

R.V.Raghunandan

BL.EN.U4AIE23147

SPEECH PROCESSING LAB 3

```
!pip install soundfile
!pip install simpleaudio
!pip install librosa
!pip install scipy

Requirement already satisfied: soundfile in
/usr/local/lib/python3.12/dist-packages (0.13.1)
Requirement already satisfied: cffi>=1.0 in
/usr/local/lib/python3.12/dist-packages (from soundfile) (2.0.0)
Requirement already satisfied: numpy in
/usr/local/lib/python3.12/dist-packages (from soundfile) (2.0.2)
Requirement already satisfied: pycparser in
/usr/local/lib/python3.12/dist-packages (from cffi>=1.0->soundfile)
(3.0)
```

Collecting simpleaudio

Downloading simpleaudio-1.0.4.tar.gz (2.0 MB)

2.0/2.0 MB 27.1 MB/s eta

0:00:00

etadata (setup.py) ... pleaudio

error: subprocess-exited-with-error

× python setup.py bdist\_wheel did not run successfully.

| exit code: 1

|> See above for output.

note: This error originates from a subprocess, and is likely not a problem with pip.

Building wheel for simpleaudio (setup.py) ... ERROR: Failed

building wheel for simpleaudio

pleaudio

Failed to build simpleaudio

ERROR: ERROR: Failed to build installable wheels for some pyproject.toml based projects (simpleaudio)

Requirement already satisfied: librosa in

/usr/local/lib/python3.12/dist-packages (0.11.0)

Requirement already satisfied: audioread>=2.1.9 in

/usr/local/lib/python3.12/dist-packages (from librosa) (3.1.0)

Requirement already satisfied: numba>=0.51.0 in

/usr/local/lib/python3.12/dist-packages (from librosa) (0.60.0)

Requirement already satisfied: numpy>=1.22.3 in

/usr/local/lib/python3.12/dist-packages (from librosa) (2.0.2)

Requirement already satisfied: scipy>=1.6.0 in

/usr/local/lib/python3.12/dist-packages (from librosa) (1.16.3)

Requirement already satisfied: scikit-learn>=1.1.0 in

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/usr/local/lib/python3.12/dist-packages (from librosa) (1.6.1)
Requirement already satisfied: joblib>=1.0 in
/usr/local/lib/python3.12/dist-packages (from librosa) (1.5.3)
Requirement already satisfied: decorator>=4.3.0 in
/usr/local/lib/python3.12/dist-packages (from librosa) (4.4.2)
Requirement already satisfied: soundfile>=0.12.1 in
/usr/local/lib/python3.12/dist-packages (from librosa) (0.13.1)
Requirement already satisfied: pooch>=1.1 in
/usr/local/lib/python3.12/dist-packages (from librosa) (1.9.0)
Requirement already satisfied: soxr>=0.3.2 in
/usr/local/lib/python3.12/dist-packages (from librosa) (1.0.0)
Requirement already satisfied: typing_extensions>=4.1.1 in
/usr/local/lib/python3.12/dist-packages (from librosa) (4.15.0)
Requirement already satisfied: lazy_loader>=0.1 in
/usr/local/lib/python3.12/dist-packages (from librosa) (0.4)
Requirement already satisfied: msgpack>=1.0 in
/usr/local/lib/python3.12/dist-packages (from librosa) (1.1.2)
Requirement already satisfied: packaging in
/usr/local/lib/python3.12/dist-packages (from lazy_loader>=0.1-
>librosa) (26.0)
Requirement already satisfied: llvmlite<0.44,>=0.43.0dev0 in
/usr/local/lib/python3.12/dist-packages (from numba>=0.51.0->librosa)
(0.43.0)
Requirement already satisfied: platformdirs>=2.5.0 in
/usr/local/lib/python3.12/dist-packages (from pooch>=1.1->librosa)
(4.9.2)
Requirement already satisfied: requests>=2.19.0 in
/usr/local/lib/python3.12/dist-packages (from pooch>=1.1->librosa)
(2.32.4)
Requirement already satisfied: threadpoolctl>=3.1.0 in
/usr/local/lib/python3.12/dist-packages (from scikit-learn>=1.1.0-
>librosa) (3.6.0)
Requirement already satisfied: cffi>=1.0 in
/usr/local/lib/python3.12/dist-packages (from soundfile>=0.12.1-
>librosa) (2.0.0)
Requirement already satisfied: pycparser in
/usr/local/lib/python3.12/dist-packages (from cffi>=1.0-
>soundfile>=0.12.1->librosa) (3.0)
Requirement already satisfied: charset_normalizer<4,>=2 in
/usr/local/lib/python3.12/dist-packages (from requests>=2.19.0-
>pooch>=1.1->librosa) (3.4.4)
Requirement already satisfied: idna<4,>=2.5 in
/usr/local/lib/python3.12/dist-packages (from requests>=2.19.0-
>pooch>=1.1->librosa) (3.11)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.12/dist-packages (from requests>=2.19.0-
>pooch>=1.1->librosa) (2.5.0)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.12/dist-packages (from requests>=2.19.0-
```

```
>pooch>=1.1->librosa) (2026.1.4)
Requirement already satisfied: scipy in
/usr/local/lib/python3.12/dist-packages (1.16.3)
Requirement already satisfied: numpy<2.6,>=1.25.2 in
/usr/local/lib/python3.12/dist-packages (from scipy) (2.0.2)
```

1

```
import numpy as np
import matplotlib.pyplot as plt
import soundfile as sf
from IPython.display import Audio
import librosa
import librosa.display

y, sr = sf.read("/content/speech.wav")
Audio(y, rate=sr)
num_samples = len(y)
duration = num_samples / sr
librosa.resample(y.astype(float), orig_sr=sr, target_sr=16000)

array([0.00000000e+00, 0.00000000e+00, 0.00000000e+00, ...,
        0.00000000e+00, 7.27595761e-12, 3.63797881e-12])
```

2

```
import torch
import librosa
import soundfile as sf
from transformers import Wav2Vec2Processor, Wav2Vec2ForCTC

processor = Wav2Vec2Processor.from_pretrained("Bluecast/wav2vec2-Phoneme")
model = Wav2Vec2ForCTC.from_pretrained("Bluecast/wav2vec2-Phoneme")

if sr != 16000:
    y = librosa.resample(y.astype(float), orig_sr=sr, target_sr=16000)
    sr = 16000

input_values = processor(y, sampling_rate=sr,
return_tensors="pt").input_values

with torch.no_grad():
    logits = model(input_values).logits

predicted_ids = torch.argmax(logits, dim=-1)
phoneme_sequence = processor.batch_decode(predicted_ids)
print("Recognized phoneme sequence:")
print(phoneme_sequence[0])
```

```
{"model_id": "64d160e11bb14bba8576e37569a7754b", "version_major": 2, "version_minor": 0}
```

```
{"model_id": "262564fa05924288b0405672eb877fe6", "version_major": 2, "version_minor": 0}
```

Recognized phoneme sequence:

sh iy jh ah jh d dh ah b l uw p eh n p uh t ih t aa n dh ah t ey b ah  
l ah n d k w ay ah t l iy w ih s p er d y eh s

```
!pip install transformers datasets torchaudio
```

```
Requirement already satisfied: transformers in  
/usr/local/lib/python3.12/dist-packages (5.0.0)  
Requirement already satisfied: datasets in  
/usr/local/lib/python3.12/dist-packages (4.0.0)  
Requirement already satisfied: torchaudio in  
/usr/local/lib/python3.12/dist-packages (2.10.0+cpu)  
Requirement already satisfied: filelock in  
/usr/local/lib/python3.12/dist-packages (from transformers) (3.24.2)  
Requirement already satisfied: huggingface-hub<2.0,>=1.3.0 in  
/usr/local/lib/python3.12/dist-packages (from transformers) (1.4.1)  
Requirement already satisfied: numpy>=1.17 in  
/usr/local/lib/python3.12/dist-packages (from transformers) (2.0.2)  
Requirement already satisfied: packaging>=20.0 in  
/usr/local/lib/python3.12/dist-packages (from transformers) (26.0)  
Requirement already satisfied: pyyaml>=5.1 in  
/usr/local/lib/python3.12/dist-packages (from transformers) (6.0.3)  
Requirement already satisfied: regex!=2019.12.17 in  
/usr/local/lib/python3.12/dist-packages (from transformers)  
(2025.11.3)  
Requirement already satisfied: tokenizers<=0.23.0,>=0.22.0 in  
/usr/local/lib/python3.12/dist-packages (from transformers) (0.22.2)  
Requirement already satisfied: typer-slim in  
/usr/local/lib/python3.12/dist-packages (from transformers) (0.24.0)  
Requirement already satisfied: safetensors>=0.4.3 in  
/usr/local/lib/python3.12/dist-packages (from transformers) (0.7.0)  
Requirement already satisfied: tqdm>=4.27 in  
/usr/local/lib/python3.12/dist-packages (from transformers) (4.67.3)  
Requirement already satisfied: pyarrow>=15.0.0 in  
/usr/local/lib/python3.12/dist-packages (from datasets) (18.1.0)  
Requirement already satisfied: dill<0.3.9,>=0.3.0 in  
/usr/local/lib/python3.12/dist-packages (from datasets) (0.3.8)  
Requirement already satisfied: pandas in  
/usr/local/lib/python3.12/dist-packages (from datasets) (2.2.2)  
Requirement already satisfied: requests>=2.32.2 in  
/usr/local/lib/python3.12/dist-packages (from datasets) (2.32.4)  
Requirement already satisfied: xxhash in  
/usr/local/lib/python3.12/dist-packages (from datasets) (3.6.0)  
Requirement already satisfied: multiprocessing<0.70.17 in
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/usr/local/lib/python3.12/dist-packages (from datasets) (0.70.16)  
Requirement already satisfied: fsspec<=2025.3.0,>=2023.1.0 in  
/usr/local/lib/python3.12/dist-packages (from  
fsspec[http]<=2025.3.0,>=2023.1.0->datasets) (2025.3.0)  
Requirement already satisfied: torch==2.10.0 in  
/usr/local/lib/python3.12/dist-packages (from torchaudio) (2.10.0+cpu)  
Requirement already satisfied: typing-extensions>=4.10.0 in  
/usr/local/lib/python3.12/dist-packages (from torch==2.10.0-  
>torchaudio) (4.15.0)  
Requirement already satisfied: setuptools in  
/usr/local/lib/python3.12/dist-packages (from torch==2.10.0-  
>torchaudio) (75.2.0)  
Requirement already satisfied: sympy>=1.13.3 in  
/usr/local/lib/python3.12/dist-packages (from torch==2.10.0-  
>torchaudio) (1.14.0)  
Requirement already satisfied: networkx>=2.5.1 in  
/usr/local/lib/python3.12/dist-packages (from torch==2.10.0-  
>torchaudio) (3.6.1)  
Requirement already satisfied: jinja2 in  
/usr/local/lib/python3.12/dist-packages (from torch==2.10.0-  
>torchaudio) (3.1.6)  
Requirement already satisfied: aiohttp!=4.0.0a0,!4.0.0a1 in  
/usr/local/lib/python3.12/dist-packages (from  
fsspec[http]<=2025.3.0,>=2023.1.0->datasets) (3.13.3)  
Requirement already satisfied: hf-xet<2.0.0,>=1.2.0 in  
/usr/local/lib/python3.12/dist-packages (from huggingface-  
hub<2.0,>=1.3.0->transformers) (1.2.0)  
Requirement already satisfied: httpx<1,>=0.23.0 in  
/usr/local/lib/python3.12/dist-packages (from huggingface-  
hub<2.0,>=1.3.0->transformers) (0.28.1)  
Requirement already satisfied: shellingham in  
/usr/local/lib/python3.12/dist-packages (from huggingface-  
hub<2.0,>=1.3.0->transformers) (1.5.4)  
Requirement already satisfied: charset\_normalizer<4,>=2 in  
/usr/local/lib/python3.12/dist-packages (from requests>=2.32.2-  
>datasets) (3.4.4)  
Requirement already satisfied: idna<4,>=2.5 in  
/usr/local/lib/python3.12/dist-packages (from requests>=2.32.2-  
>datasets) (3.11)  
Requirement already satisfied: urllib3<3,>=1.21.1 in  
/usr/local/lib/python3.12/dist-packages (from requests>=2.32.2-  
>datasets) (2.5.0)  
Requirement already satisfied: certifi>=2017.4.17 in  
/usr/local/lib/python3.12/dist-packages (from requests>=2.32.2-  
>datasets) (2026.1.4)  
Requirement already satisfied: python-dateutil>=2.8.2 in  
/usr/local/lib/python3.12/dist-packages (from pandas->datasets)  
(2.9.0.post0)  
Requirement already satisfied: pytz>=2020.1 in

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/usr/local/lib/python3.12/dist-packages (from pandas->datasets)
(2025.2)
Requirement already satisfied: tzdata>=2022.7 in
/usr/local/lib/python3.12/dist-packages (from pandas->datasets)
(2025.3)
Requirement already satisfied: typer>=0.24.0 in
/usr/local/lib/python3.12/dist-packages (from typer-slim-
>transformers) (0.24.0)
Requirement already satisfied: aiohappyeyeballs>=2.5.0 in
/usr/local/lib/python3.12/dist-packages (from aiohttp!=4.0.0a0,!
=4.0.0a1->fsspec[http]<=2025.3.0,>=2023.1.0->datasets) (2.6.1)
Requirement already satisfied: aiosignal>=1.4.0 in
/usr/local/lib/python3.12/dist-packages (from aiohttp!=4.0.0a0,!
=4.0.0a1->fsspec[http]<=2025.3.0,>=2023.1.0->datasets) (1.4.0)
Requirement already satisfied: attrs>=17.3.0 in
/usr/local/lib/python3.12/dist-packages (from aiohttp!=4.0.0a0,!
=4.0.0a1->fsspec[http]<=2025.3.0,>=2023.1.0->datasets) (25.4.0)
Requirement already satisfied: frozenlist>=1.1.1 in
/usr/local/lib/python3.12/dist-packages (from aiohttp!=4.0.0a0,!
=4.0.0a1->fsspec[http]<=2025.3.0,>=2023.1.0->datasets) (1.8.0)
Requirement already satisfied: multidict<7.0,>=4.5 in
/usr/local/lib/python3.12/dist-packages (from aiohttp!=4.0.0a0,!
=4.0.0a1->fsspec[http]<=2025.3.0,>=2023.1.0->datasets) (6.7.1)
Requirement already satisfied: propcache>=0.2.0 in
/usr/local/lib/python3.12/dist-packages (from aiohttp!=4.0.0a0,!
=4.0.0a1->fsspec[http]<=2025.3.0,>=2023.1.0->datasets) (0.4.1)
Requirement already satisfied: yarl<2.0,>=1.17.0 in
/usr/local/lib/python3.12/dist-packages (from aiohttp!=4.0.0a0,!
=4.0.0a1->fsspec[http]<=2025.3.0,>=2023.1.0->datasets) (1.22.0)
Requirement already satisfied: anyio in
/usr/local/lib/python3.12/dist-packages (from httpx<1,>=0.23.0-
>huggingface-hub<2.0,>=1.3.0->transformers) (4.12.1)
Requirement already satisfied: httpcore==1.* in
/usr/local/lib/python3.12/dist-packages (from httpx<1,>=0.23.0-
>huggingface-hub<2.0,>=1.3.0->transformers) (1.0.9)
Requirement already satisfied: h11>=0.16 in
/usr/local/lib/python3.12/dist-packages (from httpcore==1.*-
>httpx<1,>=0.23.0->huggingface-hub<2.0,>=1.3.0->transformers) (0.16.0)
Requirement already satisfied: six>=1.5 in
/usr/local/lib/python3.12/dist-packages (from python-dateutil>=2.8.2-
>pandas->datasets) (1.17.0)
Requirement already satisfied: mpmath<1.4,>=1.1.0 in
/usr/local/lib/python3.12/dist-packages (from sympy>=1.13.3-
>torch==2.10.0->torchaudio) (1.3.0)
Requirement already satisfied: click>=8.2.1 in
/usr/local/lib/python3.12/dist-packages (from typer>=0.24.0->typer-
slim->transformers) (8.3.1)
Requirement already satisfied: rich>=12.3.0 in
/usr/local/lib/python3.12/dist-packages (from typer>=0.24.0->typer-
```

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slim->transformers) (13.9.4)
Requirement already satisfied: annotated-doc>=0.0.2 in
/usr/local/lib/python3.12/dist-packages (from typer>=0.24.0->typer-
slim->transformers) (0.0.4)
Requirement already satisfied: MarkupSafe>=2.0 in
/usr/local/lib/python3.12/dist-packages (from jinja2->torch==2.10.0-
>torchaudio) (3.0.3)
Requirement already satisfied: markdown-it-py>=2.2.0 in
/usr/local/lib/python3.12/dist-packages (from rich>=12.3.0-
>typer>=0.24.0->typer-slim->transformers) (4.0.0)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in
/usr/local/lib/python3.12/dist-packages (from rich>=12.3.0-
>typer>=0.24.0->typer-slim->transformers) (2.19.2)
Requirement already satisfied: mdurl~=0.1 in
/usr/local/lib/python3.12/dist-packages (from markdown-it-py>=2.2.0-
>rich>=12.3.0->typer>=0.24.0->typer-slim->transformers) (0.1.2)

```

3

```

phoneme_sequence_str = processor.batch_decode(predicted_ids)[0]
words = phoneme_sequence_str.strip().split(" ")
frame_ids = torch.argmax(logits, dim=-1)[0].cpu().numpy()
frame_phonemes = processor.batch_decode([frame_ids])[0]
frame_duration = model.config.inputs_to_logits_ratio / sr

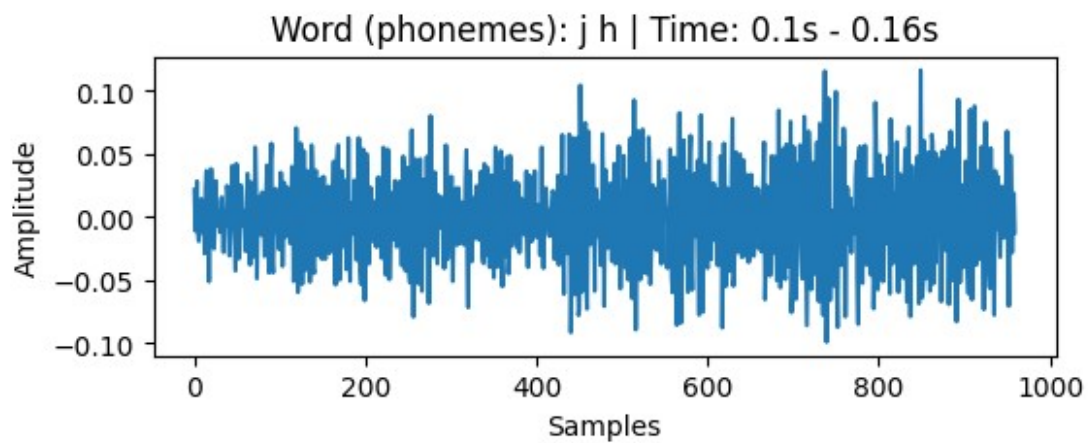
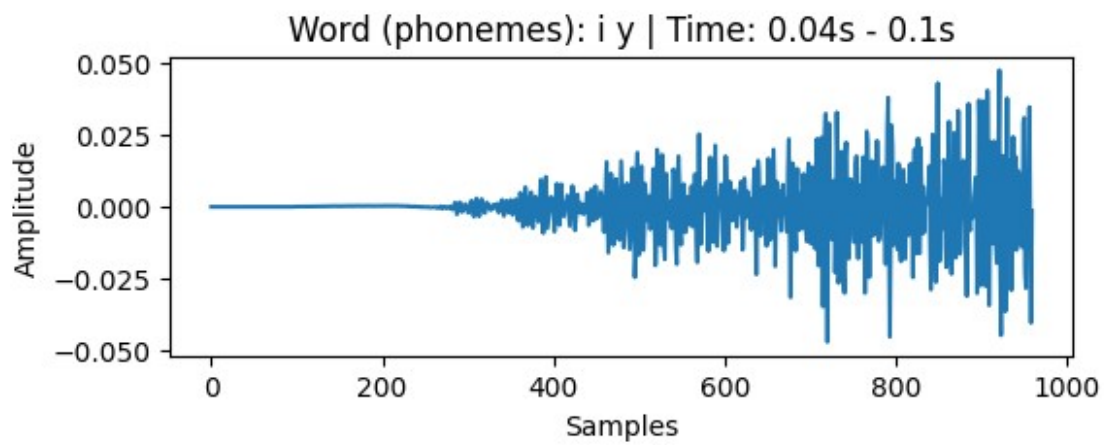
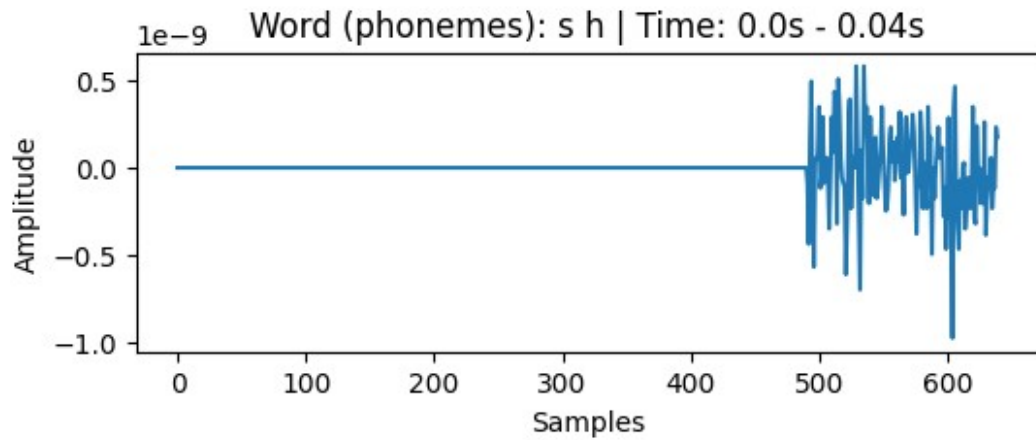
segments = []
current_word = []
start_time = 0.0

for i, phoneme in enumerate(frame_phonemes):
    if phoneme == " " or phoneme == "|":
        if current_word:
            end_time = i * frame_duration
            segments.append((" ".join(current_word), start_time,
end_time))
            current_word = []
            start_time = end_time
        else:
            current_word.append(phoneme)
    if current_word:
        segments.append((" ".join(current_word), start_time,
len(frame_phonemes) * frame_duration))

for word, start, end in segments:
    start_sample = int(start * sr)
    end_sample = int(end * sr)
    plt.figure(figsize=(6, 2))
    plt.plot(y[start_sample:end_sample])
    plt.title(f"Word (phonemes): {word} | Time: {round(start,2)}s -

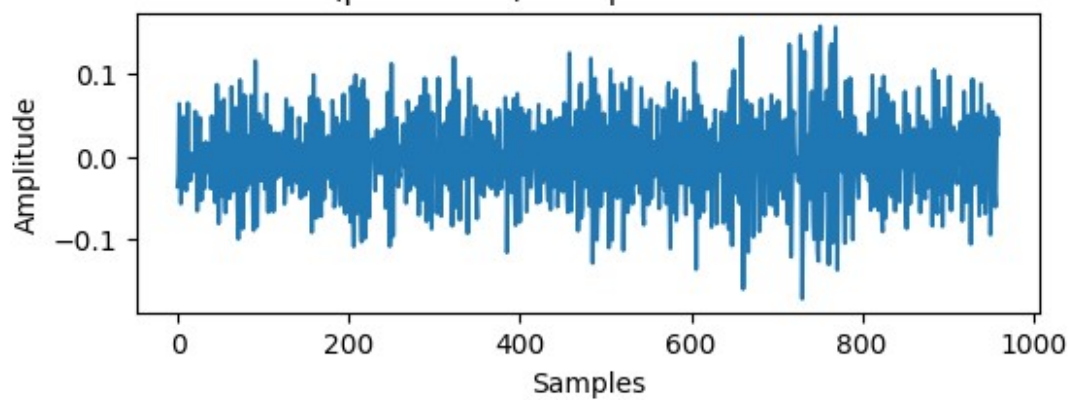
```

```
{round(end,2)}s")  
plt.xlabel("Samples")  
plt.ylabel("Amplitude")  
plt.show()
```

