Solutions: Session 9

Exercise 1

Answers

1) We know that the measured signal $e(t)$ can be written in terms of the applied magnetic field $B(t)$ and instantaneous blood velocity (that we would like to measure) $v(t)$ as:

$$e(t) = \alpha v(t)B(t) + \beta \frac{dB(t)}{dt}$$

Where α and β are proportionality constants having appropriate units.

To find $e(t)$, we need to first find $\frac{dB(t)}{dt}$, the term representing the undesirable induced transformer voltage. This is shown in dark blue in Fig. 1. Then, just below it in red is the underlying instantaneous blood velocity $v(t)$, and in yellow is the actual measured voltage $e(t)$ which includes the undesirable transformer voltage.

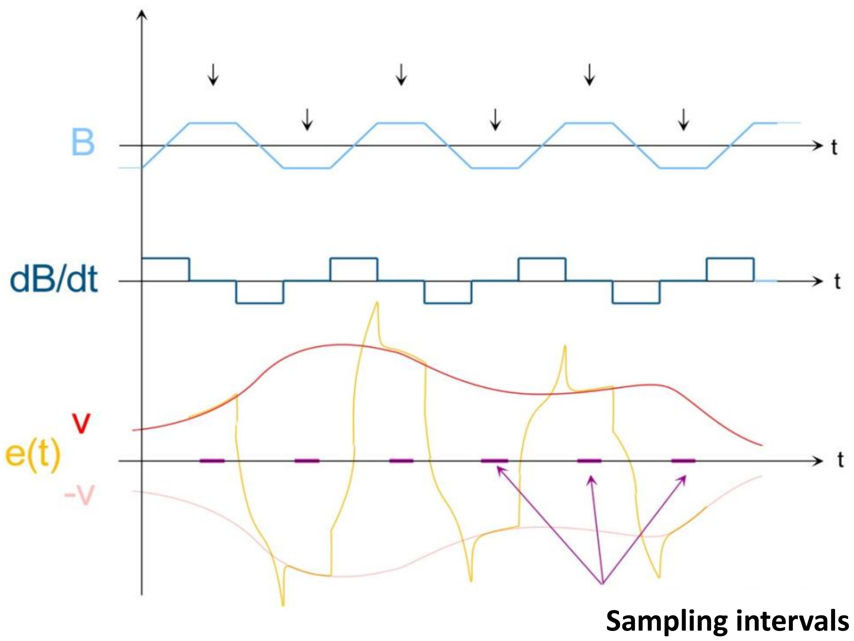

Figure 1: Plots of $B(t)$ (in light blue), dB/dt (in dark blue), $v(t)$ (in red), and $e(t)$ (in yellow)

2) We want to get a signal "close to" $v(t)$, so we want to remove $\frac{dB(t)}{dt}$. To do this, we can choose to down-sample the signal at a specific frequency: **when** $\frac{dB(t)}{dt} = 0$. In the figure above, the sampling intervals, chosen in the region where $\frac{dB(t)}{dt}$ (and hence transformer voltage) is zero, are marked in purple in the bottom-most graph and with arrows in the topmost one.

For additional examples on best times to sample when different kinds of power signals are used (i.e. instead of a trapezoidal signal), one may refer to Example 8.3 on Page 349 of Webster's book (the reference book for this course).

Exercise 2

Answers

1) The elastic modulus of the ligament is greater when the force is higher. In fact, the more the ligament is stretched, the more the fibers are well "aligned" in the ligament and thus the more they are able to resist the load. $Y = \sigma/\varepsilon$; σ can be measured from the load applied and the surface of application. ε can be estimated from the original length l_o and Δl can be measured by the LVDT.

2) Fig. 3 depicts a typical demodulation procedure for an amplitude-modulated signal. Let's assume that the original signal to be transmitted was a simple sinusoidal signal. An oscillator fixed at the carrier frequency (which is a much higher frequency than the original sinusoidal signal) changes the signal's characteristics before transmission as shown in (1) in the figure below – the amplitude of the fixed-frequency carrier wave is changed according to the signal to be transmitted (thus, the amplitude of the "envelope" of the signal changes according to a sine wave, as shown in (1)).

