which corresponds to the representation described in a problem ([Discrete-Time](#_bookmark395) [Systems in the Time-Domain (Page 228)](#_bookmark395)) of a length-*q* boxcar flter.

###### Solution to Exercise 5.14.4

The unit-sample response's duration is q +1 and the signal's *Nx*. Thus the statement is correct.

###### Solution to Exercise 5.15.1

Let *N* denote the input's total duration. The time-domain implementation requires a total of *N(2q + 1)* computations, or *2q +1* computations per input value. In the frequency domain, we split the input into



sections, each of which requires



per input in the section. Because we divide **again** by *Nx* to fnd the number of computations per input value in the entire input, this quantity decreases as *Nx* increases. For the time-domain implementation, it stays constant.

###### Solution to Exercise 5.15.2



The delay is not computational delay here the plot shows the frst output value is aligned with the flter's frst input although in real systems this is an important consideration. Rather, the delay is due to the flter's phase shift: A phase-shifted sinusoid is equivalent to a time-delayed one:



All flters have phase shifts. This delay could be removed if the flter introduced no phase shift. Such flters do not exist in analog form, but digital ones can be programmed, but not in real time. Doing so would require the output to emerge before the input arrives!

###### Solution to Exercise 5.16.1

We have *p* + *q* +1 multiplications and *p* + *q* − 1 additions. Thus, the total number of arithmetic operations equals 2(*p* + *q*).