

## Errata

J. Pan and W. J. Tompkins, A real-time QRS detection algorithm. *IEEE Trans. Biomed. Eng.*, **BME-32**(3):230-236, 1985.

This article includes several errors, particularly in equations for the high-pass filter and the derivative.

### Low-pass filter

The group delay of the filter was stated incorrectly to be six samples. It is actually five samples (corresponding to 25 ms at the 200 sps sampling rate).

### High-pass filter

The high-pass filter is implemented by subtracting a low-pass filter from an all-pass filter. The low-pass filter is an integer-coefficient filter having the transfer function:

$$H_{lp}(z) = \frac{1 - z^{-32}}{1 - z^{-1}} \quad (2.1)$$

This low-pass filter has a *dc* gain of 32 and a group delay 15.5 samples (i.e., 77.5 ms). To produce the high-pass filter, the output of the low-pass filter is divided by its *dc* gain and subtracted from the original signal. Before subtraction, the original signal is delayed by 16*T* (i.e.,  $z^{-16}$ ) to compensate for the low-pass filter's group delay.

The transfer function of the high-pass filter is derived from:

$$H_{hp}(z) = z^{-16} - \frac{H_{lp}(z)}{32} \quad (2.2)$$

Substituting Eq. (2.1) into (2.2) and solving for  $H_{hp}(z)$ , the transfer function for the high-pass filter is:

$$H_{hp}(z) = \frac{-\frac{1}{32} + z^{-16} - z^{-17} + \frac{z^{-32}}{32}}{1 - z^{-1}} \quad (2.3)$$

This filter may be implemented with the difference equation:

$$y(nT) = y(nT - T) - \frac{x(nT)}{32} + x(nT - 16T) - x(nT - 17T) + \frac{x(nT - 32T)}{32} \quad (2.4)$$

The low cutoff frequency is about 5 Hz, and the gain is one. The equation for the amplitude response is much more complicated than the one given in the article. This filter has a group delay of about  $16T$  (80 ms).

### **Derivative**

The derivative is a 5-point derivative with the transfer function:

$$H(z) = \frac{1}{10} \left( -2z^{-2} - z^{-1} + z^1 + 2z^2 \right) \quad (2.5)$$

The derivative is implemented with the difference equation:

$$y(nT) = \frac{1}{8} \left[ 2x(nT) + x(nT - T) - x(nT - 3T) - 2x(nT - 4T) \right] \quad (2.6)$$

The fraction of  $1/8$  is a reasonable approximation of the actual gain factor of  $1/10$  to permit fast power-of-two division. This derivative approximates an ideal derivative between dc and 30 Hz. The derivative has a group delay of  $2T$  (10 ms).

### **Squaring function**

The output of the squaring function is hard-limited to a maximal value of 255.