Appendix A

Logarithms

Exponents

A logarithm (log) is the exponent to which a given base must be raised to equal the quantity. For example:

Since $Log^2 = 100$, then the log of 100 to the base 10 is equal to 2, or, $Log_{10}100 = 2$

Bases

There are three popular bases in use: 10, 2, and $\boldsymbol{e}$. Logarithms to the base 10 are called common logarithms (log). Logarithms in base $\boldsymbol{e}$ are called natural logarithms, where $\boldsymbol{e} \approx 2.71828$, abbreviated Ln:

Base 10

$Log_{10} 2 = 0.301$ is $10^{0.301} = 2$
$Log_{10} 200 = 2.301$ is $10^{2.301} = 200$

Base 2

$Log_2 8 = 3$ is $2^3 = 8$
$Log_2 256 = 8$ is $2^8 = 256$

Base e

$Ln_e 2.71828 = 1$ is $\boldsymbol{e}^1 = 2.71828$

$Ln_e 7.38905 = 2$ is $\boldsymbol{e}^2 = 7.38905$

Rules of Exponents

Since a logarithm is an exponent, the rules of exponents apply to logarithms:

$\log (M \times N) = (\log M) + (\log N)$
$\log (M / N) = (\log M) - (\log N)$
$\log M^N = N \log M$

Decibels

The bel is a logarithmic unit used to indicate a ratio of two *power levels* (sound, noise, or signal voltage, or microwaves). It is named in honor of Alexander Graham Bell (1847-1922) whose research accomplishments in sound were fundamental. A 1-bel change in strength represents a change of ten times the *power ratio*. In normal practice, the bel is a rather large unit, so the decibel (dB), which is $\frac{1}{10}$ of a bel, is commonly used.

$$\text{Number of dB} = 10 \log P2/P1$$

A 1dB increase is an increase of 1.258 times the power ratio: 1dB = 10 log 1.258. A 10dB increase is an increase of 10 times the power ratio, or 10dB = 10 log 10.

Other examples are:

3dB = 2 times the power ratio
20dB = 100 times the power ratio
-30dB = 0.001 times the power ratio

Note that the decibel is *not* an absolute quantity. It merely represents a change in power level relative to the level at some different time or place. It is meaningless to say that a given amplifier has an output of *x*dB unless that output is referenced to a specific power level. If we know the value of the input power, then the *ratio* of the output power to the specific input power (the power *gain*) may be expressed in dB.

If a standard *reference level* is used, then absolute power may be expressed in dB relative to that standard reference, commonly 1mW. Power refrenced to this level is expressed in dBm. Here are a few power ratios and associated dBms:

Power Ratio	dBm
1.258	1
2	3
10	10
100	20
0.001	-30

Appendix B

Alternating Current

To calculate power requirements:

The power required by an electrical device will be expressed in either *watts* (W), *amperes* (A), or as *VA* (Volt Amperes). For these purposes, VA=W. To convert from A or VA to W:

$$P = E \times I \quad \text{or,} \quad P/E = I$$

Where P=power in Watts, E is the voltage (in Volts, either 120 or 240), and I is amps. Ultimately, the total power should be expressed in amperes because electrical circuits are rated in amperes. A standard outlet is 15A. For example, if a mixer is 120V and 70W, the formula is 70 / 120 = .58A. If a limiter is 120V, 30VA, the power required is 30 / 120 = .25A.

Wiring practice: 220VAC One-Phase

For single-phase, 220VAC split into two 110VAC halves, at the transformer, the high-voltage inputs come in via three wires: the 220VAC output winding is divided into two equal parts and the third wire is the *center tap*. If the center tap is used as a reference, the voltage between it and either of the other two wires will be equal, or about 110VAC; these wires are called *legs*.

The three wires from the transformer are twisted together and run as a bundle to the service entrance. The non-insulated wire is the center tap and the electrical code requires that this wire be connected to ground at the service entrance.

Inside the main circuit breaker box are two large, insulated (usually black) wires that go to the two large screw terminals at the top of the banks of the circuit breakers. A volt meter will read 220VAC across the two wires, and 110VAC between either of the wires and the metal case of the box. Circuit breaker boxes are set up so that the breakers in a column alternate legs so as to load-share the current draw from the transformer.

The third wire, color-coded white, goes to a separate terminal block away from the circuit breakers. This is the neutral, the center tap of the transformer. This wire is connected to ground at this point. The terminal block has both the white neutral wires from all the circuits and all the ground wires from these circuits. This is the only place where ground and neutral should be connected. Ground wire is green.