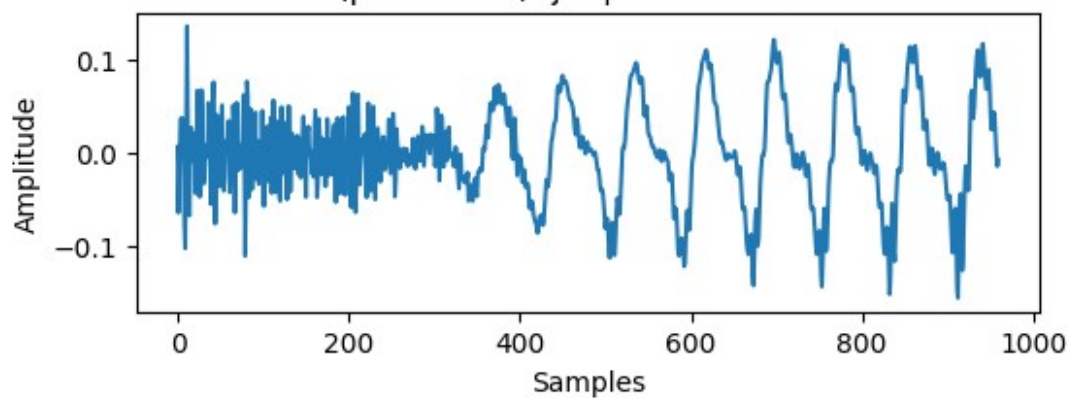




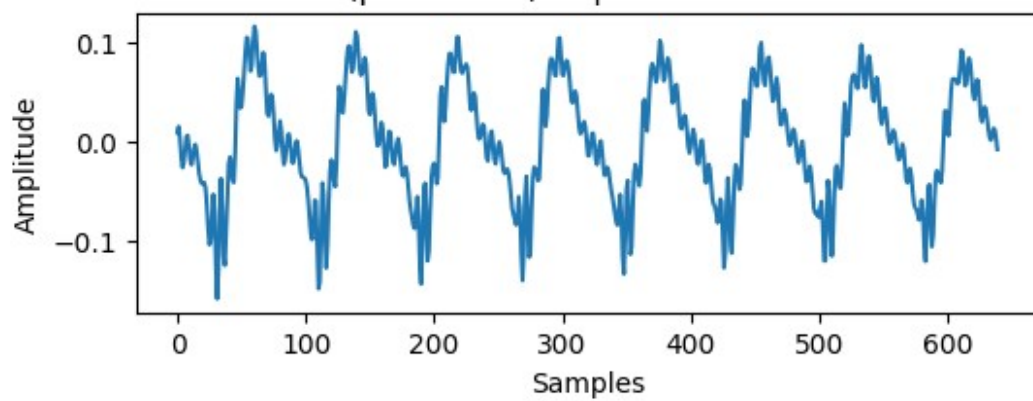
Word (phonemes): a h | Time: 0.16s - 0.22s



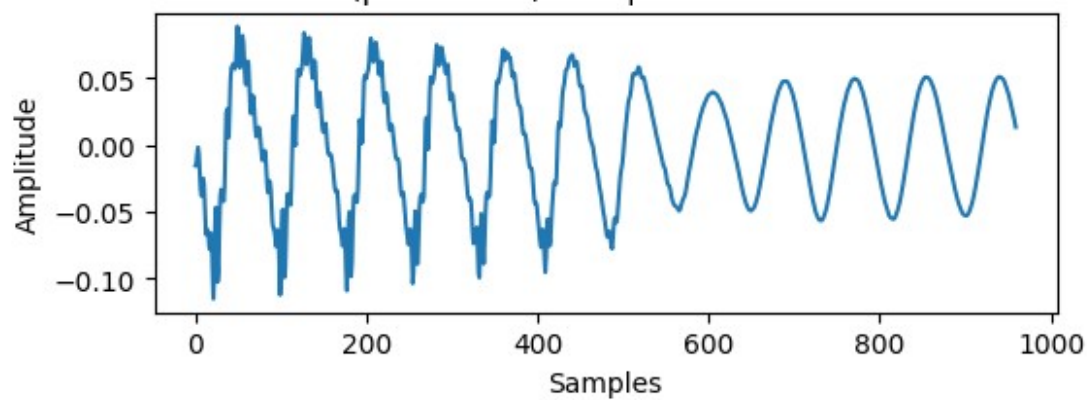
Word (phonemes): j h | Time: 0.22s - 0.28s



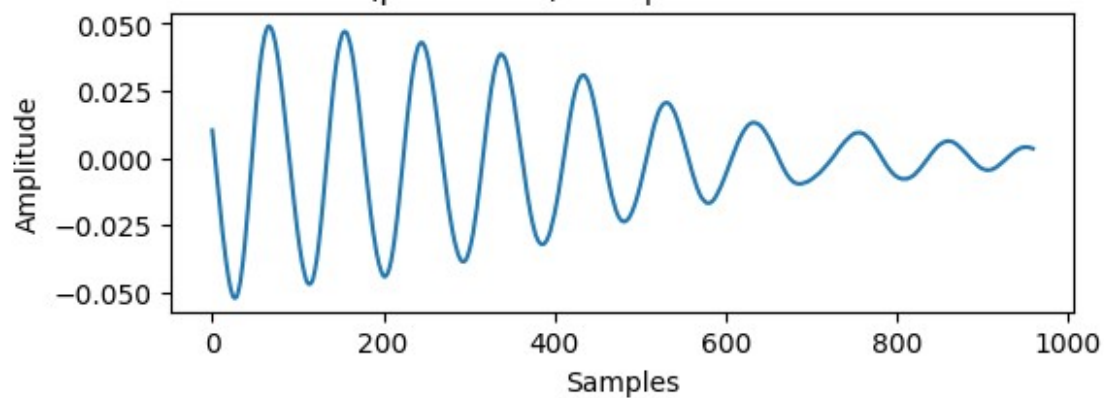
Word (phonemes): d | Time: 0.28s - 0.32s



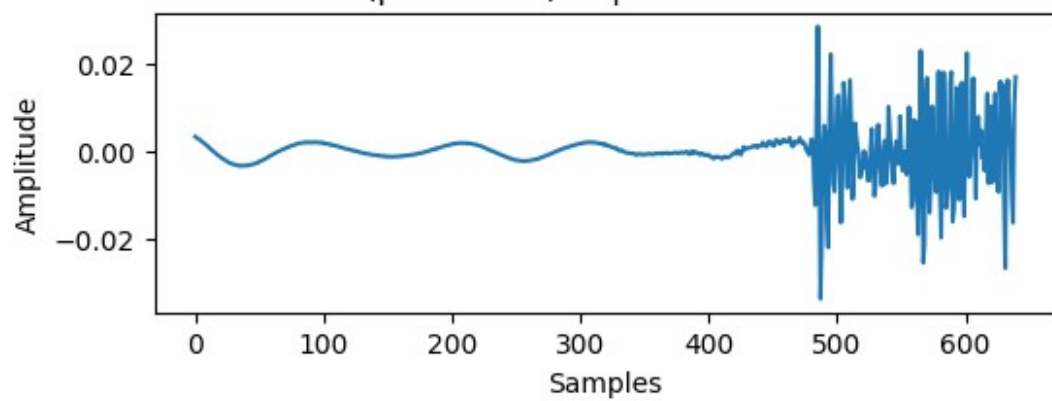
Word (phonemes): d h | Time: 0.32s - 0.38s



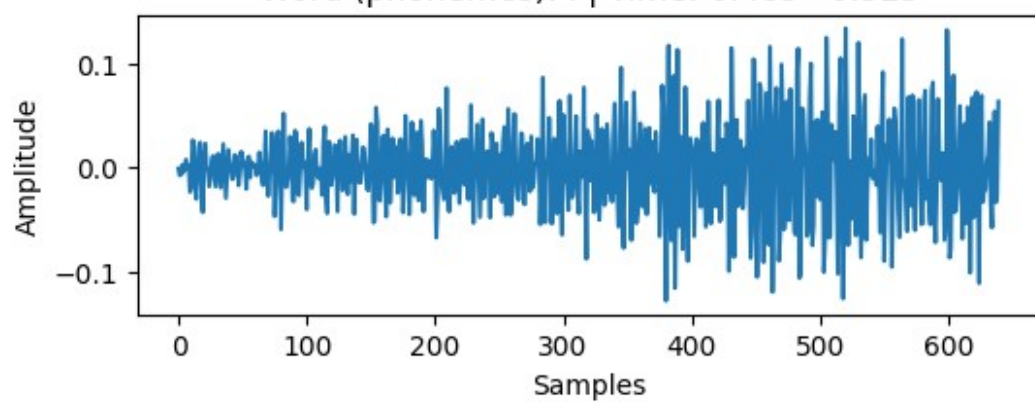
Word (phonemes): a h | Time: 0.38s - 0.44s



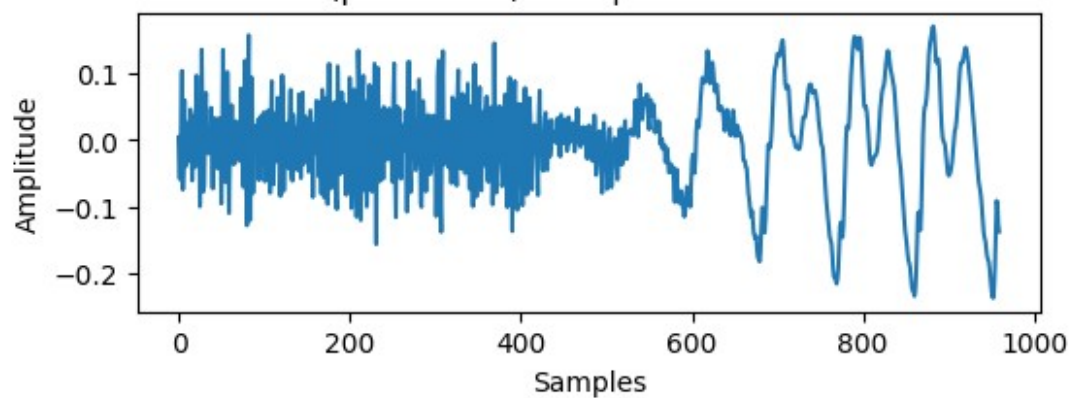
Word (phonemes): b | Time: 0.44s - 0.48s



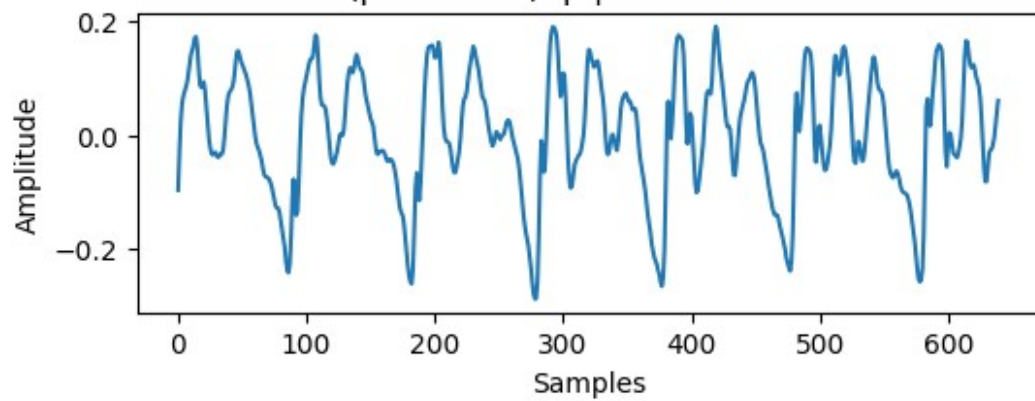
Word (phonemes): l | Time: 0.48s - 0.52s



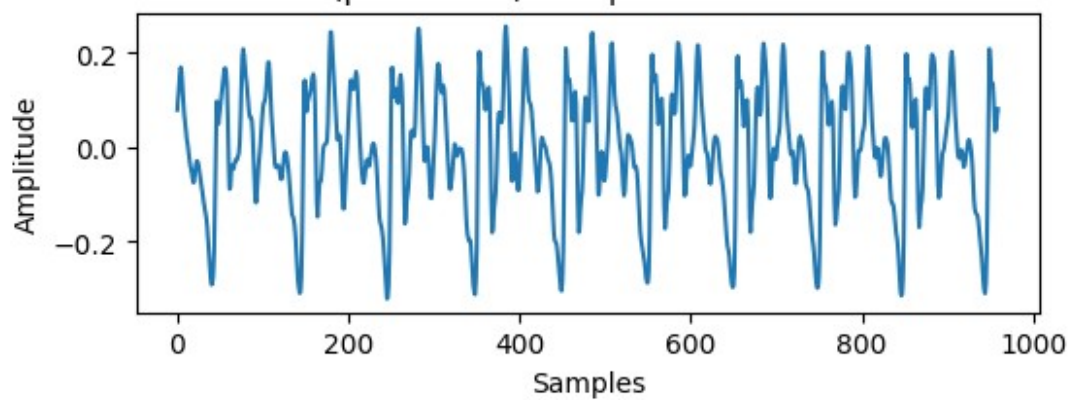
Word (phonemes): u w | Time: 0.52s - 0.58s



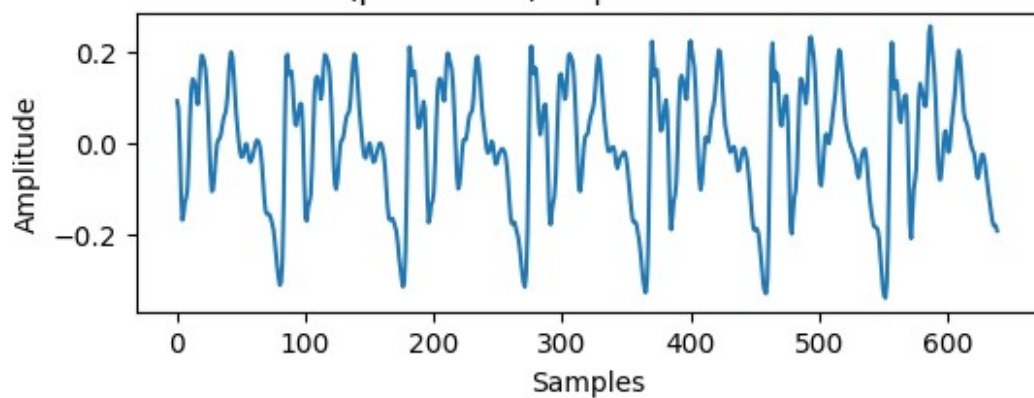
Word (phonemes): p | Time: 0.58s - 0.62s



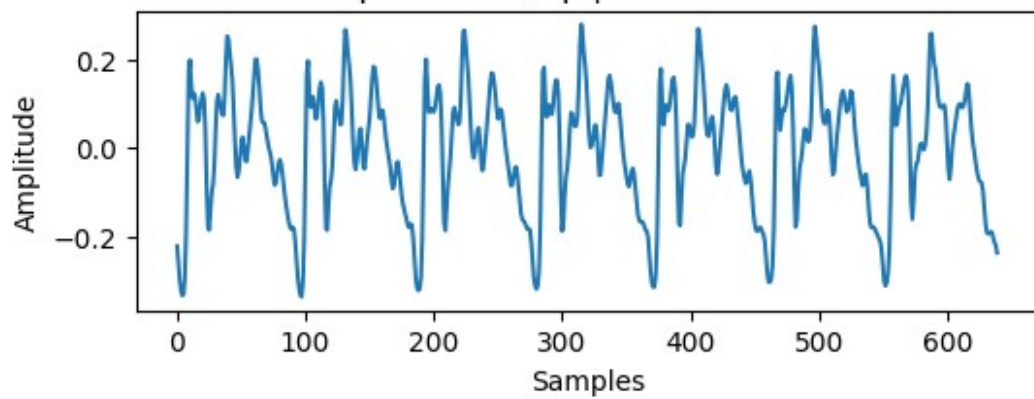
Word (phonemes): e h | Time: 0.62s - 0.68s



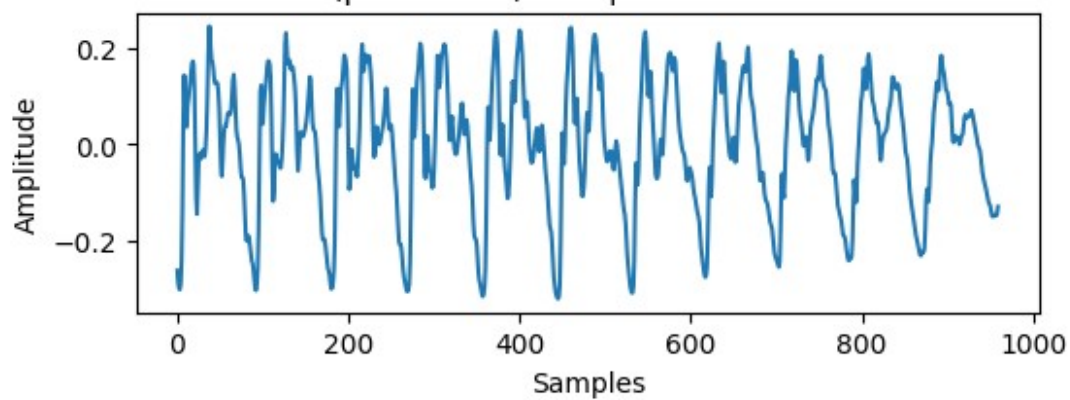
Word (phonemes): n | Time: 0.68s - 0.72s



