low amplitude (0.5 mV and 1 mV) ECG signal and pulse signal stimulus simultaneously allowing designers to make real-time adjustments to their pacemaker designs.

Keywords—pacemaker, pulse signal, pacing, ECG, narrow pulse, pacemaker sensitivity, cardiac

Introduction

What is a pacemaker? According to the American Heart Association, a pacemaker is a small device that helps the heart beats more regularly and properly. It does this with a small electric stimulation that controls the heartbeat. An engineer may refer to a pacemaker device as a “pulse generator”. Pacemakers perform four major critical functions:

- Stimulate cardiac depolarization;
- Sense intrinsic cardiac function;
- Respond to increase metabolic demand by providing rate responsive pacing; and
- Provide diagnostic information stored by the pacemaker

In clinical use, three common types of pacemakers are [1]

1. Implantable,
   - Long-term permanent use
2. External, and
   - Miniaturized, transistorized, battery-powered
3. Console
   - Battery- or AC-powered defibrillators

In addition, other sub-options includes unipolar pacing, bipolar pacing, asynchronous (fix rate), synchronous (on demand), single or dual chamber, programmable and non-programmable.

Pacing system

In the typical pacing system, the pacemaker provides the voltage and the current (electrons) flows down the conductor through the electrode, and towards the tip of the lead (positive terminal, cathode). The tip of the lead touches the myocardium (the muscular tissue of the heart) where the electrical resistance is produced and stimulates the heart. Then the current flows through the body tissue to the tip of the lead (negative terminal, anode) and back to the pacemaker.

Electrical Testing of Pacemaker

Electrical testing parameters involve in testing a pacemaker, include battery testing, pacing impedance and pulse generation. Within pulse generation, there are pulse generation, sensitivity test, timing test, mode switching and rate adaptive sensor. The focus in this paper is on pulse generation and sensitivity test of the pacemaker.

1. PULSE GENERATION

The pacemaker designer needs to allow for many adjustments, including the signal’s amplitude and pulse width. These are the most important settings used in the pacemaker pacing. Pulse width is the time or duration of the pacing pulse and is expressed in milliseconds. Pulse width must be wide enough to allow for the delivery of each pacing pulse and must be long enough for the depolarization to disperse into the surrounding muscle tissues. Widening the pulse width improves the ability of the pacemaker to capture the cardiac signal and maintains synchronization. Narrowing the pulse width improves battery life span and reduces side effects of electrical signals; these side effects include twitching of the pectoral muscles and interrupting the normal breathing pattern by stimulating the diaphragm. The pacemaker produces a narrow pulse signal approximately 71 beats per minute and a pulse width around 0.5 msec. [2]
Amplitude is the amount of voltage delivered to the heart by the pacemaker. Amplitude reflects the strength or height of the pulse signal. The amplitude of the pulse must be large enough to cause depolarization (i.e. “capture” the heart), “capture” is the nomenclature for effective stimulation of cardiac depolarization by the pacemaker. On top of that, the amplitude of the pulse must be sufficient to provide an appropriate pacing safety margin. The pacemaker produces a pulse burst amplitude approximately 5.0V and this corresponds to a narrow “spike” in the ECG.

Figure 1 [3]: This is the output pulse of the pacemaker. The voltage of the pacemaker is referring to the amplitude of the leading edge. The droop is influenced by many factors including the electrode’s lead impedance. The output pulse corresponds to a narrow pulse or “spike” on the ECG signal.

A. Pulse Generations Solutions

A function generator is the best solution for a pacemaker designer to simulate the narrow pulses. Most of the new function generators have built-in pulse capability to generate basic pulses. For older function generators, the designer can use the built-in square wave capability to generate pulse signal by varying the duty cycle between 20 and 80 percent. Some designers also use the arbitrary waveform generator (AWG) to generate a pulse because it allows them to top up with additional customizations such as adding overshoot or undershoot into the pulse signal.

Questions might arise on why the designer does not use a PC sound card to generate a pulse signal. The disadvantages of using a PC sound card include poor waveform quality, distortion, noise, signal ringing and imprecise amplitude. These disadvantages far outweigh the main advantages of sound card’s low cost and availability.

B. Narrower Pulses

Pacemaker designers require narrow pulses for testing. This is achieved by using the built-in BURST mode capability in the function generator or arbitrary function generator. BURST mode capability allows the user to configure the instrument to output a waveform for a specific number of cycles. The user can control the amount of time that elapses between bursts with the internal timer or external triggering.

For example, the designer can output a very narrow pulse signal of 1us pulse width by adjusting the frequency range value and duty cycle of the signal, then switch on the BURST mode feature to adjust the burst rate to achieve the narrow pulse.

Figure 2: 1µsec pulse signal generate from function generator

II. SENSITIVITY TEST FOR PACEMAKER

What is the sensitivity of a pacemaker? [4] This is defined as the minimum myocardial voltage required to be detected as a P wave or R wave, measured in mV. Why is this important? If the pacemaker is overly sensitive, any random fluctuations of electrical signal from cardiac activity could be mistaken by the pacemaker and leads the pacemaker to keep pacing continuously. This can lead to “madness”. On the other hand, the pacemaker would not fire at all because the cardiac activity is considered within normal range. Hence proper timing and sensitivity need to be calibrated appropriately to avoid unnecessary complications later.

Figure 3: Typical setup for testing the sensitivity of the pacemaker

Figure 3 shows the typical test setup for testing the sensitivity of the pacemaker. In this test, the designer sets the pacemaker to output a signal of 70 beats per minute. The function generator produces the cardiac signal to simulate the heart signal to the pacemaker. The designer tunes the amplitude of
the cardiac signal from the function generator (in mV level) and the sensitivity of the pacemaker is measured using the oscilloscope. This minimum sensitivity value is the sensitivity threshold. Next-generation function generators do not need an attenuator because they are able to generate an accurate signal at low amplitude.

**REFERENCES**