Wiring practice: 3-Phase Wye 120/208

There are four wires used in this connection. A, B, and C are the three hot leads and the fourth wire is neutral. If you measure the voltage between each of the leads and neutral, you will find 120VAC. If you measure between any two of the hot leads, you will find 208VAC (because the two 120VAC circuits are 120˚ apart in phase.) There is no ground connection because the ground is made at the service entrance.

Because of Ohm's law and the resistance in the neutral wire, long runs will develop a voltage in the neutral wire. It can get upwards of 80VAC between neutral and ground in a long power run;

Wiring practice: 3-Phase Delta 120/208

Delta wiring has three wires, the main configuration used in major high-tension lines because there is no need for a fourth wire. Four-wire Delta has the fourth wire coming form the center tap of only one of three transformer windings, requiring a more complicated transformer. Because of this, you only have two connections that yield 120V; connecting to the third hot lead will give you 208V, between the wild leg* and neutral. If you measure between any two of the hot leads, you will find 240V. Note that Wye and Delta look the same; it takes a volt meter to tell the difference. (Ø = phase)

Wires	Wye	Delta
ØA to Neutral	120VAC	120VAC
ØB to Neutral	120VAC	208VAC*
ØB to Neutral	120VAC	120VAC
ØA to ØB	208VAC	208VAC
ØB to ØC	208VAC	208VAC
ØC to ØA	208VAC	208VAC

Appendix B

Troubleshooting

First, find the main circuit breaker box. This will yield the power available and its type. Optimally, there should be a master label which tells you if the panel is one-phase or three-phase. If there is a large master breaker at the top of the box, look at the number of sections operated: if there are two, there is most likely single-phase. If there are three, then it is probably three-phase.

Underneath the master breaker (if there is one), there will usually be two columns of breakers. In the case of a single-phase box, every other breaker in a column is connected to the same leg, and so also for rows. With three-phase, it is every third breaker in each column. To connect to power on the same leg, look for outlets with circuit breakers that are separated. Adjacent breakers are on different legs.

Next, look for grounded outlets close to where you need power. Make a visual inspection, looking for any damage to outlets or covers, and for evidence of major wear, such as a loose fit when a plug is inserted. If possible, check to make sure that the circuit breaker in question actually controls the outlet in question.

Use a voltmeter to check the outlets. There should be 120VAC between hot and neutral and also between hot and ground. Then make sure there is minimal voltage between neutral and ground. Between outlets (using an extension cord), measuring from hot to hot will yield 0V if the outlets are on the same leg; 208V if they are on different legs of a three-phase circuit; 240V for different single-phase circuit.

Impedance

Impedance and signal level are two different things. Level is the voltage swing in a circuit; the higher the level, the higher the voltage swings. Impedance is the resistance to signal flow in a circuit. It is the amount of power needed to move a signal around a circuit.

Connecting two devices and sending a signal between the two uses power. The sending device has to supply power in the form of a signal that is sent to the receiving device.

To determine the impedance of cables and patch cords, first, look at the spec for the cable. On it will be a value for capacitance per foot and inductance per foot. Using

$$\mathbf{Z = \sqrt{L/C}}$$

where Z = the cable impedance in Ω, L = the cable inductance in Henrys and C = the cable capacitance in Farads. For example, for

$$C = 34\text{pF}, \quad L = .17\mu\text{H}, \quad Z \approx 70\Omega$$

Professional line-level equipment designed to drive low source impedances, e.g., 600Ω loads, tends to have source output impedances in the range of 50Ω-600Ω. There is no relationship between impedance and balanced circuits. In practice, there are very few low source load impedances: telephone lines and tube circuits.

Semi-professional equipment, designed to drive loads of 10KΩ, tend to have source output impedances in the range of 600Ω-2KΩ.

Devices that are designed to be connected as bridging a 600Ω source load impedance typically have impedances of 5KΩ-10KΩ or greater.

Microphone inputs typically have a load termination impedance of about 1.4KΩ for low impedance microphones (mics with a source output impedance of 50Ω-600Ω), mid-range mics 1kΩ-4kΩ, and high impedance mics above 25kΩ. Low impedance microphones are better as they allow for long mic cables without noticeable hum or high-frequency loss.

Home stereo equipment has source output impedances between 1KΩ-10KΩ. This is the actual value inside the box at the circuit level; their load termination impedance ranges from 50KΩ-200KΩ.

Appendix C

Each waveform contains a unique profile of *harmonics* which determines its characteristic *timbre*.