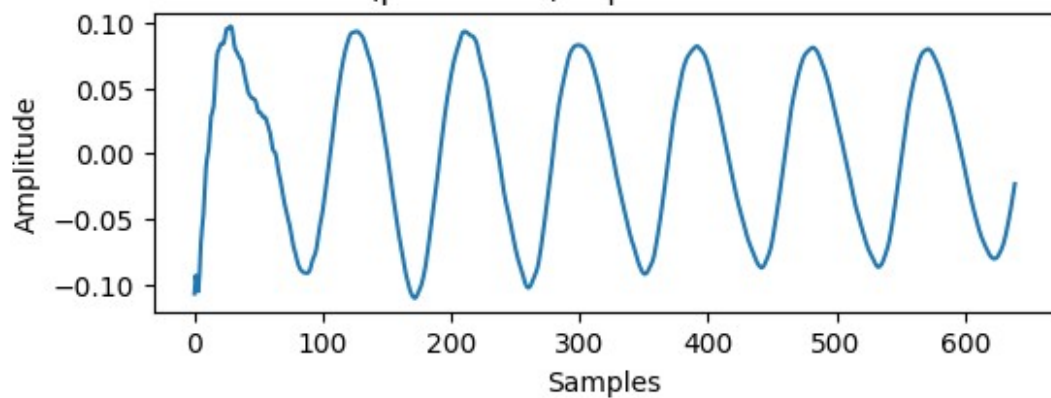
Word (phonemes): p | Time: 0.72s - 0.76s



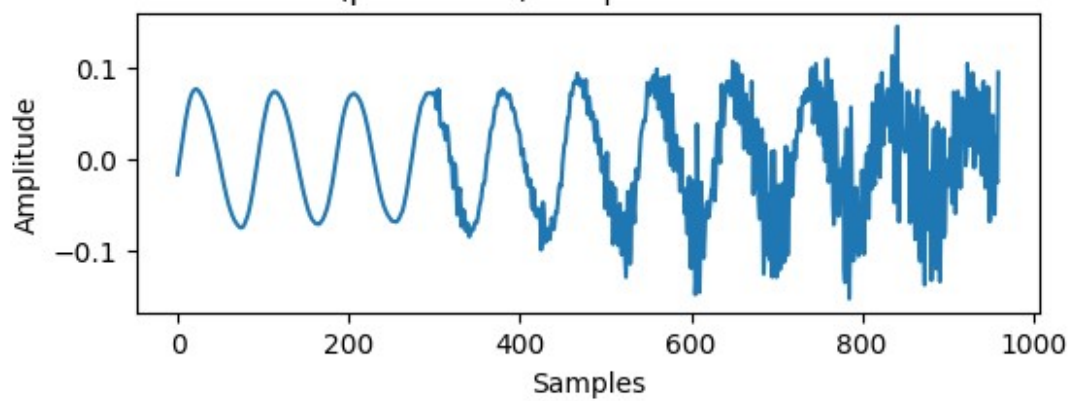
Word (phonemes): u h | Time: 0.76s - 0.82s



Word (phonemes): t | Time: 0.82s - 0.86s

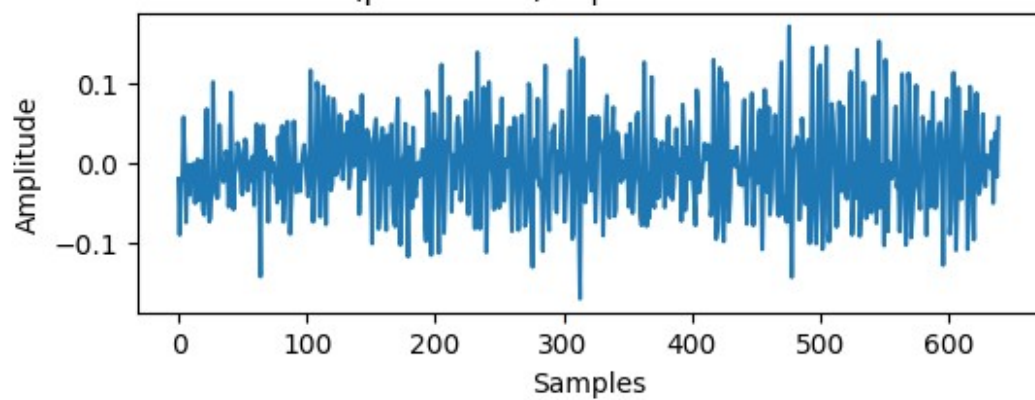


Word (phonemes): i h | Time: 0.86s - 0.92s

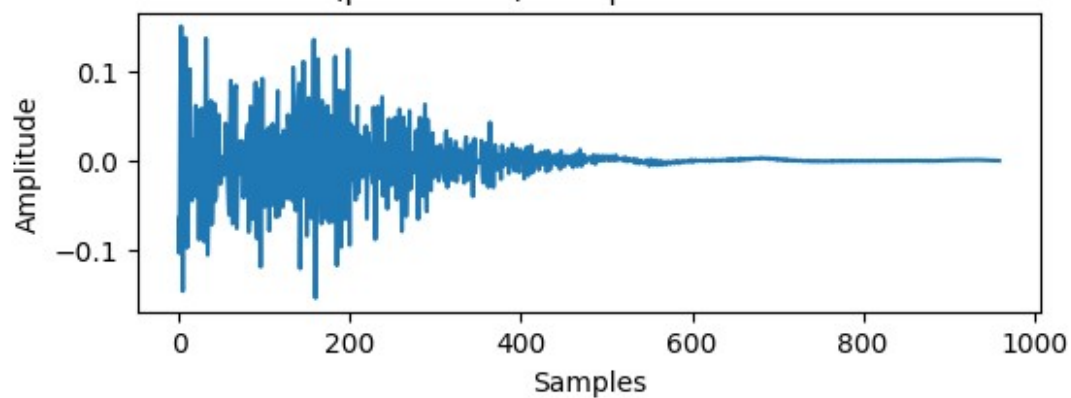




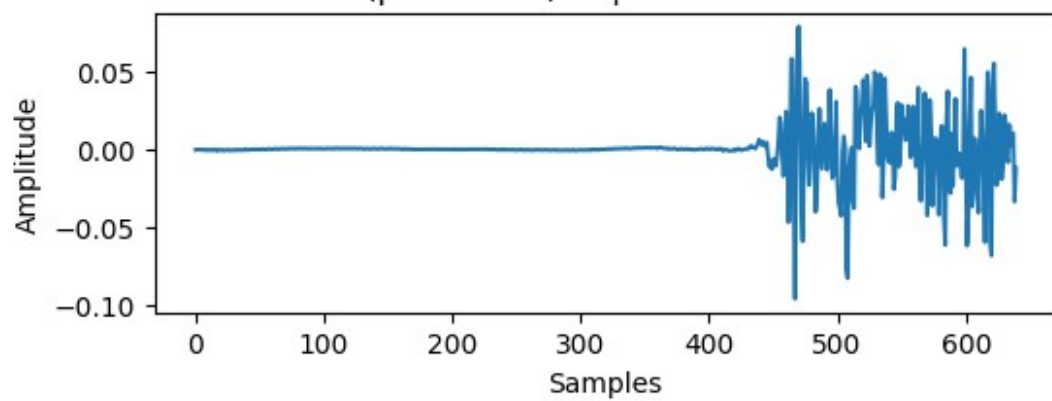
Word (phonemes): t | Time: 0.92s - 0.96s



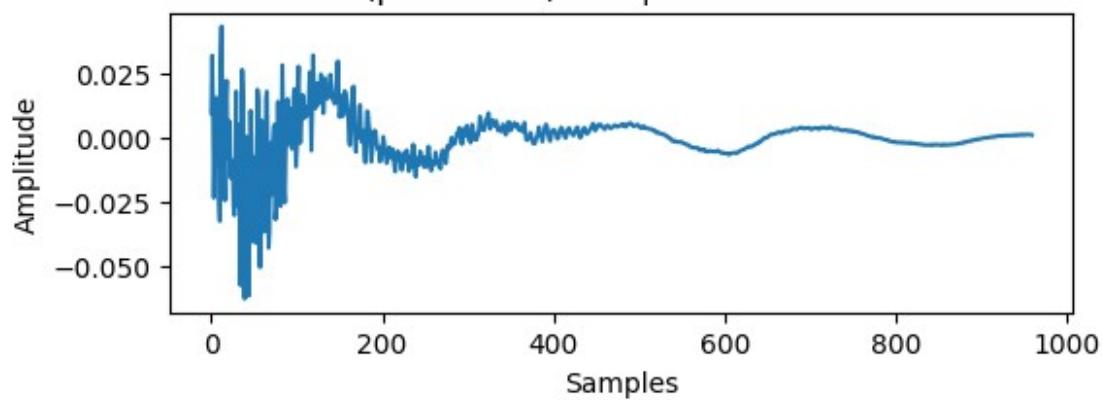
Word (phonemes): a a | Time: 0.96s - 1.02s



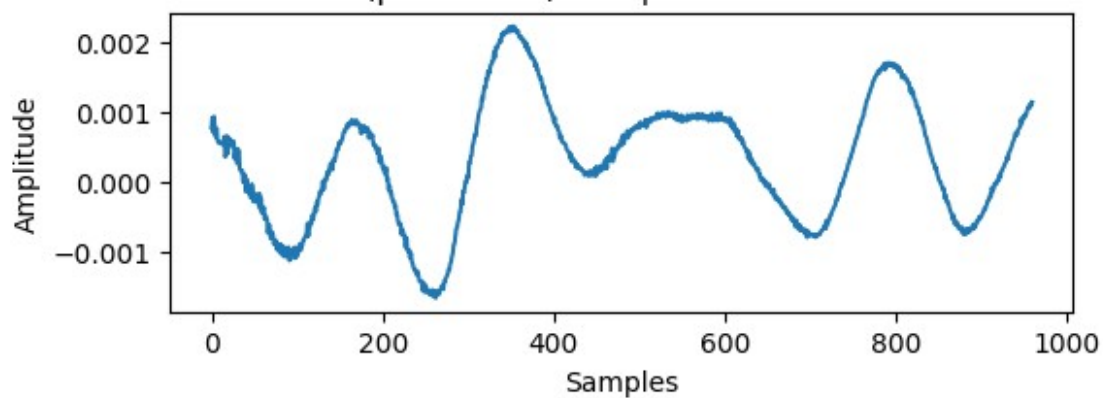
Word (phonemes): n | Time: 1.02s - 1.06s



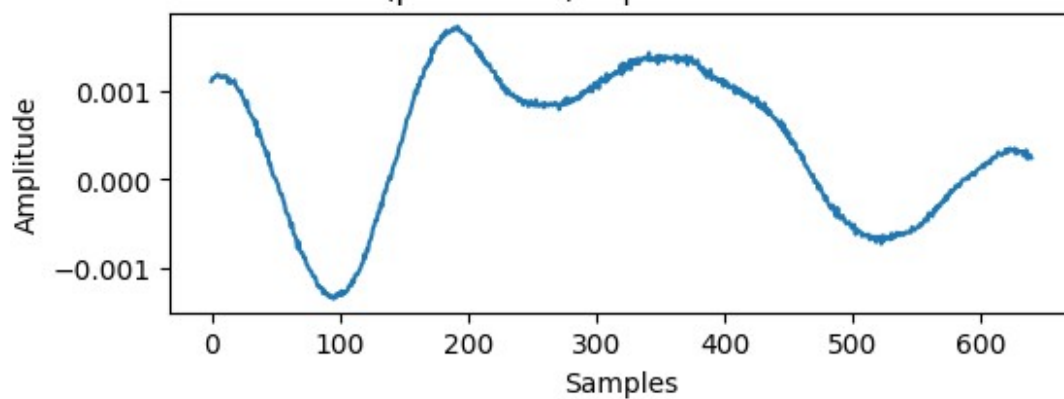
Word (phonemes): d h | Time: 1.06s - 1.12s

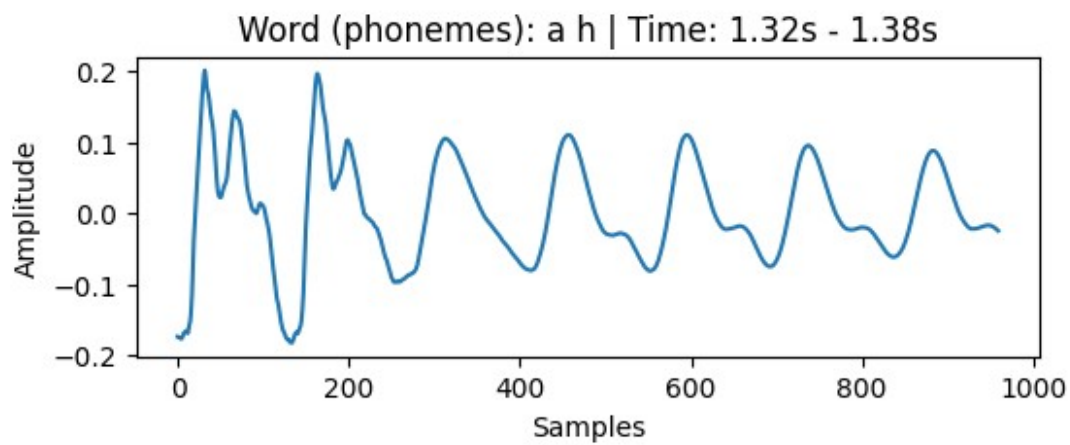
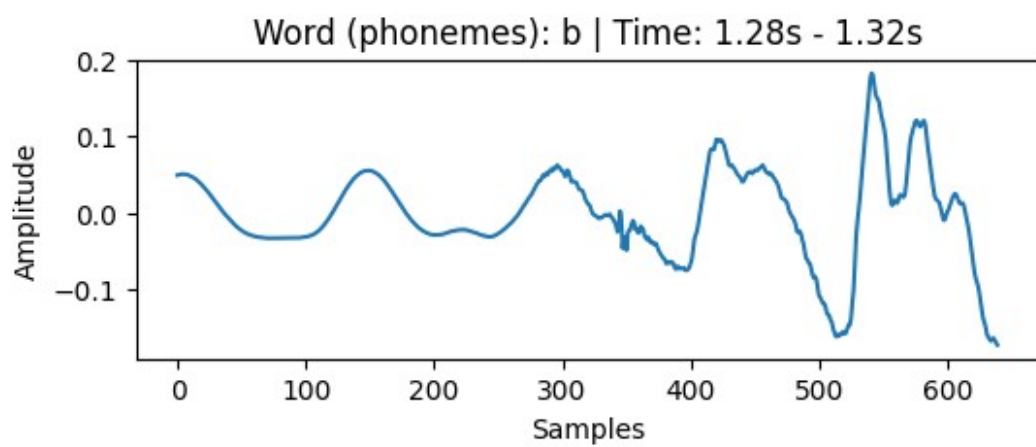
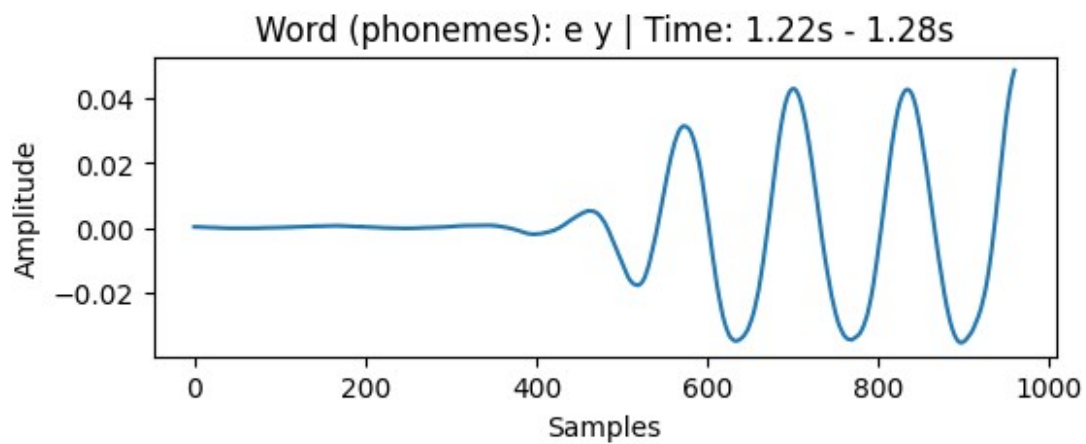


Word (phonemes): a h | Time: 1.12s - 1.18s

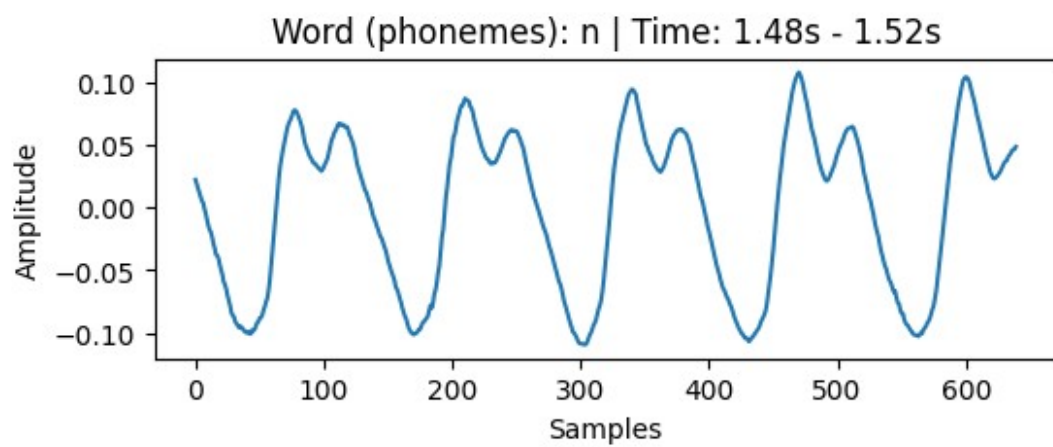
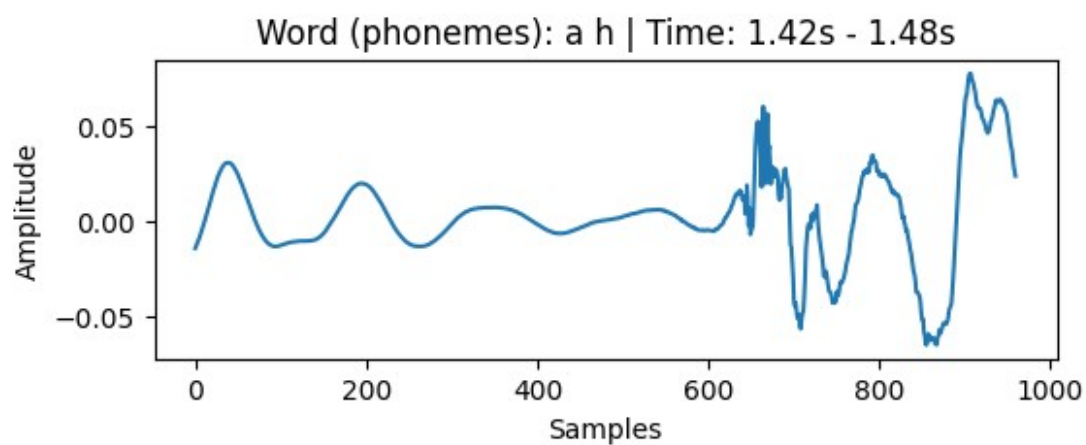
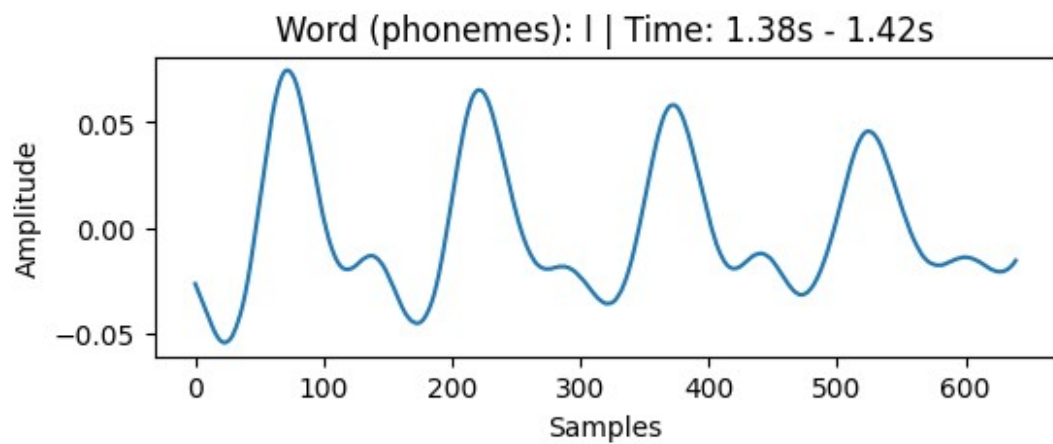


