# CHAPTER 2
## *The Digital Representation of Sound, Part Two: Playing by the Numbers*

"The *Nyquist sampling theorem*...states that to well represent a signal, the sampling rate...needs to be at least twice the highest frequency contained in the sound of the signal."

– Burke et al., *Music and Computers*

## Terms & Concepts

**2.1 Digital Representation of Sound**
Time series
Continuous function (analog)
Discrete function (digital)
Analog to digital converter (ADC)
Digital to analog converter (DAC)
Interpolation
Audio graphs
- Audiogram ($a$ vs. $t$)
- Time-freq. rep. ($f$ vs. $t$)
Brightness <-> high $f$ content

**2.2 Analog vs. Digital**
Sampling
Sample rate ($sr$)
Sample resolution
Staircasing
Quantization error

**2.3 Sampling Theory**
Nyquist sampling theorem
Aliasing/foldover
Undersampling
Band-limited waveform
Nyquist frequency ($sr/2$)
Anti-aliasing filters
- Low-pass filter
- Pass band
- Roll off
- Frequency response

**2.4 Binary Numbers**
Binary number
Decimal number
Hexadecimal number
Bit (0 or 1)
Most significant bit
Least significant bit
$n$-bit system
Range of values in a $n$-bit system: 0 to ($2^n$ - 1)
$2^8 = 256$
$2^{16} = 65,536$
$2^{24} = 16,777,216$
etc.

**2.5 Bit Width**
Bit width/depth
Byte
Word
Kilobyte (K)
Megabyte (MB)
Gigabyte (GB)
Terabyte (TB)
*Petabyte, Exabyte, etc.*

**2.6 Digital Copying**
Digital vs. analog copies
Generations
Degradation
Sonic detail
Loss of high frequency information
Copyright Law

Performance rights organizations
- ASCAP
- BMI
- HFA
- SESAC
U.S. Constitution, Article I, Section 8
Digital watermarking

**2.7 Storage Concerns: The Size of Sound**
Compact disc technology
CD quality audio
- 44.1KHz
- 16 bit
- Stereo

**2.8 Compression**
Eliminating redundancy
Perceptual encoding
- mp3 and mp4
- $\mu$-law
Prediction algorithm
Adaptive compression technique
**M**oving **P**ictures **E**xpert **G**roup

**Misc.**
High quality audio sampling resolutions:
  - 16 bit
  - 24 bit
- etc.
Other sampling rates:
  - 48KHz (DVD soundtrack)
  - 96KHz

**Reference**
Burk, Phil, Larry Polansky, Douglas Repetto, Mary Roberts and Dan Rockmore. 2011. *Music and Computers: A Theoretical and Historical Approach*, Archival Version. Available online at:
<http://music.columbia.edu/cmc/MusicAndComputers/>.