The sine wave is a “pure” tone, i.e., one which contains no harmonics. It is used in additive synthesis to build up more complex sounds, in analog synthesis for *LFO* modulation (such as *vibrato* and *tremolo*), and also as an audio test signal.

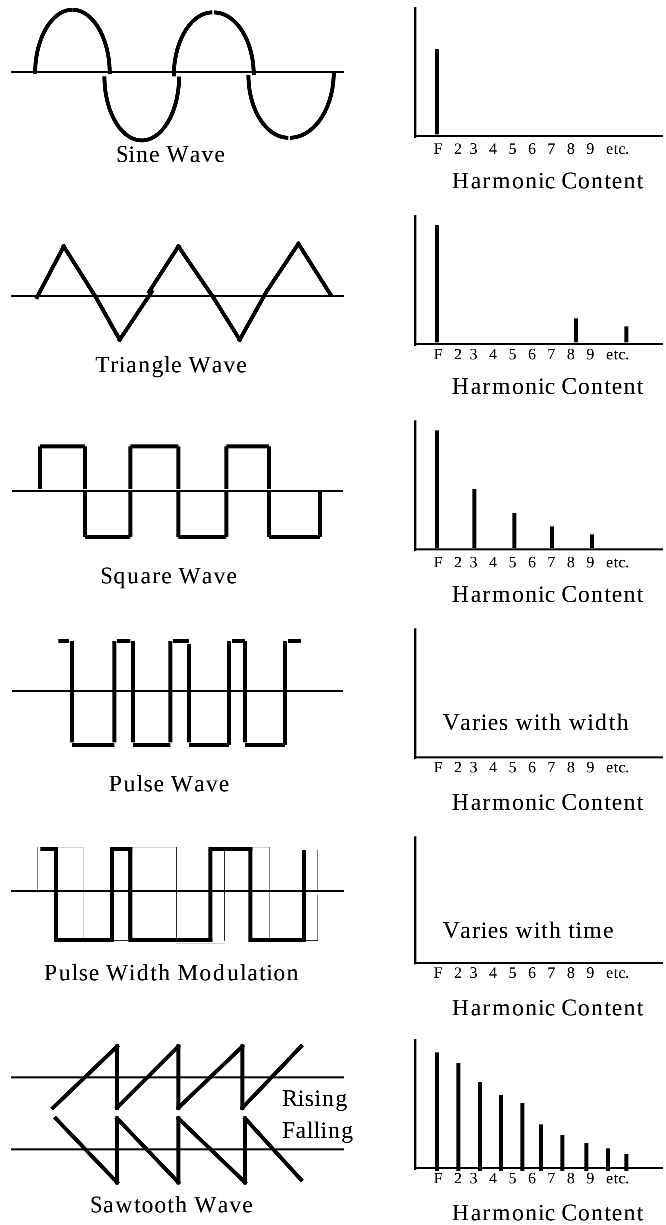
The sawtooth waveform, in contrast, contains all the harmonics in the audio range, although not in the same quantities. The loudness of each harmonic is inversely proportional to its frequency, so the harmonic with double the frequency of the fundamental is at half the volume, three times the frequency is at a third the volume, etc. This makes an ideal waveform for producing fuller sounds as it contains all of the frequencies related to the fundamental. The sawtooth may be either rising or falling.

The square wave contains only odd-numbered harmonics, again in inverse proportion to their frequency. The hollow sound produced by the square wave sounds much like the clarinet.