Word (phonemes): t | Time: 1.18s - 1.22s

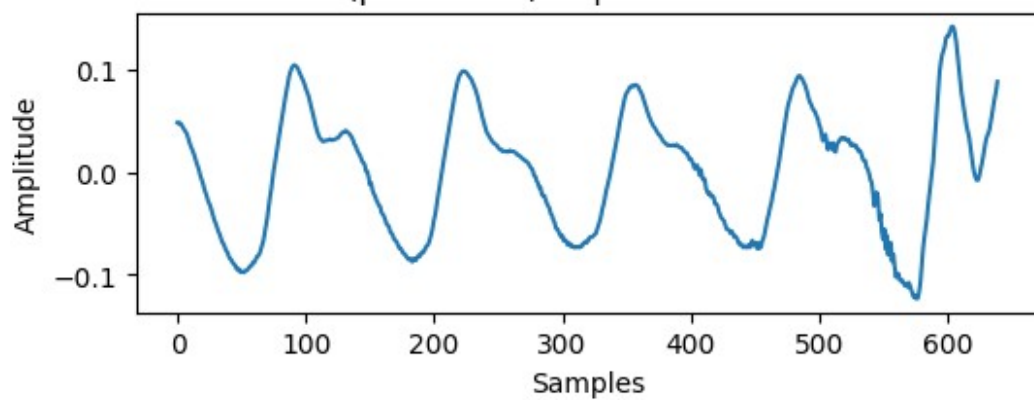




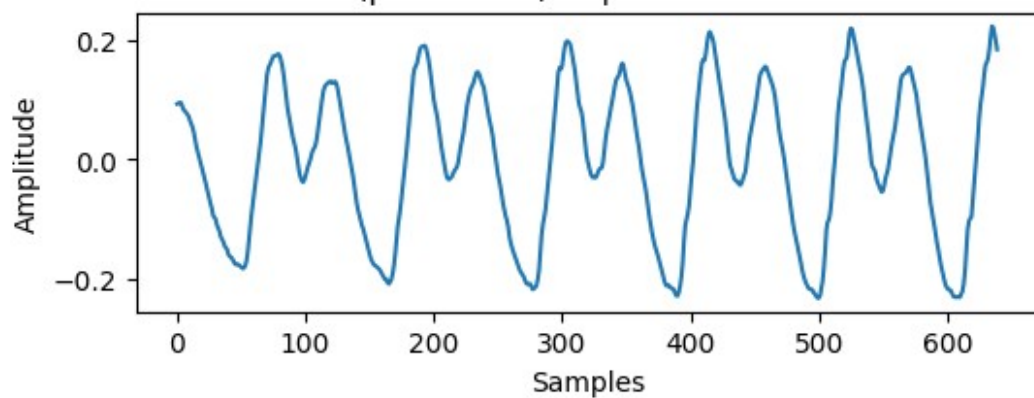




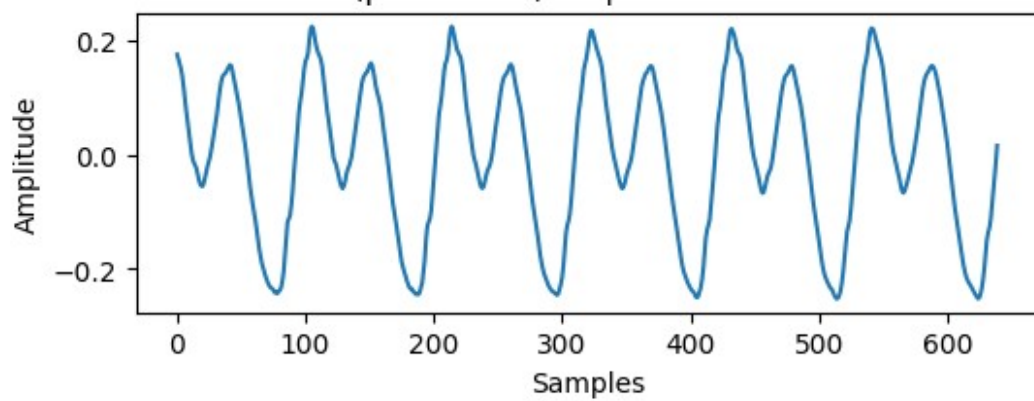
Word (phonemes): d | Time: 1.52s - 1.56s

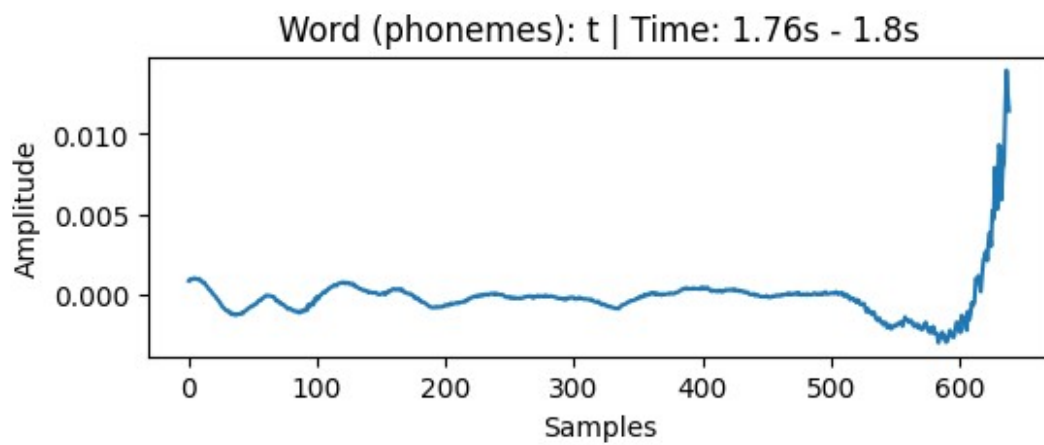
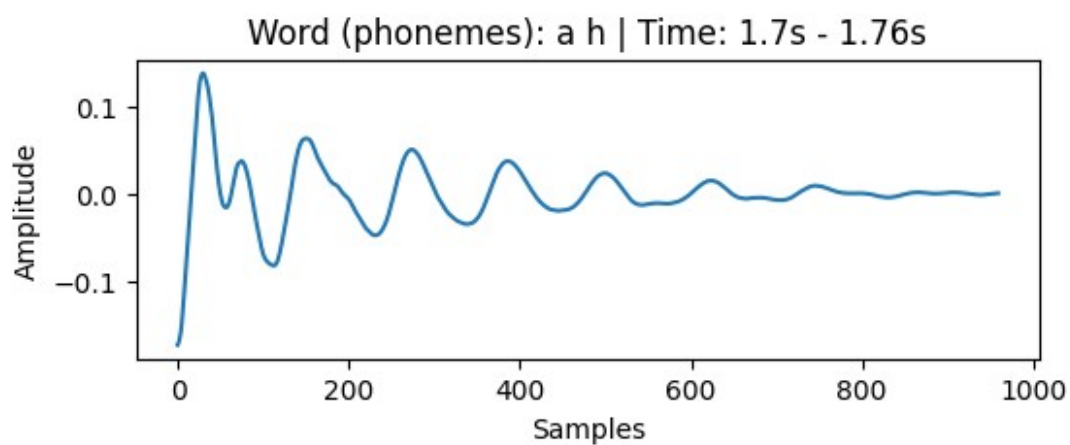
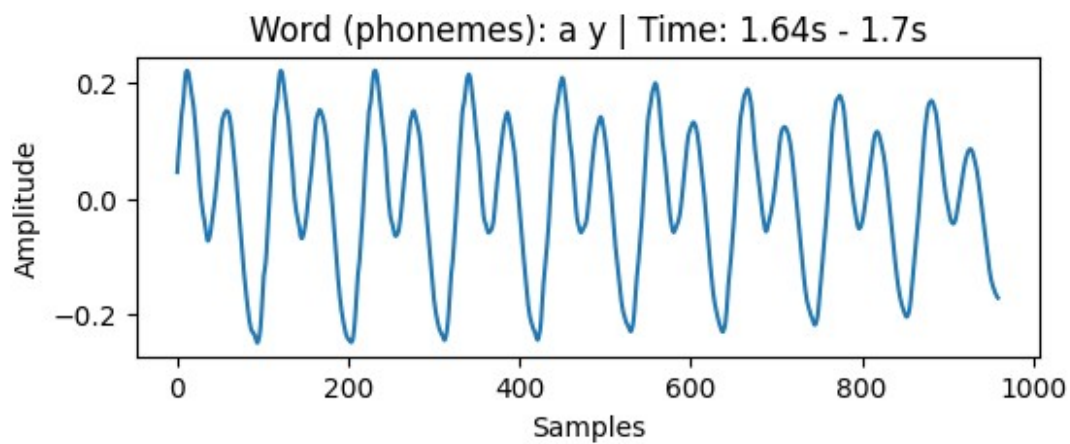


Word (phonemes): k | Time: 1.56s - 1.6s

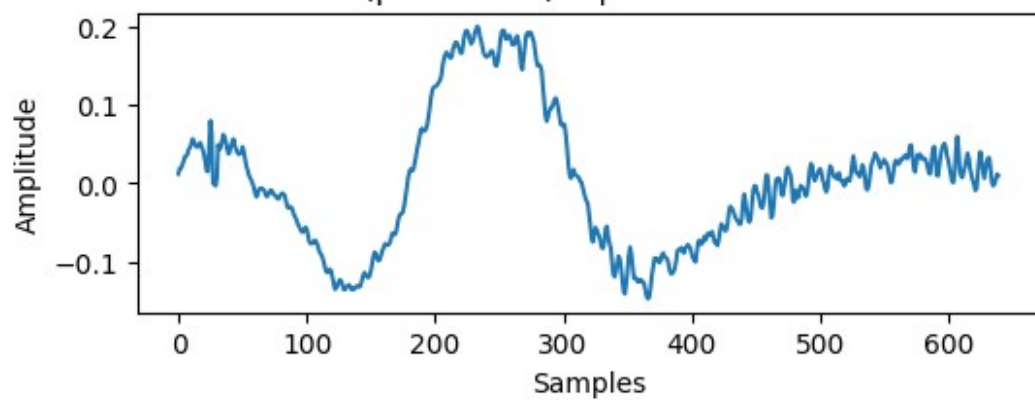


Word (phonemes): w | Time: 1.6s - 1.64s

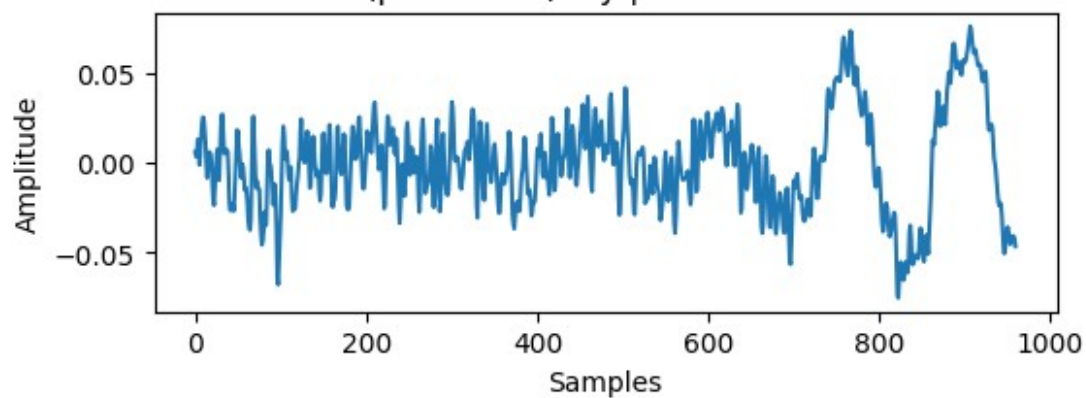




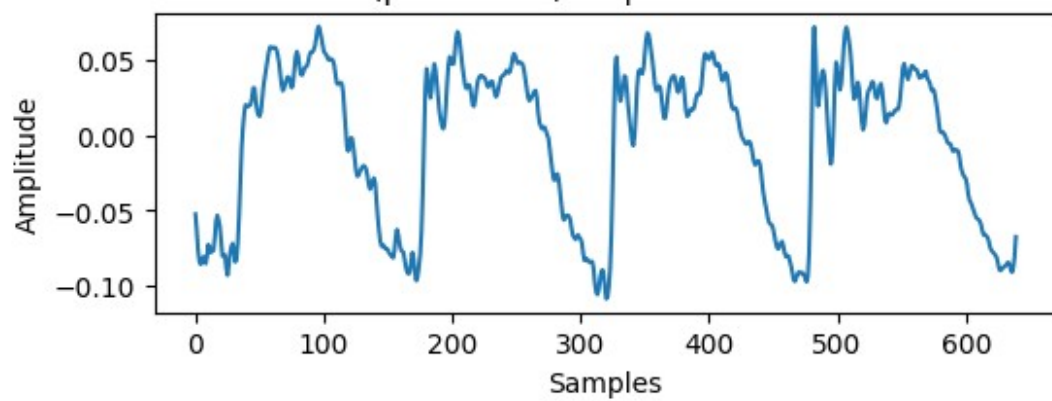
Word (phonemes): l | Time: 1.8s - 1.84s



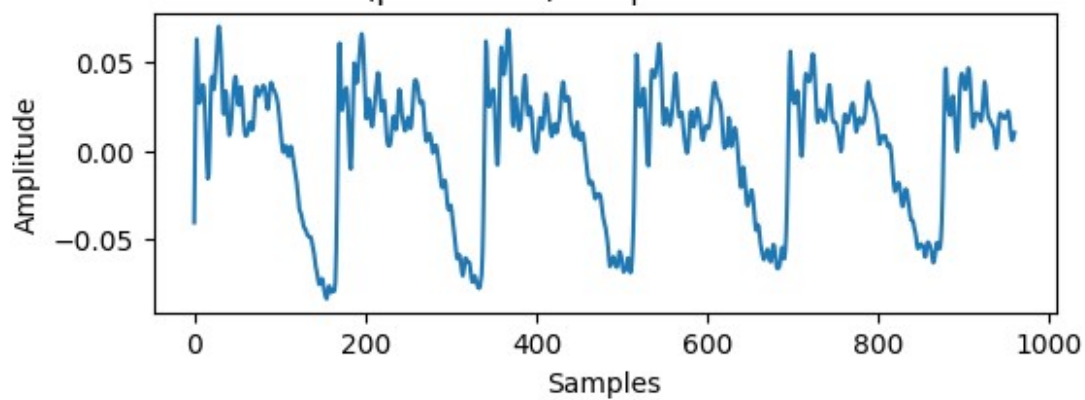
Word (phonemes): i y | Time: 1.84s - 1.9s



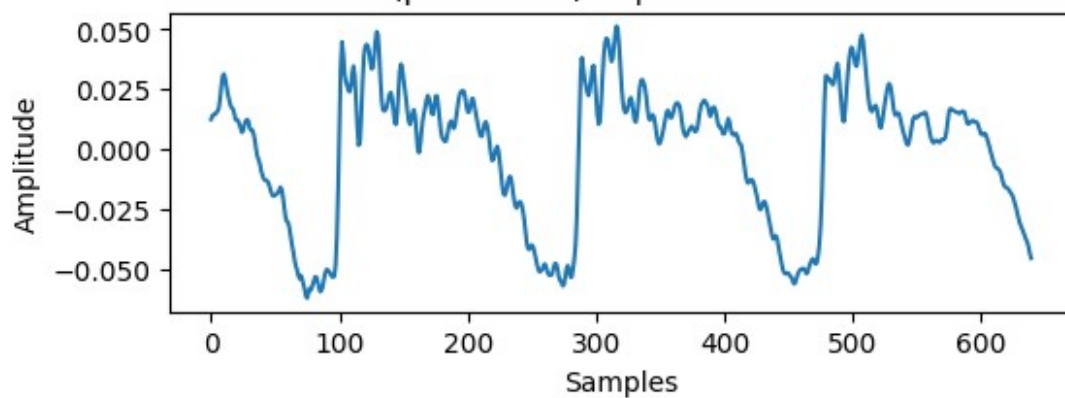
Word (phonemes): w | Time: 1.9s - 1.94s



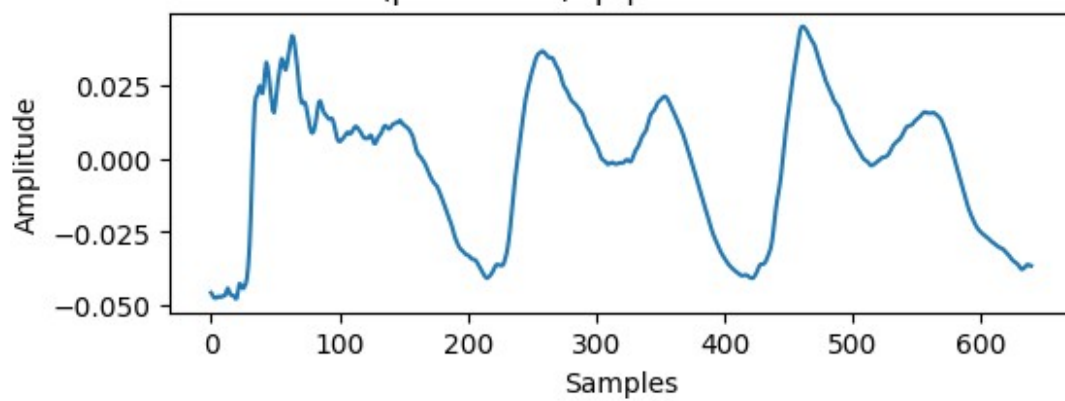
Word (phonemes): i h | Time: 1.94s - 2.0s

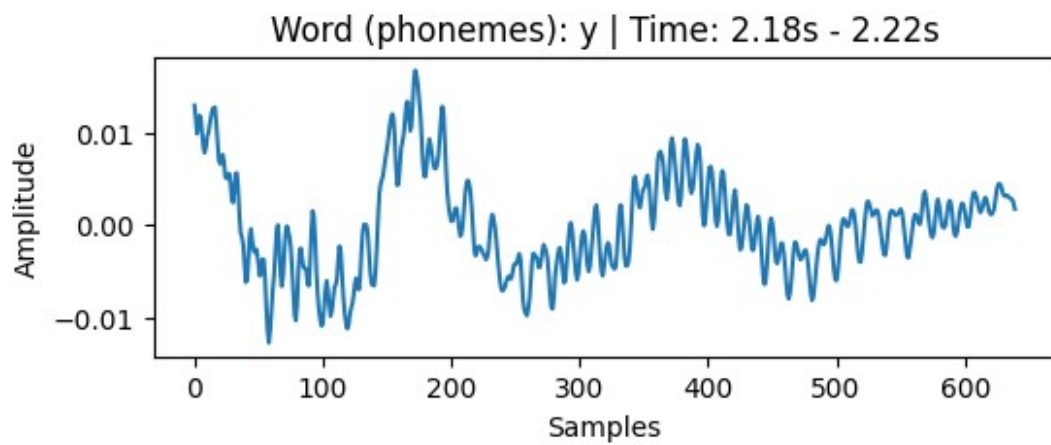
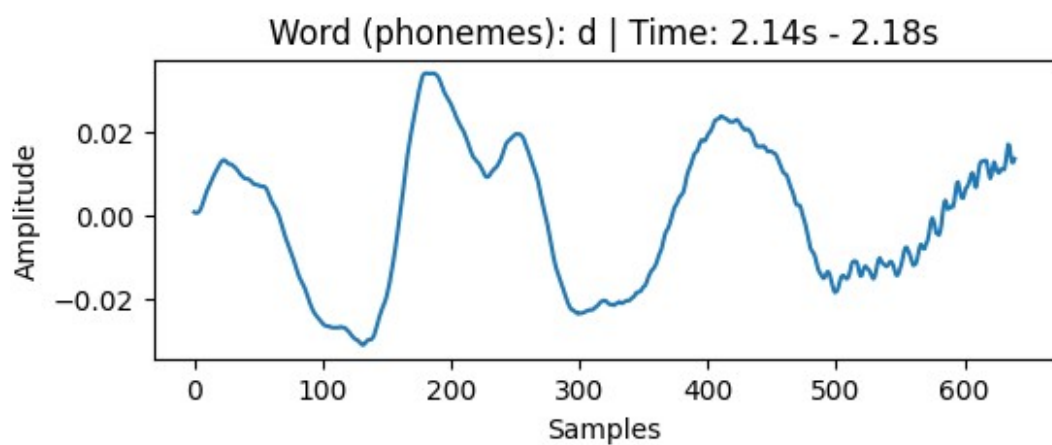
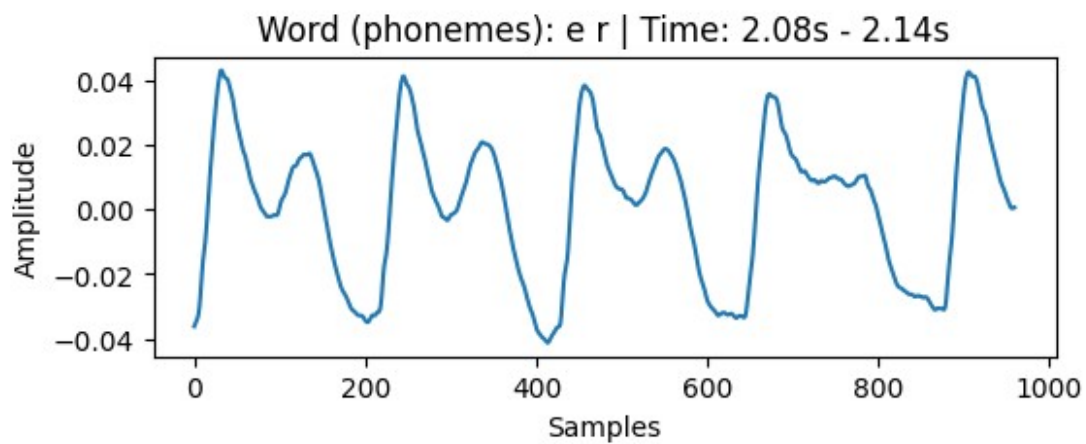


