In [2]:
```
import numpy as np
import matplotlib.pyplot as plt

from thinkdsp import decorate
```

exer02

In [3]:
```
from thinkdsp import Chirp
from thinkdsp import normalize, unbias

PI2 = 2 * np.pi

class SawtoothChirp(Chirp):
    """Represents a sawtooth signal with varying frequency."""

    def evaluate(self, ts):
        """Helper function that evaluates the signal.

        ts: float array of times
        """
        freqs = np.linspace(self.start, self.end, len(ts))
        dts = np.diff(ts, prepend=0)
        dphis = PI2 * freqs * dts
        phases = np.cumsum(dphis)
        cycles = phases / PI2
        frac, _ = np.modf(cycles)
        ys =  normalize(unbias(frac), self.amp)
        return ys
```

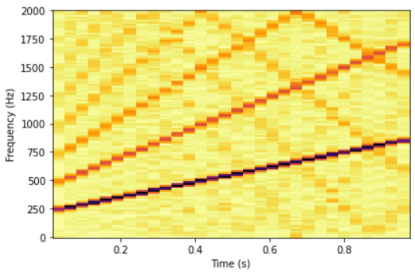
這就是它的聲音。

In [5]:
```
signal = SawtoothChirp(start=220, end=880)
wave = signal.make_wave(duration=1, framerate=4000)
wave.apodize()
wave.make_audio()
```

Out[5]:

這是頻譜圖。

In [6]:
```
sp = wave.make_spectrogram(256)
sp.plot()
decorate(xlabel='Time (s)', ylabel='Frequency (Hz)')
```



exer03

In [7]:
```
signal = SawtoothChirp(start=2500, end=3000)
wave = signal.make_wave(duration=1, framerate=20000)
wave.make_audio()
```

Out[7]:

In [8]:
```
wave.make_spectrum().plot()
decorate(xlabel='Frequency (Hz)')
```