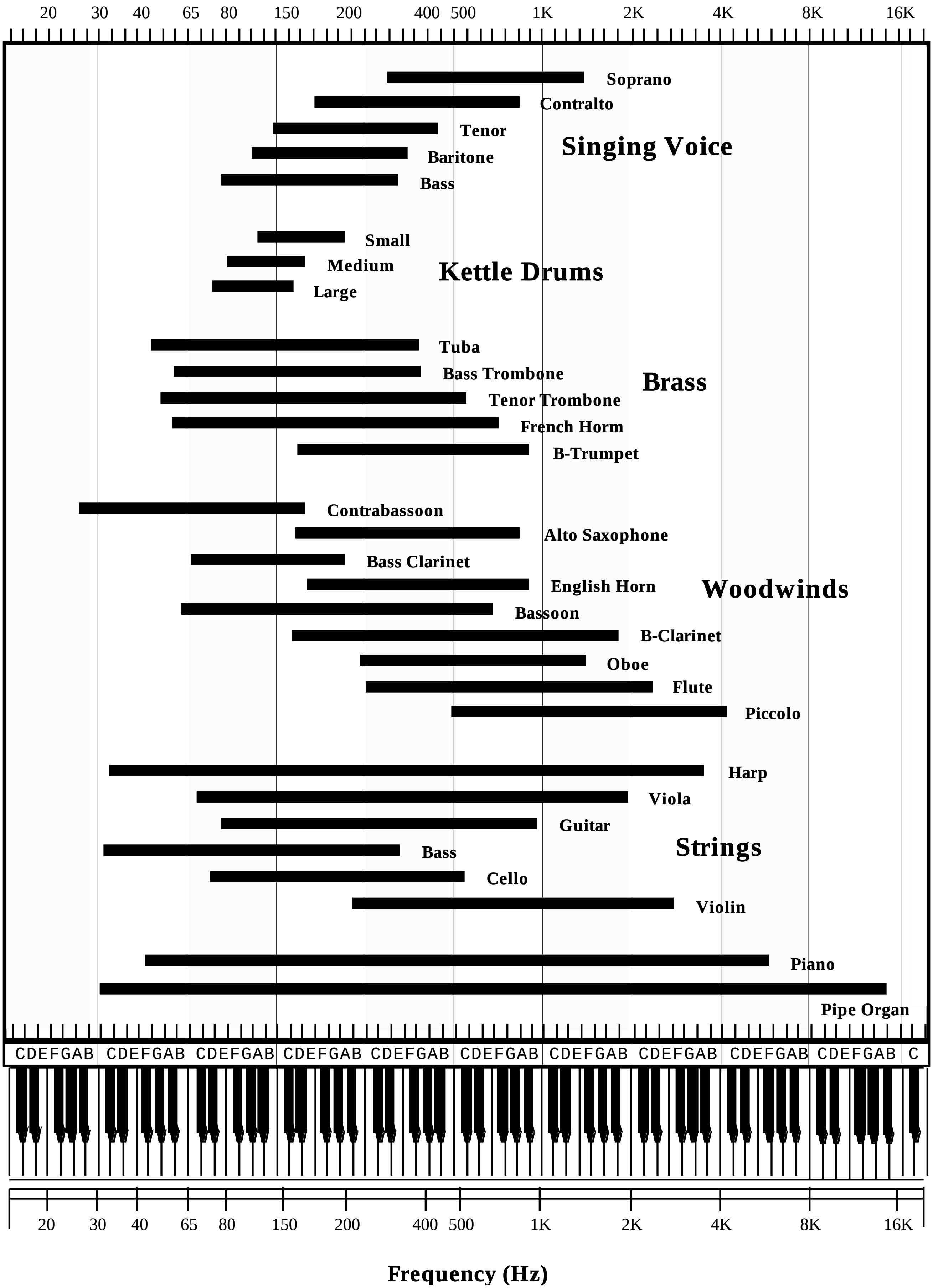
The square wave is actually a special case of the pulse wave, where the negative and positive sections of the cycle are of equal duration. It is the variable nature of the pulse wave which makes it interesting in sound synthesis. Not only are there infinite variations on the harmonic spectra available, but the pulse width may be swept. This is known as *pulse width modulation*. See *PWM*. The width parameter refers to the duration of the positive component in proportion to that of the complete cycle.

The square, sawtooth, and pulse waves contain whole families of frequencies in harmonic series. This means that the human ear perceives these sounds as a single pitch whose tonal quality is determined by the exact mix of harmonics present.

The triangle wave contains the fundamental and a few high harmonics. Normally found only in analog synthesis as a variant on sine wave modulation, but can be used as an alternative to the sine wave for LFO modulation, producing exponential, rather than linear variations.



Appendix D


20 30 40 65 80 150 200 400 500 1K 2K 4K 8K 16K
Soprano
Contralto
Tenor
Baritone
Bass
Singing Voice
Small
Medium
Large
Kettle Drums
Tuba
Bass Trombone
Tenor Trombone
French Horm
B-Trumpet
Brass
Contrabassoon
Alto Saxophone
Bass Clarinet
English Horn
Bassoon
B-Clarinet
Oboe
Flute
Piccolo
Woodwinds
Harp
Viola
Guitar
Bass
Cello
Violin
Strings
Piano
Pipe Organ
CDEFGAB CDEFGAB CDEFGAB CDEFGAB CDEFGAB CDEFGAB CDEFGAB CDEFGAB CDEFGAB CDEFGAB C
20 30 40 65 80 150 200 400 500 1K 2K 4K 8K 16K
Frequency (Hz)