Word (phonemes): s | Time: 2.0s - 2.04s

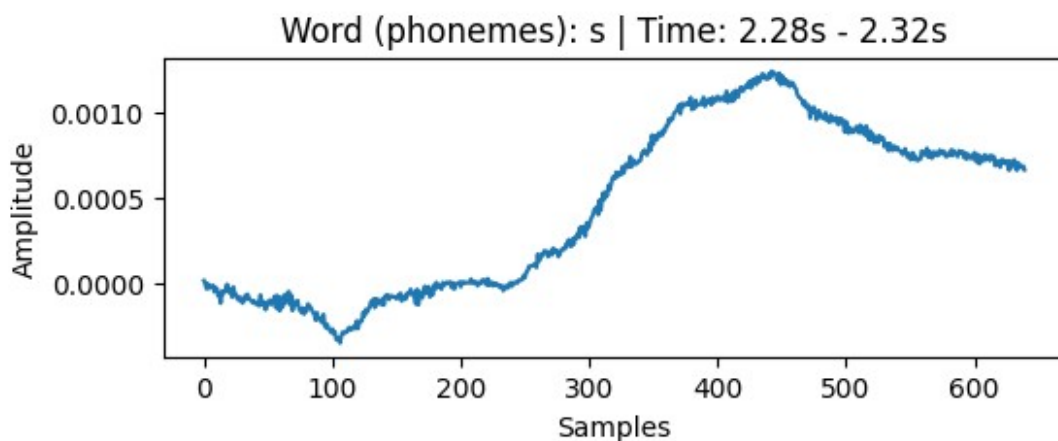
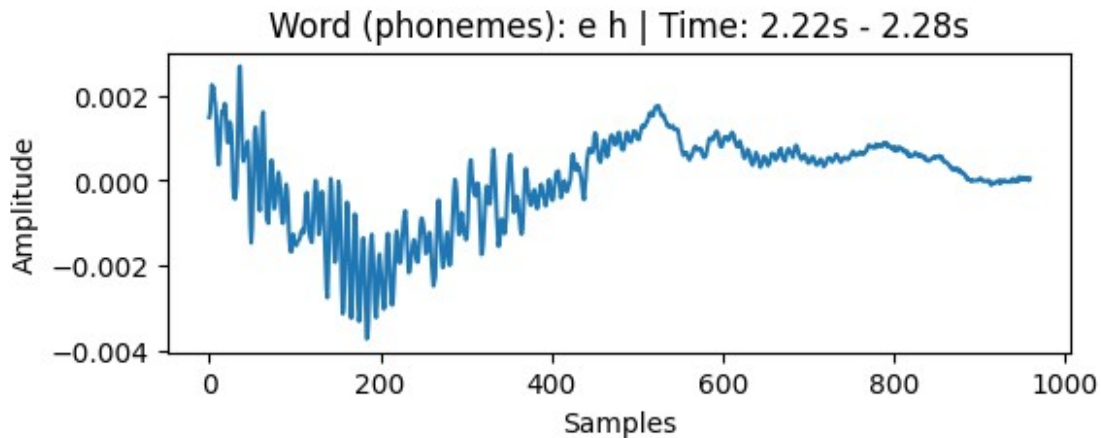


Word (phonemes): p | Time: 2.04s - 2.08s









```
!pip install librosa
```

```
Requirement already satisfied: librosa in  
/usr/local/lib/python3.12/dist-packages (0.11.0)  
Requirement already satisfied: audioread<=2.1.9 in  
/usr/local/lib/python3.12/dist-packages (from librosa) (3.1.0)  
Requirement already satisfied: numba<=0.51.0 in  
/usr/local/lib/python3.12/dist-packages (from librosa) (0.60.0)  
Requirement already satisfied: numpy<=1.22.3 in  
/usr/local/lib/python3.12/dist-packages (from librosa) (2.0.2)  
Requirement already satisfied: scipy<=1.6.0 in  
/usr/local/lib/python3.12/dist-packages (from librosa) (1.16.3)  
Requirement already satisfied: scikit-learn<=1.1.0 in  
/usr/local/lib/python3.12/dist-packages (from librosa) (1.6.1)  
Requirement already satisfied: joblib<=1.0 in  
/usr/local/lib/python3.12/dist-packages (from librosa) (1.5.3)  
Requirement already satisfied: decorator<=4.3.0 in  
/usr/local/lib/python3.12/dist-packages (from librosa) (4.4.2)  
Requirement already satisfied: soundfile<=0.12.1 in  
/usr/local/lib/python3.12/dist-packages (from librosa) (0.13.1)  
Requirement already satisfied: pooch<=1.1 in
```

```

/usr/local/lib/python3.12/dist-packages (from librosa) (1.9.0)
Requirement already satisfied: soxr>=0.3.2 in
/usr/local/lib/python3.12/dist-packages (from librosa) (1.0.0)
Requirement already satisfied: typing_extensions>=4.1.1 in
/usr/local/lib/python3.12/dist-packages (from librosa) (4.15.0)
Requirement already satisfied: lazy_loader>=0.1 in
/usr/local/lib/python3.12/dist-packages (from librosa) (0.4)
Requirement already satisfied: msgpack>=1.0 in
/usr/local/lib/python3.12/dist-packages (from librosa) (1.1.2)
Requirement already satisfied: packaging in
/usr/local/lib/python3.12/dist-packages (from lazy_loader>=0.1-
>librosa) (26.0)
Requirement already satisfied: llvmlite<0.44,>=0.43.0dev0 in
/usr/local/lib/python3.12/dist-packages (from numba>=0.51.0->librosa)
(0.43.0)
Requirement already satisfied: platformdirs>=2.5.0 in
/usr/local/lib/python3.12/dist-packages (from pooch>=1.1->librosa)
(4.9.2)
Requirement already satisfied: requests>=2.19.0 in
/usr/local/lib/python3.12/dist-packages (from pooch>=1.1->librosa)
(2.32.4)
Requirement already satisfied: threadpoolctl>=3.1.0 in
/usr/local/lib/python3.12/dist-packages (from scikit-learn>=1.1.0-
>librosa) (3.6.0)
Requirement already satisfied: cffi>=1.0 in
/usr/local/lib/python3.12/dist-packages (from soundfile>=0.12.1-
>librosa) (2.0.0)
Requirement already satisfied: pycparser in
/usr/local/lib/python3.12/dist-packages (from cffi>=1.0-
>soundfile>=0.12.1->librosa) (3.0)
Requirement already satisfied: charset_normalizer<4,>=2 in
/usr/local/lib/python3.12/dist-packages (from requests>=2.19.0-
>pooch>=1.1->librosa) (3.4.4)
Requirement already satisfied: idna<4,>=2.5 in
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>pooch>=1.1->librosa) (3.11)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.12/dist-packages (from requests>=2.19.0-
>pooch>=1.1->librosa) (2.5.0)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.12/dist-packages (from requests>=2.19.0-
>pooch>=1.1->librosa) (2026.1.4)

```

4

```

phoneme_categories = {
    "vowel": ["a a", "a e", "a h", "a o", "e h", "e r", "i h", "i y", "u
h", "u w"],
    "plosive": ["p", "b", "t", "d", "k", "g"],

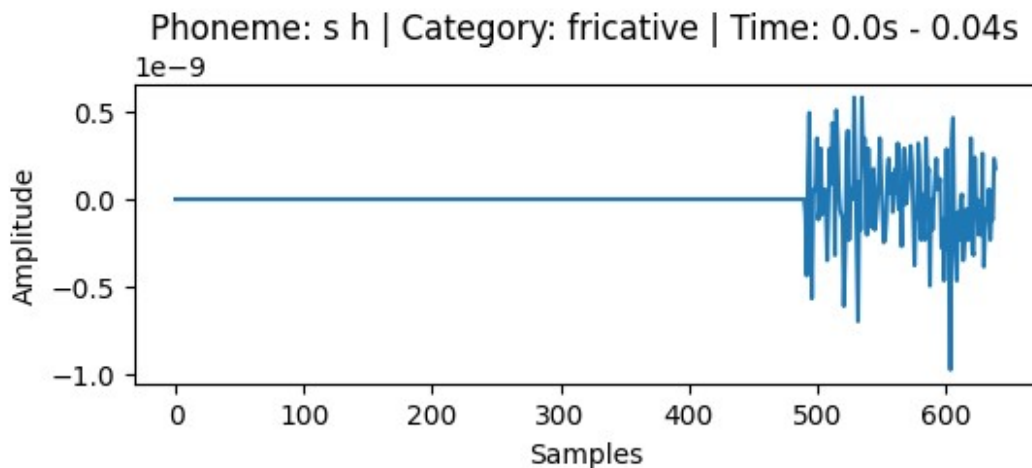
```

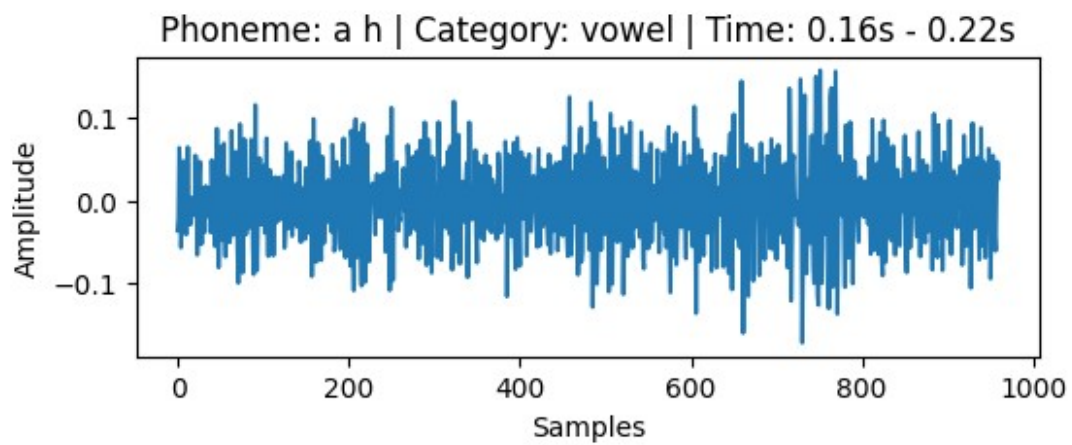
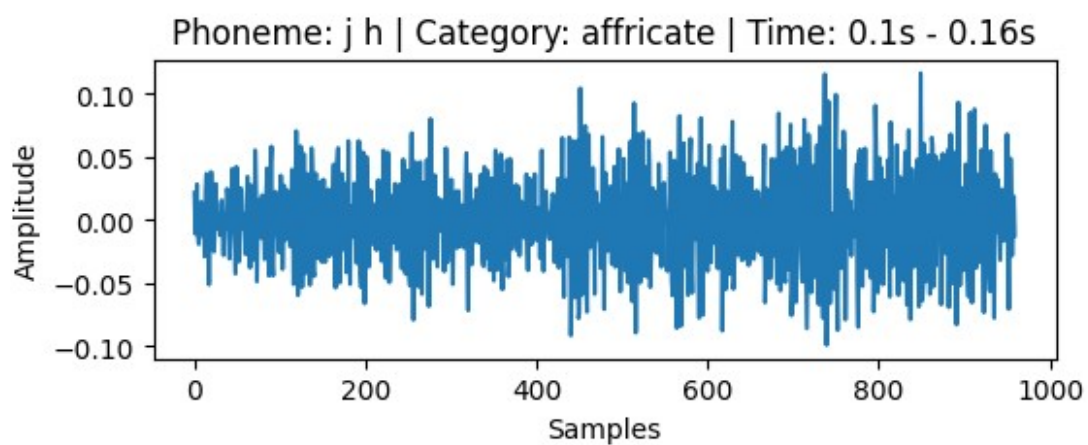
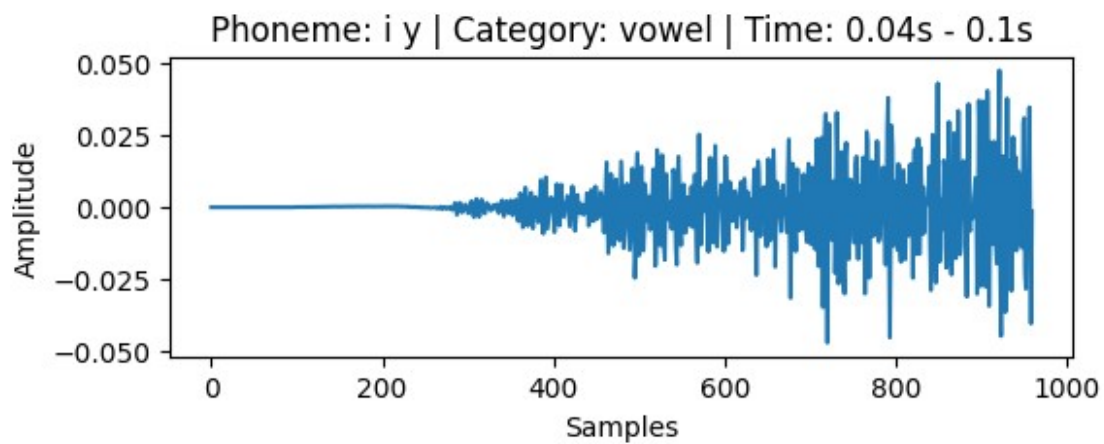


