Hanning window was applied with a half-frame overlap. A length-512 FFT of each frame was computed, with the magnitude of the frst 257 FFT values displayed vertically, with spectral amplitude values color-coded.

###### Exercise 5.10.3

Why the specifc values of 256 for *N* and 512 for *K*? Another issue is how was the length-512 transform of each length-256 windowed frame computed?

### Discrete-Time Systems

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When we developed analog systems, interconnecting the circuit elements provided a natural starting place for constructing useful devices. In discrete-time signal processing, we are not limited by hardware considerations but by what can be constructed in software.

###### Exercise 5.11.1

One of the frst analog systems we described was the amplifer ([Amplifers (Page 27)](#_bookmark54): Amplifers). We found that implementing an amplifer was difcult in analog systems, requiring an op-amp at least. What is the discrete-time implementation of an amplifer? Is this especially hard or easy?

In fact, we will discover that frequency-domain implementation of systems, wherein we multiply the input signal's Fourier transform by a frequency response, is not only a viable alternative, but also a computationally efcient one. We begin with discussing the underlying mathematical structure of linear, shift-invariant systems, and devise how software flters can be constructed.

### Discrete-Time Systems in the Time-Domain

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A discrete-time signal *s(n)* is delayed by *n*0 samples when we write *s*(*n - n*0), with *n*0 > 0. Choosing *n*0 to be negative advances the signal along the integers. As opposed to analog delays ([Delay (Page 28)](#_bookmark56) : Delay), discrete-time delays can **only** be integer valued. In the frequency domain, delaying a signal corresponds to a linear phase shift of the signal's discrete-time Fourier transform :



**Linear** discrete-time systems have the superposition property. (5.40)