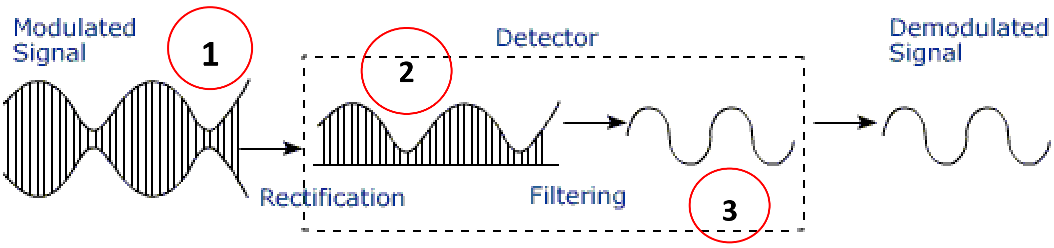

Figure 3

When this amplitude-modulated signal is to be detected, two steps need to be carried out at the receiver to retrieve the original signal (in this case, a simple sine wave) that was transmitted, and these steps constitute what is known as the "demodulator" – rectification and filtering. Rectification can be of two types – half-wave or full-wave (see Fig. 4). In the simpler case of half-wave rectification that we shall consider in this part, only the positive values of the incoming signal are selected, and the other values are put to zero; this is shown in (2) in the figure below. Next, to remove the high frequencies associated with the carrier wave and other noise added to the signal during signal propagation, a simple low pass filter is used, as shown in (3) in the figure below. The final output of the detector, or demodulator, is the demodulated signal.

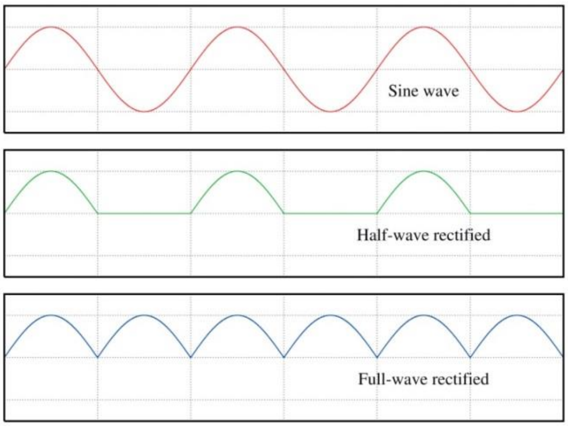

Figure 4

This question asks us to represent the circuit of a simple demodulator. For the first step, i.e. rectification, a simple diode may be used. Then for the second step, a simple low pass filter implemented as an RC circuit added in series to the diode may be used. This circuit, commonly known as the “envelope detector circuit”, is shown in the figure below, and the labels (1), (2) and (3) correspond to the waveforms shown in the figure above:

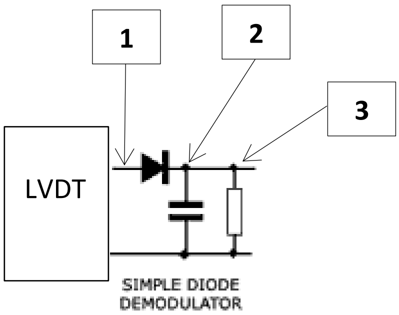

Figure 5

3) The signal of interest is given to be around 10 Hz. Now, the low-pass-filter part of the circuit in the figure above (the RC circuit) has a cutoff frequency of $f_{cutoff} = \frac{1}{2\pi RC}$. Then, selecting $f_{cutoff} = 15\ Hz$, the following could be plausible values for R and C:

$$\boldsymbol{R = 10\ k\Omega;\ C = 1\ \mu F}$$

4) In synchronous detection, rectifying is carried out in phase with the modulated signal, i.e. if the signal is positive, it is positively rectified, and if the signal is negative, it is negatively rectified. As a result, the output of synchronous detection can provide the sign of the displacement (positive or negative).