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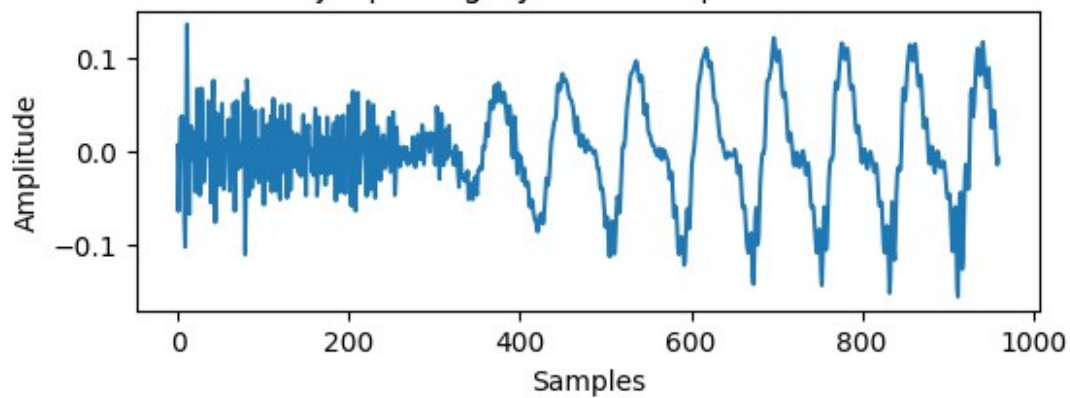
"fricative": ["f", "v", "t h", "d h", "s", "z", "s h", "z h", "h h"],
"affricate": ["c h", "j h"],
"semivowel": ["i", "r", "w", "y"],
"diphthong": ["a y", "e y", "o y", "a w", "o w"],
"whisper": ["s i l", "s p n"]
}
def get_category(phoneme):
    for category, phones in phoneme_categories.items():
        if phoneme in phones:
            return category
    return "unknown"
for phoneme, start, end in segments:
    category = get_category(phoneme)
    start_sample = int(start * sr)
    end_sample = int(end * sr)
    plt.figure(figsize=(6, 2))
    plt.plot(y[start_sample:end_sample])
    plt.title(f"Phoneme: {phoneme} | Category: {category} | Time:
{round(start,2)}s - {round(end,2)}s")
    plt.xlabel("Samples")
    plt.ylabel("Amplitude")
    plt.show()

```

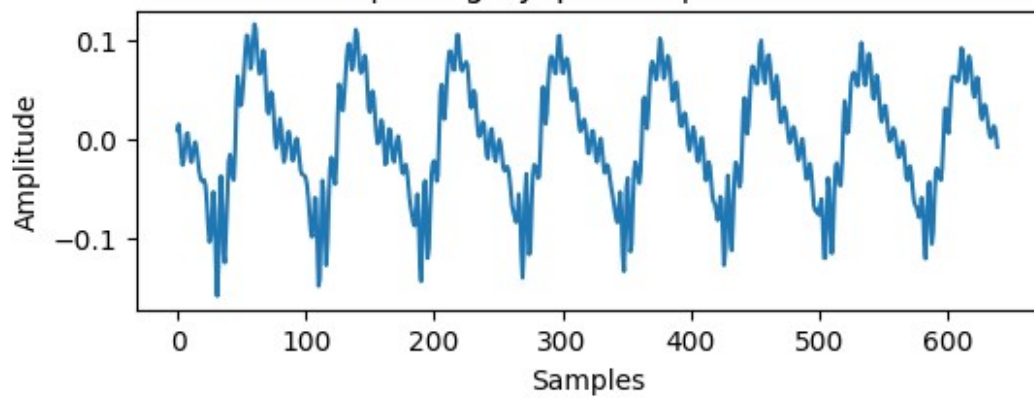




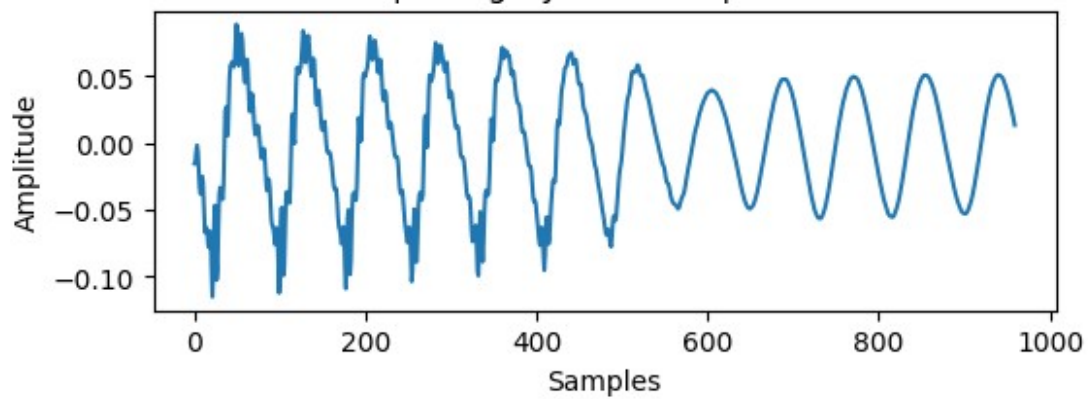
Phoneme: j h | Category: affricate | Time: 0.22s - 0.28s

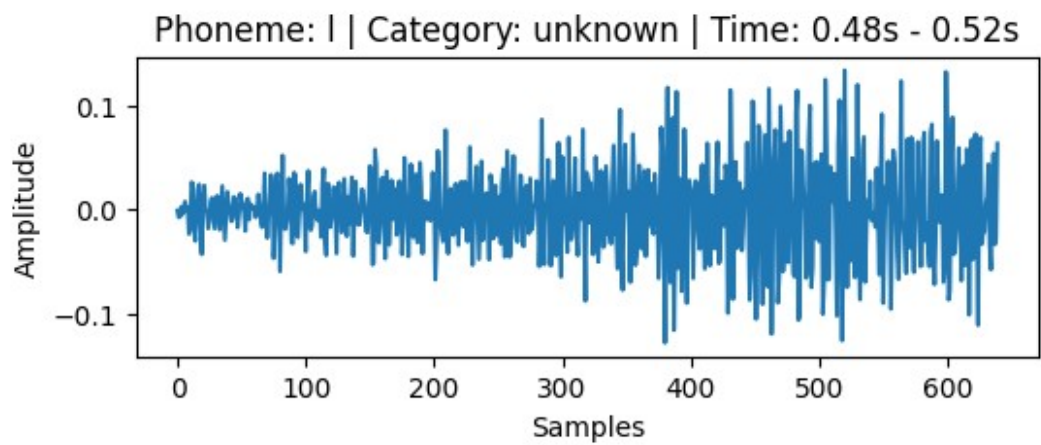
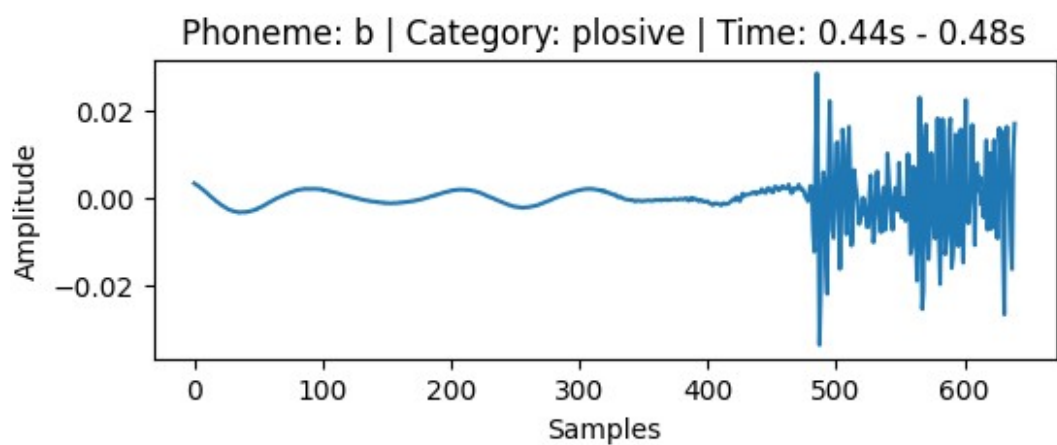
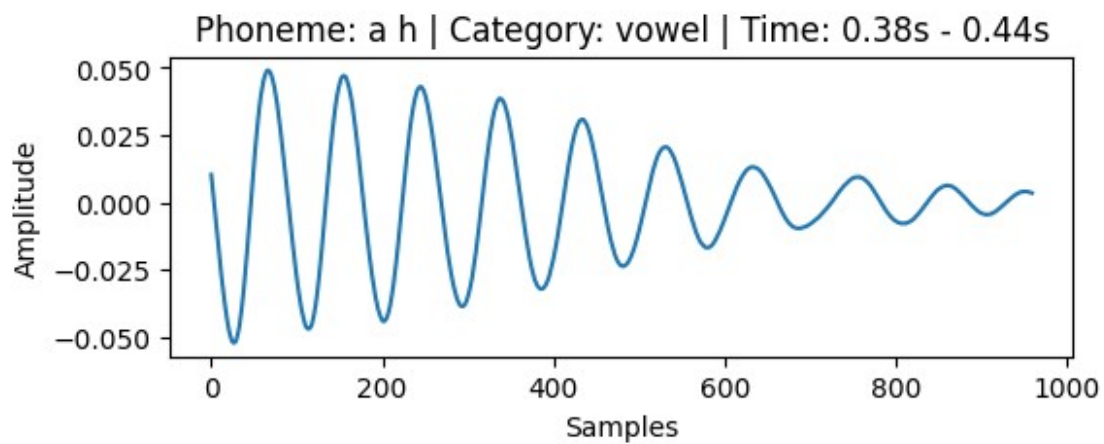


Phoneme: d | Category: plosive | Time: 0.28s - 0.32s

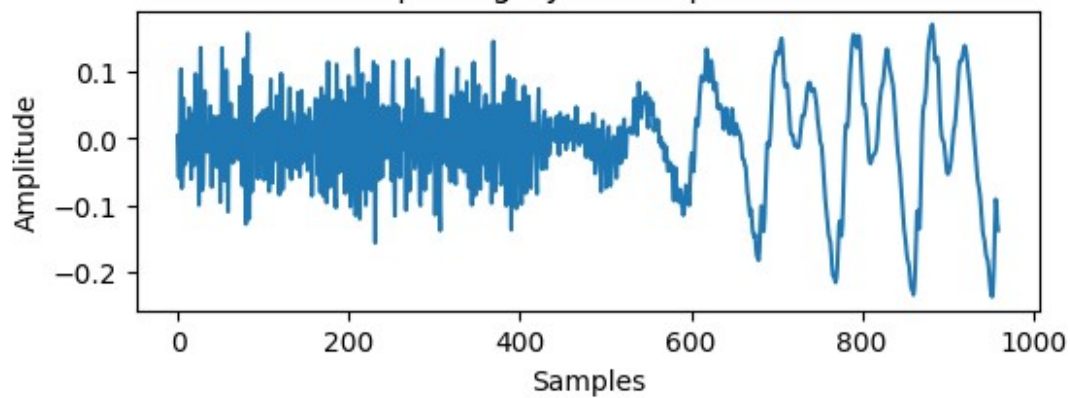


Phoneme: d h | Category: fricative | Time: 0.32s - 0.38s

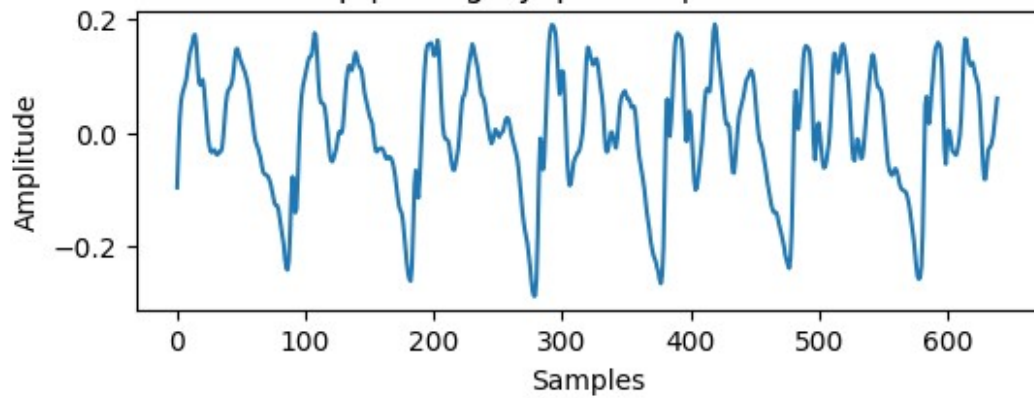




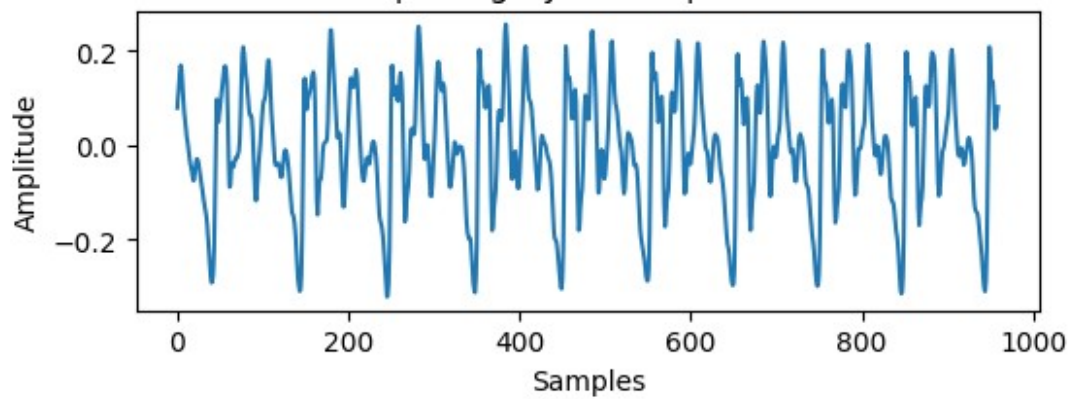
Phoneme: u w | Category: vowel | Time: 0.52s - 0.58s



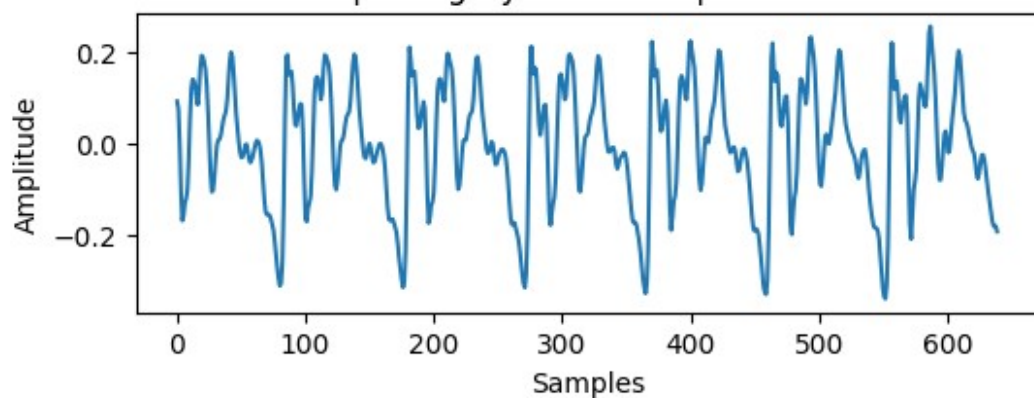
Phoneme: p | Category: plosive | Time: 0.58s - 0.62s



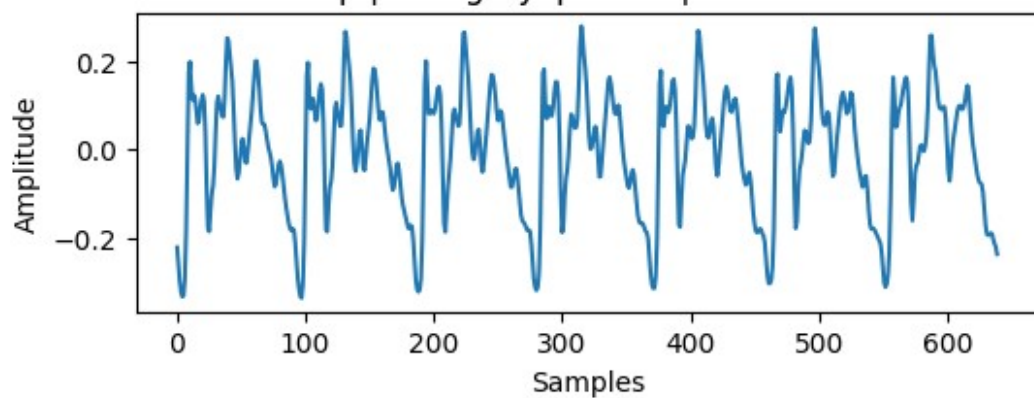
Phoneme: e h | Category: vowel | Time: 0.62s - 0.68s



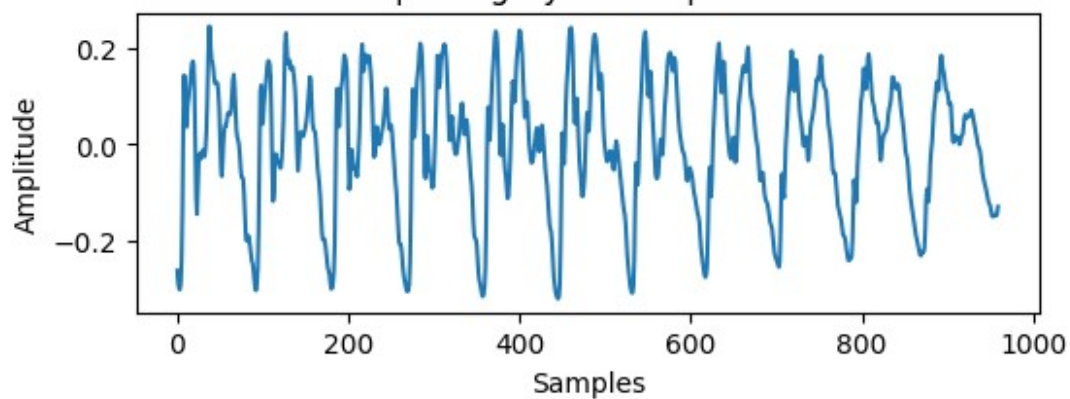
Phoneme: n | Category: unknown | Time: 0.68s - 0.72s



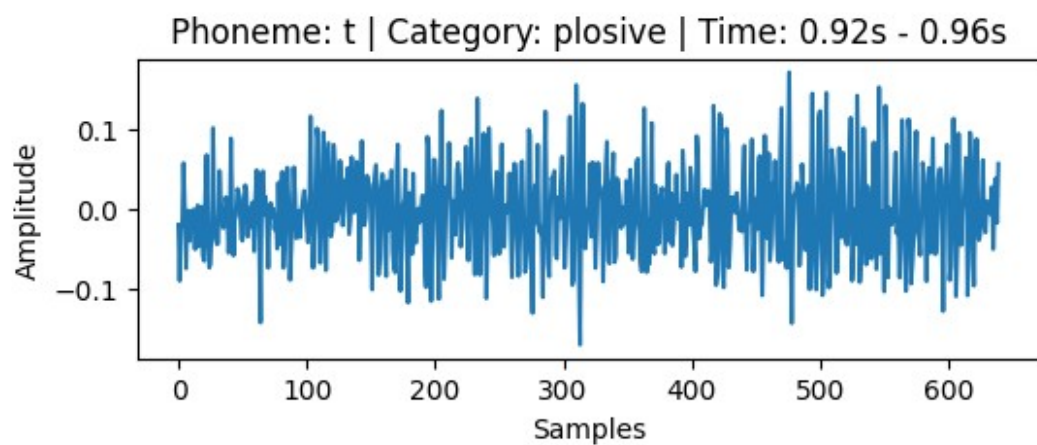
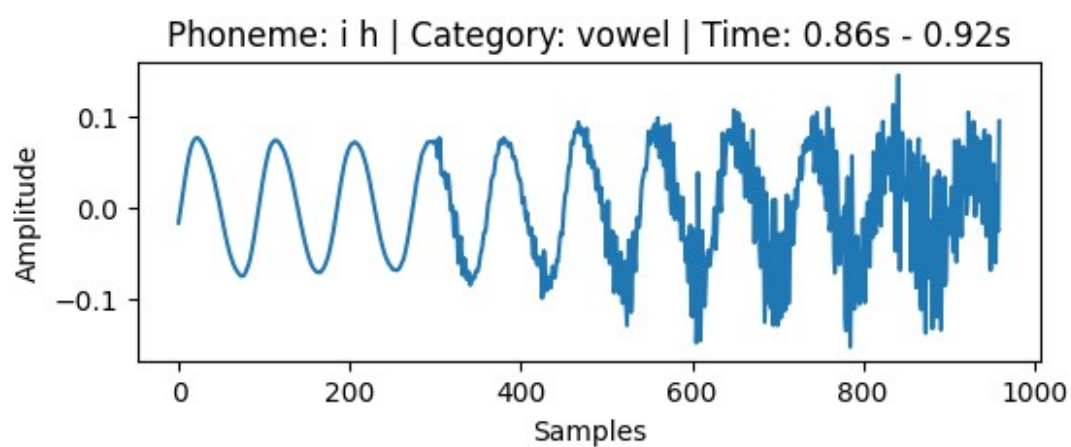
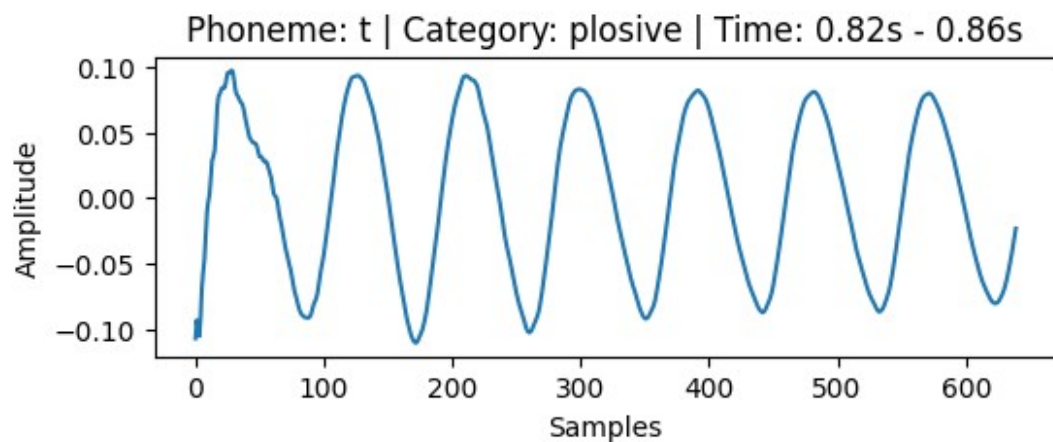
Phoneme: p | Category: plosive | Time: 0.72s - 0.76s



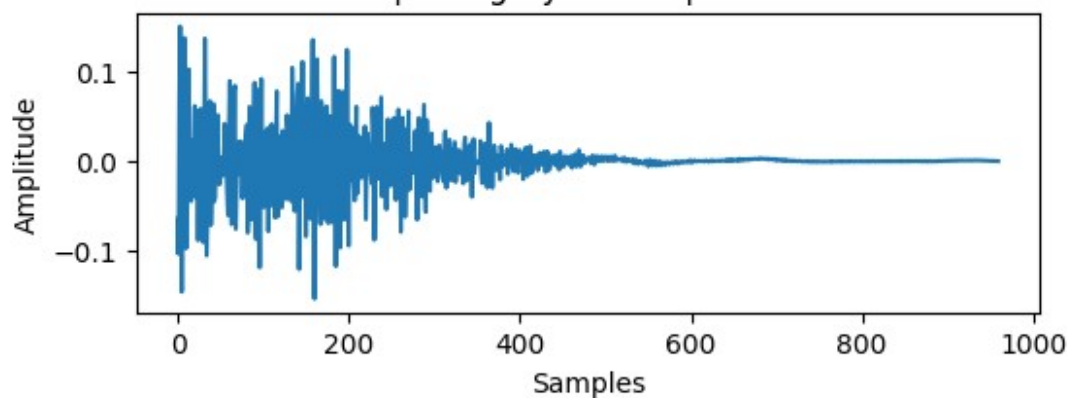
Phoneme: u h | Category: vowel | Time: 0.76s - 0.82s



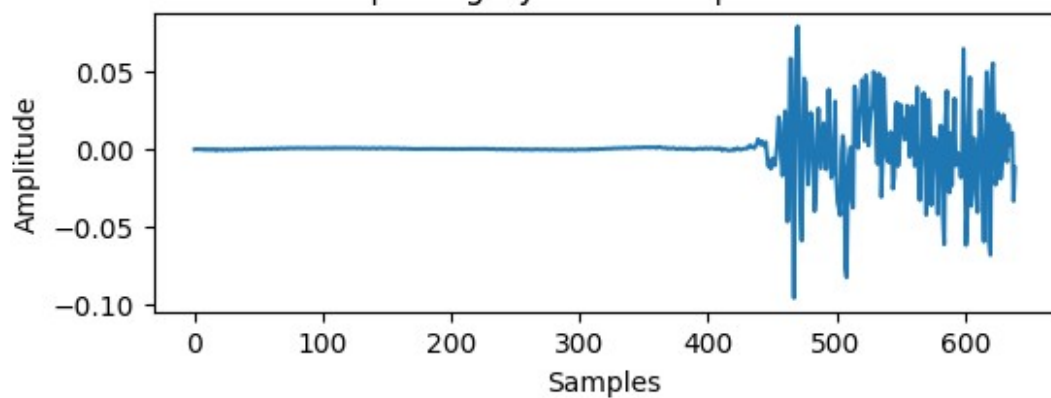




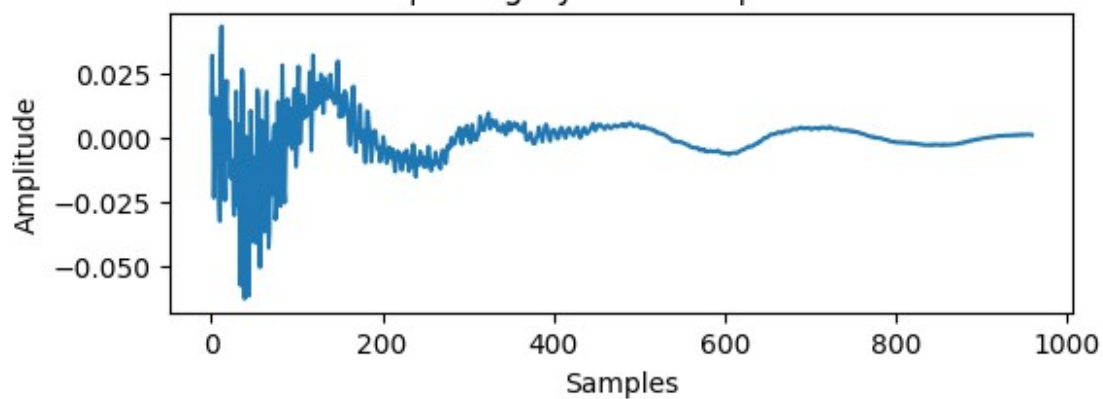
Phoneme: a a | Category: vowel | Time: 0.96s - 1.02s



Phoneme: n | Category: unknown | Time: 1.02s - 1.06s

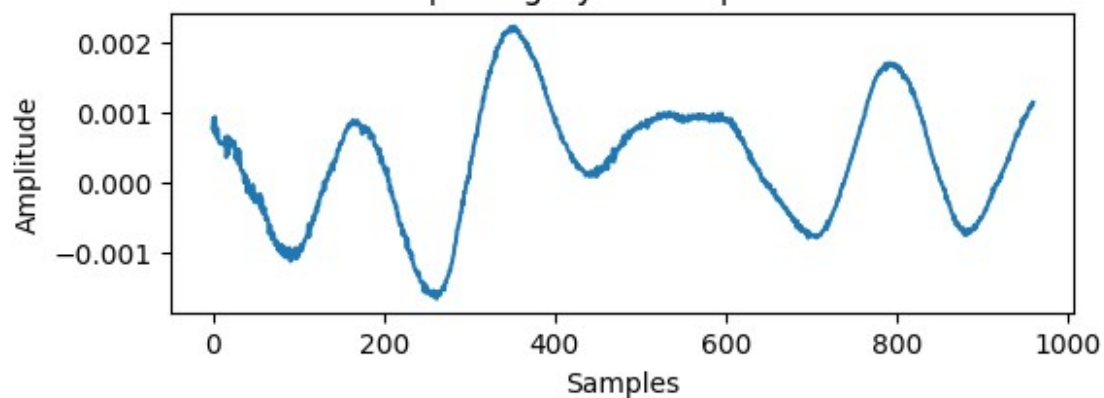


Phoneme: d h | Category: fricative | Time: 1.06s - 1.12s

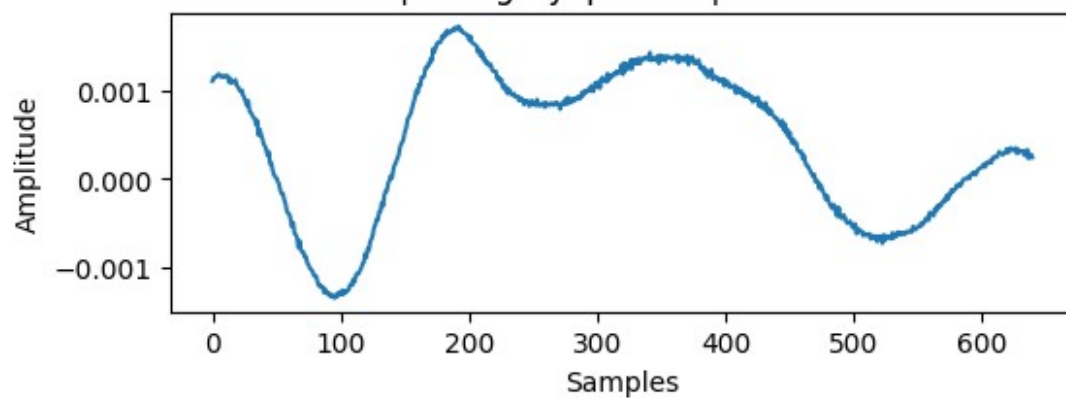




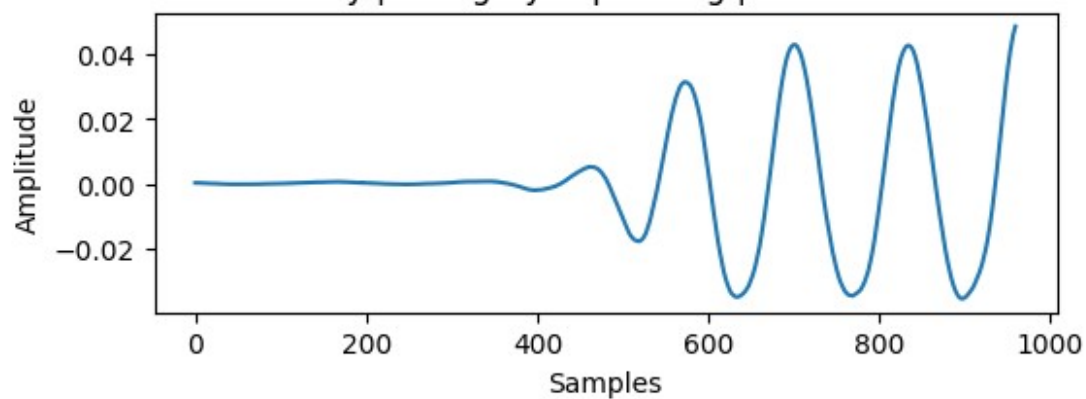
Phoneme: a h | Category: vowel | Time: 1.12s - 1.18s

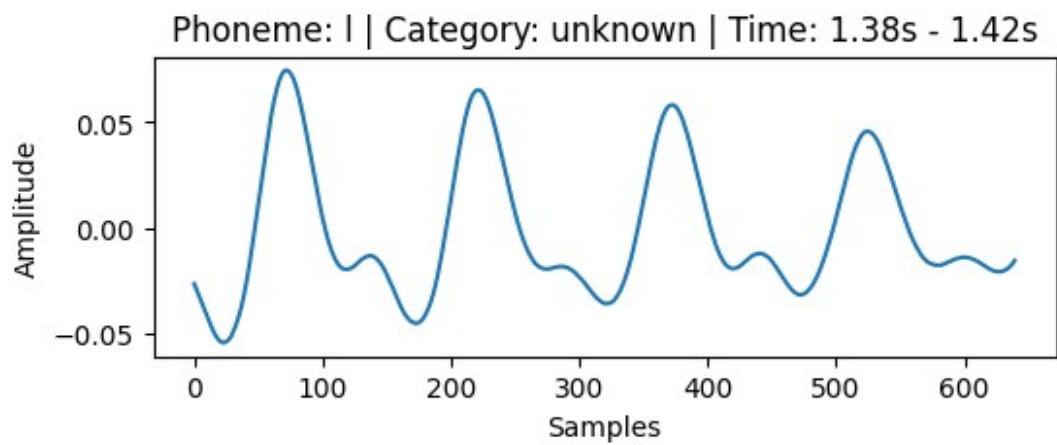
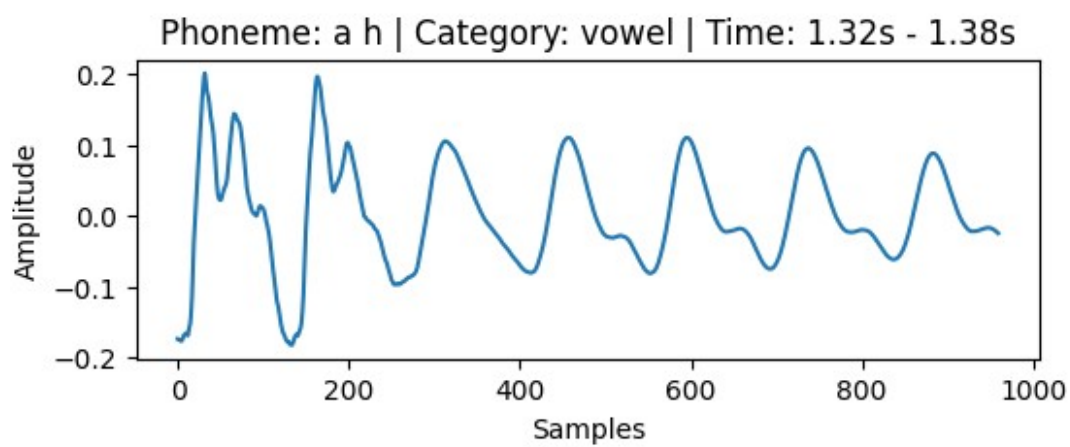
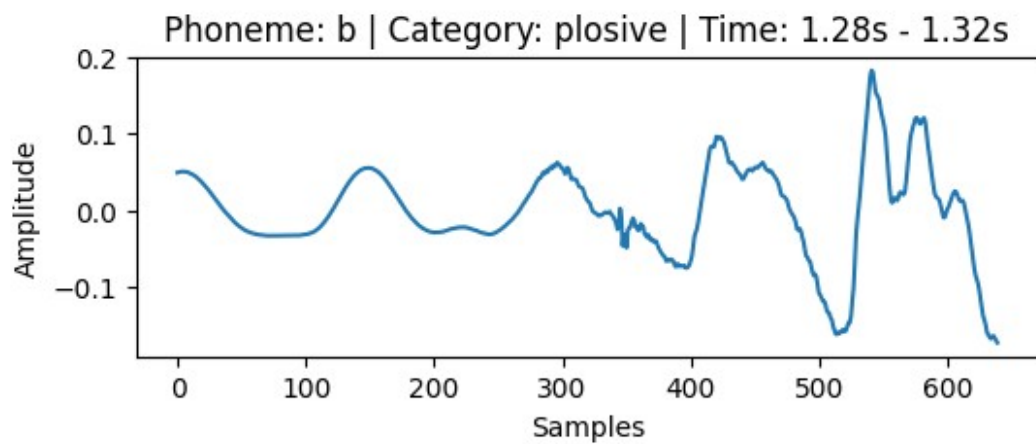


Phoneme: t | Category: plosive | Time: 1.18s - 1.22s

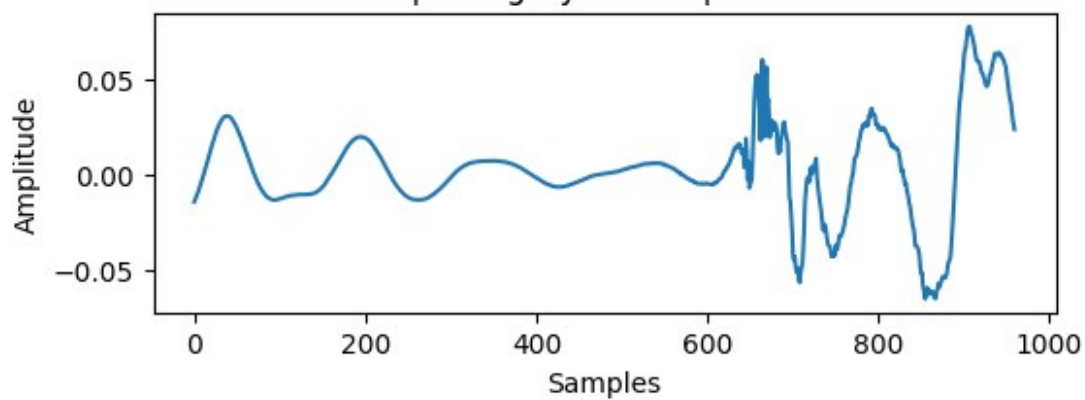


Phoneme: e y | Category: diphthong | Time: 1.22s - 1.28s

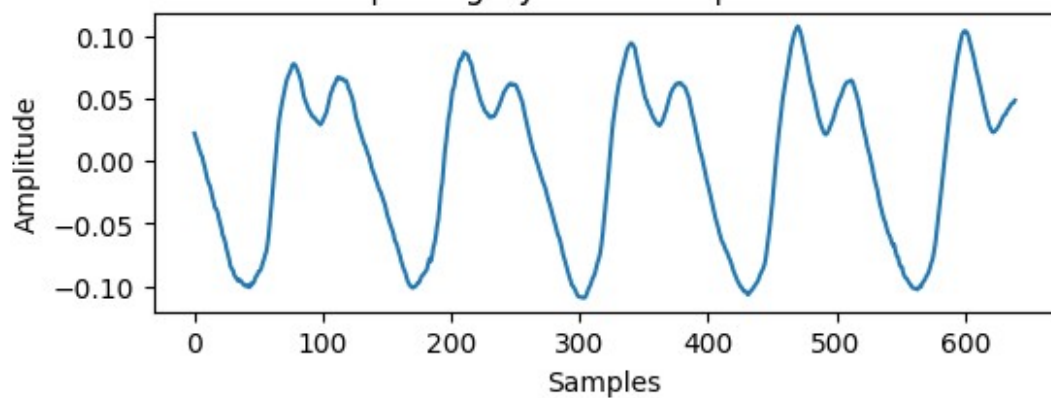




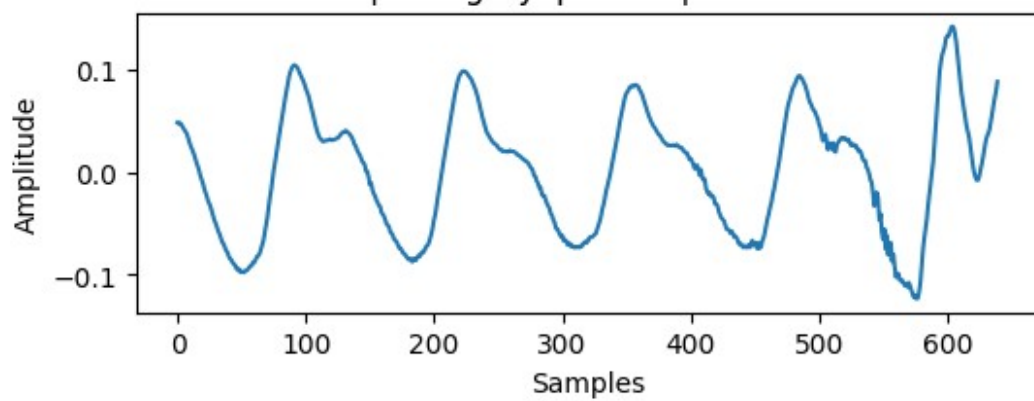
Phoneme: a h | Category: vowel | Time: 1.42s - 1.48s

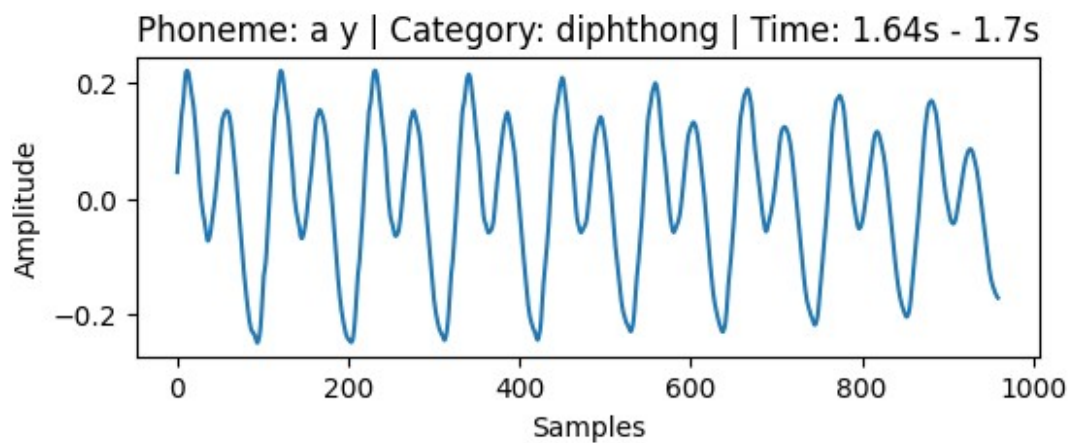
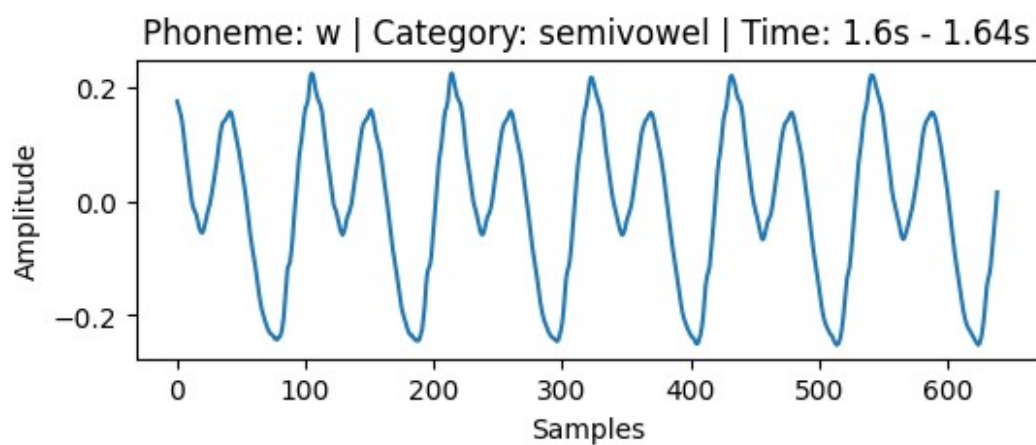
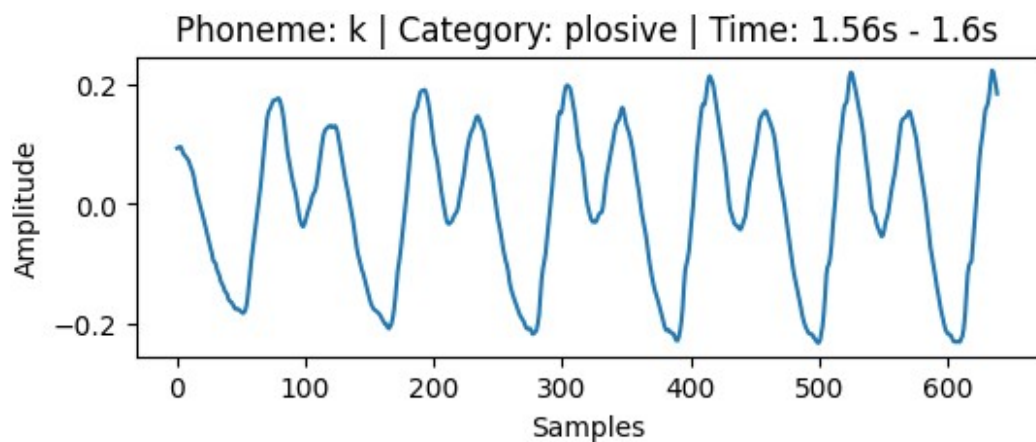


Phoneme: n | Category: unknown | Time: 1.48s - 1.52s

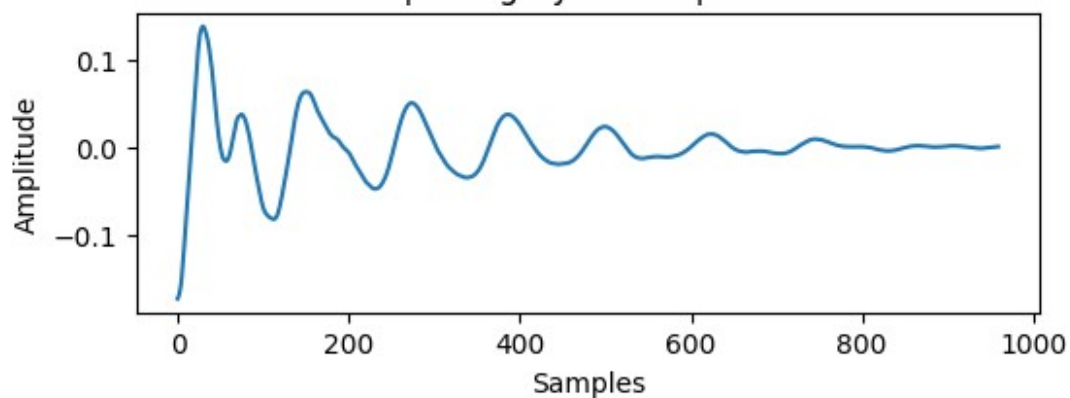


Phoneme: d | Category: plosive | Time: 1.52s - 1.56s

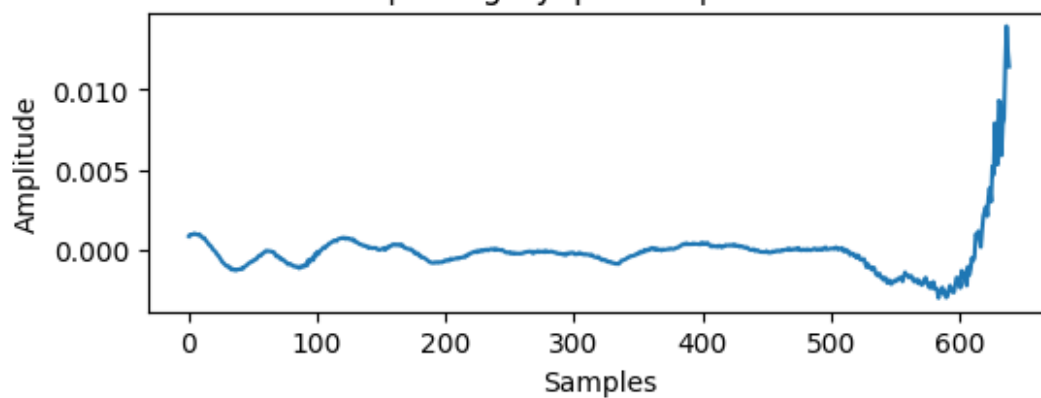




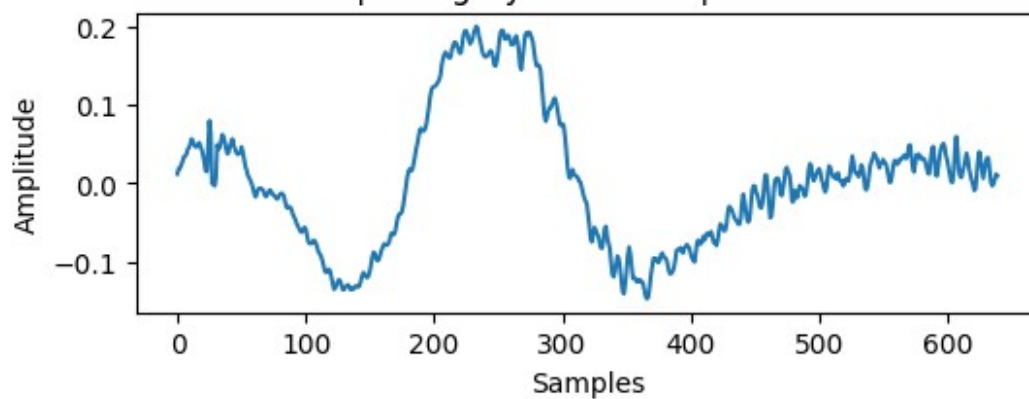
Phoneme: a h | Category: vowel | Time: 1.7s - 1.76s



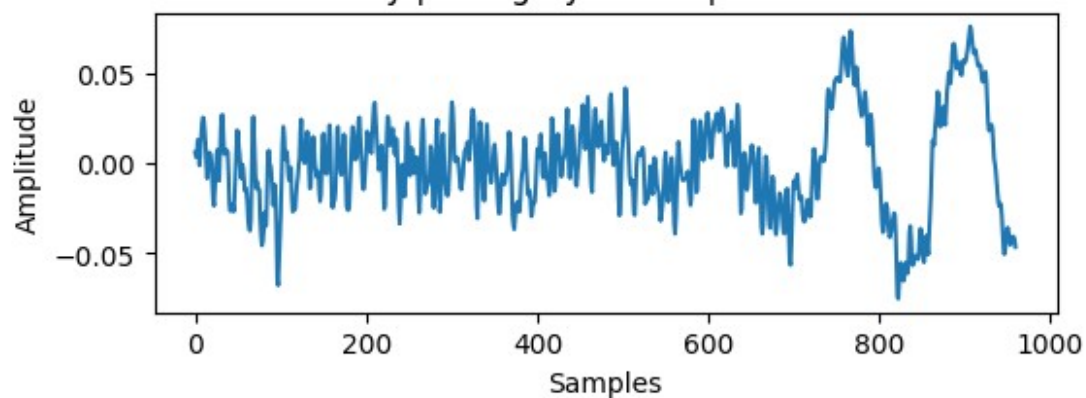
Phoneme: t | Category: plosive | Time: 1.76s - 1.8s



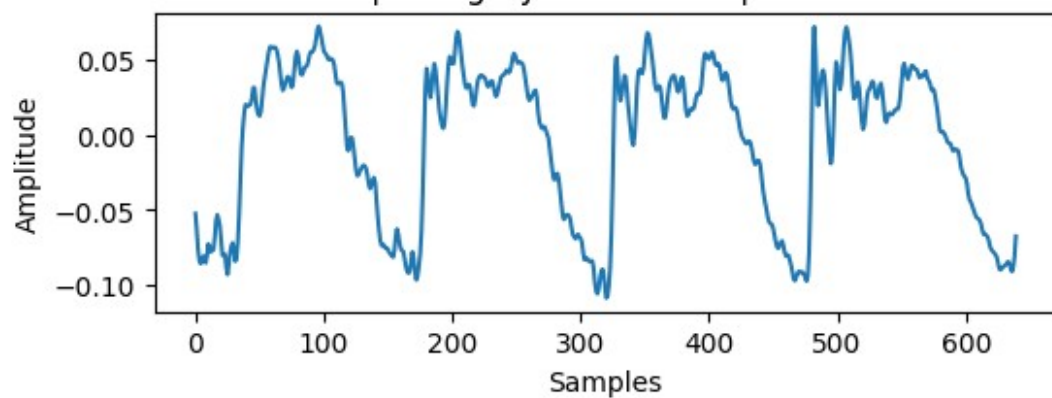
Phoneme: l | Category: unknown | Time: 1.8s - 1.84s



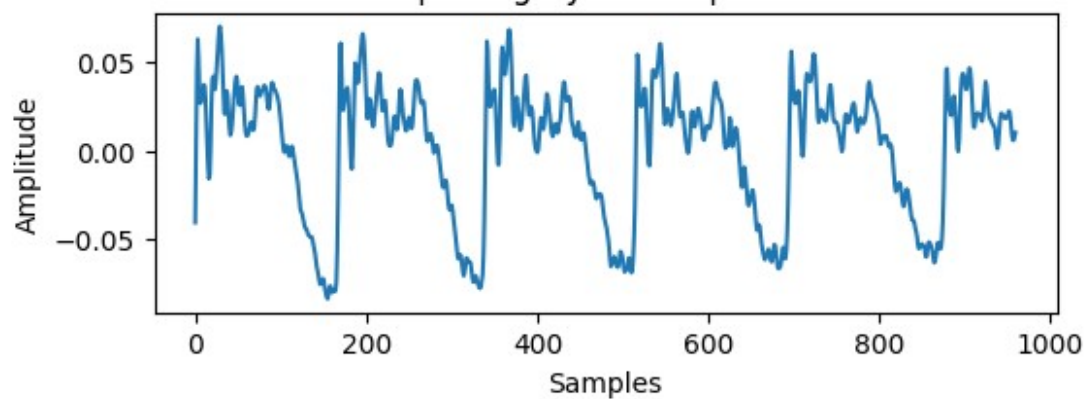
Phoneme: i y | Category: vowel | Time: 1.84s - 1.9s



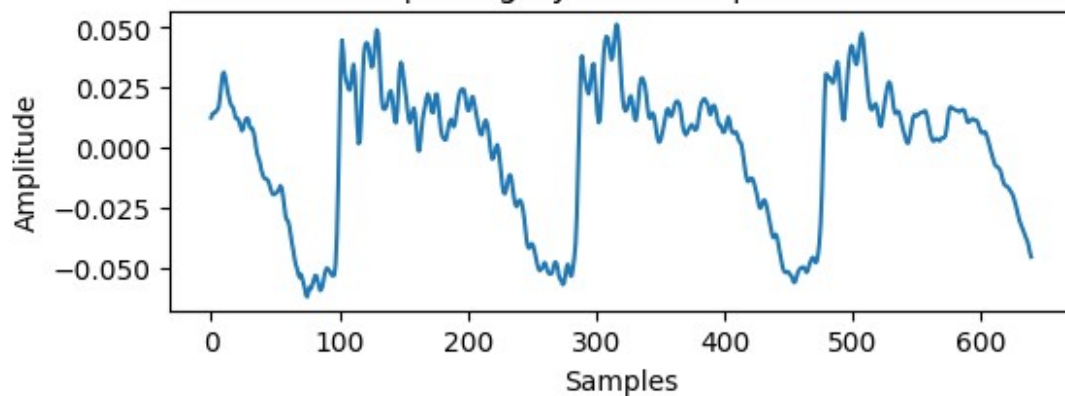
Phoneme: w | Category: semivowel | Time: 1.9s - 1.94s



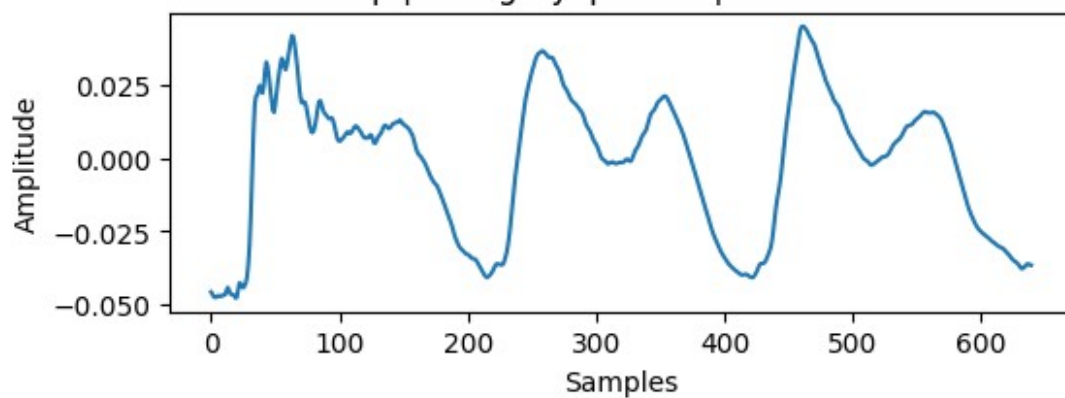
Phoneme: i h | Category: vowel | Time: 1.94s - 2.0s



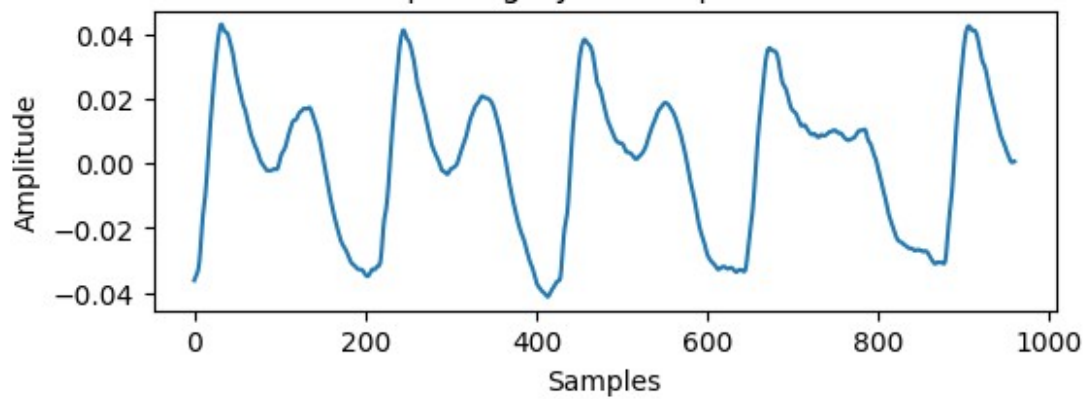
Phoneme: s | Category: fricative | Time: 2.0s - 2.04s



Phoneme: p | Category: plosive | Time: 2.04s - 2.08s

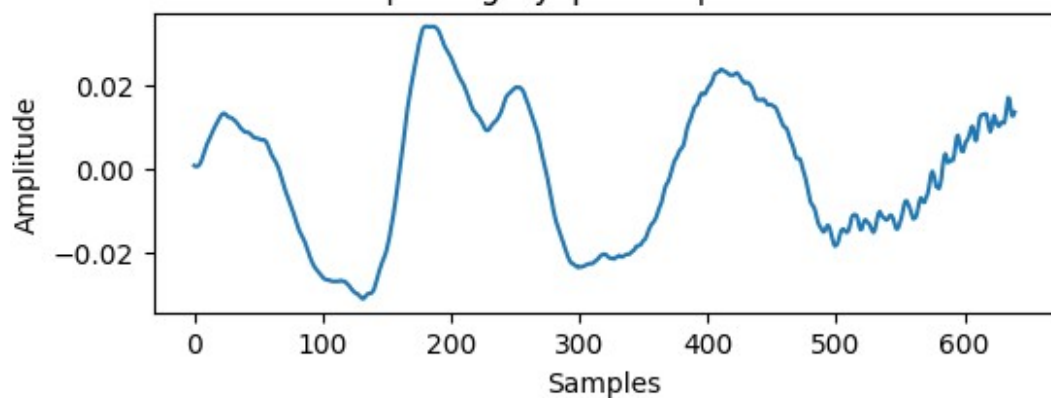


Phoneme: e r | Category: vowel | Time: 2.08s - 2.14s

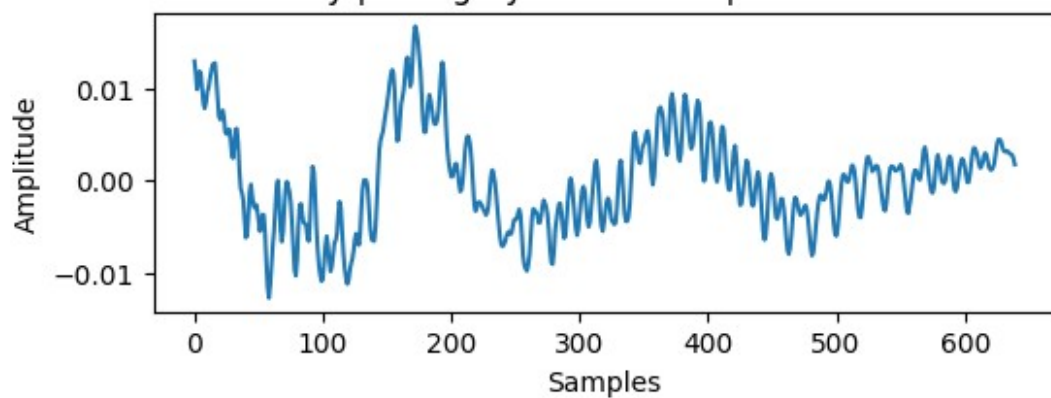




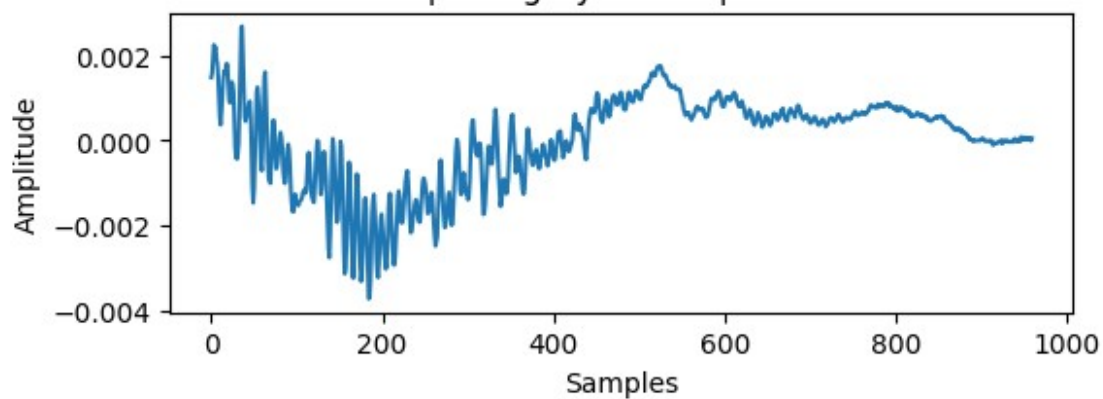
Phoneme: d | Category: plosive | Time: 2.14s - 2.18s



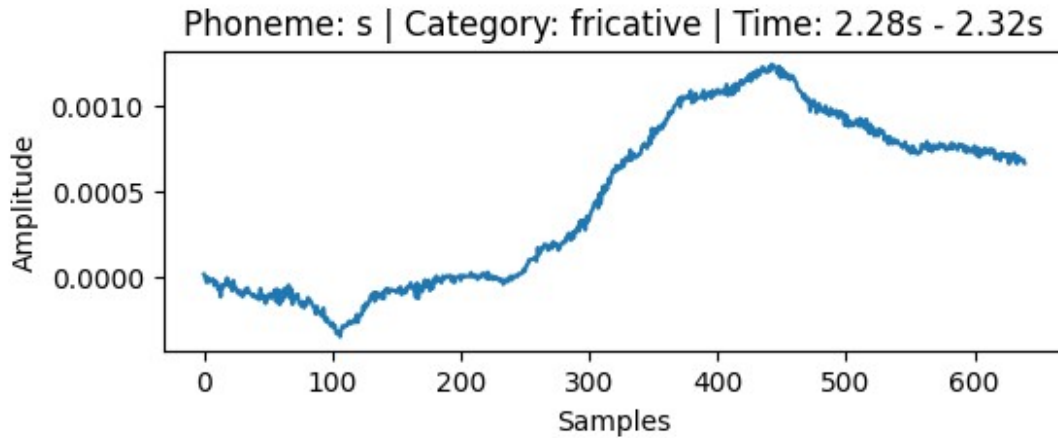
Phoneme: y | Category: semivowel | Time: 2.18s - 2.22s



Phoneme: e h | Category: vowel | Time: 2.22s - 2.28s







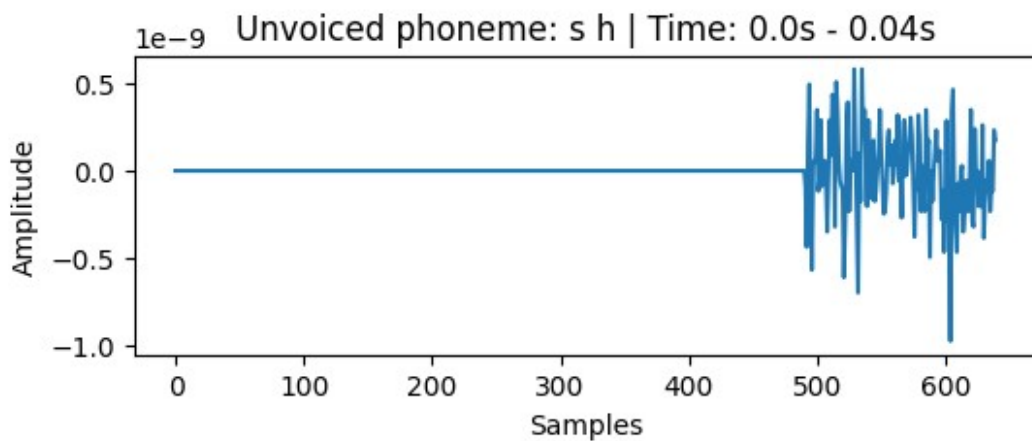
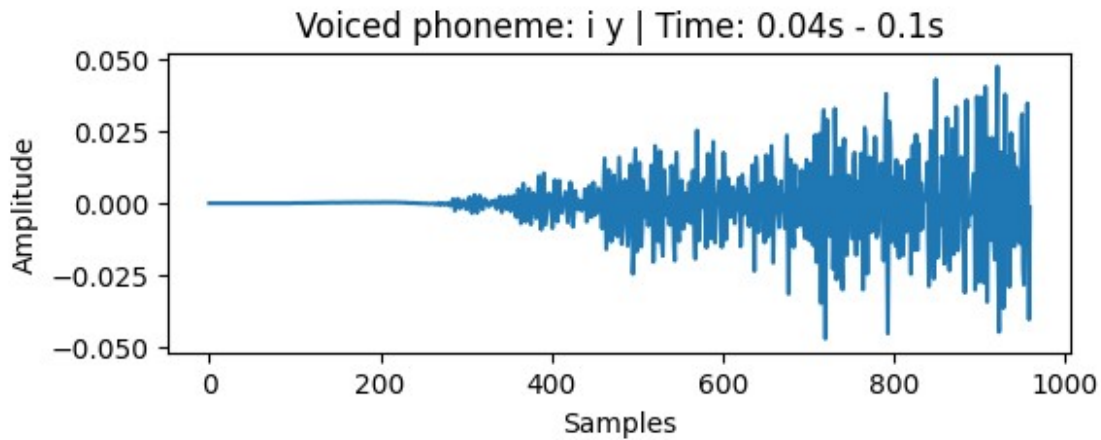
5

```
voiced_phonemes = ["a a", "a e", "a h", "a o", "e h", "e r", "i h", "i y", "u h", "u w", "b", "d", "g", "v", "z", "m", "n", "l", "r", "w", "y", "j h"]
unvoiced_phonemes = ["p", "t", "k", "f", "s", "s h", "t h", "c h", "h h"]

voiced_segment = None
unvoiced_segment = None

for phoneme, start, end in segments:
    if voiced_segment is None and phoneme in voiced_phonemes:
        voiced_segment = (phoneme, start, end)
    if unvoiced_segment is None and phoneme in unvoiced_phonemes:
        unvoiced_segment = (phoneme, start, end)
    if voiced_segment and unvoiced_segment:
        break

for label, segment in [("Voiced", voiced_segment), ("Unvoiced", unvoiced_segment)]:
    if segment:
        phoneme, start, end = segment
        start_sample = int(start * sr)
        end_sample = int(end * sr)
        plt.figure(figsize=(6, 2))
        plt.plot(y[start_sample:end_sample])
        plt.title(f"{label} phoneme: {phoneme} | Time: {round(start,2)}s - {round(end,2)}s")
        plt.xlabel("Samples")
        plt.ylabel("Amplitude")
        plt.show()
```



objective 2

(i)

```
import soundfile as sf
import librosa
y, sr = sf.read("/content/speech (1).wav")
print("Original sample rate:", sr)
print("Original shape:", y.shape)
if y.ndim > 1:
    y = librosa.to_mono(y.T)
if sr != 16000:
    y = librosa.resample(y.astype(float), orig_sr=sr, target_sr=16000)
    sr = 16000
print("Resampled sample rate:", sr)
print("Number of samples:", len(y))
print("Duration (sec):", round(len(y)/sr, 3))
```

Original sample rate: 24000  
Original shape: (36288,)  
Resampled sample rate: 16000

Number of samples: 24192  
Duration (sec): 1.512

(ii)

```
import soundfile as sf
import librosa
import torch
from transformers import Wav2Vec2Processor, Wav2Vec2ForCTC
import matplotlib.pyplot as plt

processor = Wav2Vec2Processor.from_pretrained("Bluecast/wav2vec2-Phoneme")
model = Wav2Vec2ForCTC.from_pretrained("Bluecast/wav2vec2-Phoneme")

input_values = processor(y, sampling_rate=sr,
return_tensors="pt").input_values
with torch.no_grad():
    logits = model(input_values).logits

predicted_ids = torch.argmax(logits, dim=-1)
phoneme_sequence = processor.batch_decode(predicted_ids)

print("Recognized phoneme sequence:")
print(phoneme_sequence[0])

frame_ids = torch.argmax(logits, dim=-1)[0].cpu().numpy()
frame_phonemes = processor.batch_decode([frame_ids])[0]

frame_duration = model.config.inputs_to_logits_ratio / sr
segments = []
current_phoneme = frame_phonemes[0]
start_time = 0.0

for i, phoneme in enumerate(frame_phonemes[1:], start=1):
    if phoneme != current_phoneme:
        end_time = i * frame_duration
        segments.append((current_phoneme, start_time, end_time))
        current_phoneme = phoneme
        start_time = end_time

segments.append((current_phoneme, start_time, len(frame_phonemes) *
frame_duration))

print("Number of phoneme segments:", len(segments))

{"model_id": "7eec8352770049118784b30fc1f09a8e", "version_major": 2, "version_minor": 0}
```

Recognized phoneme sequence:

sh iy s iy z y uw

Number of phoneme segments: 17

```
phoneme_categories = {
    "vowel": ["a a", "a e", "a h", "a o", "e h", "e r", "i h", "i
y", "u h", "u w"],
    "plosive": ["p", "b", "t", "d", "k", "g"],
    "fricative": ["f", "v", "t h", "d h", "s", "z", "s h", "z h", "h
h"],
    "affricate": ["c h", "j h"],
    "semivowel": ["l", "r", "w", "y"],
    "diphthong": ["a y", "e y", "o y", "a w", "o w"],
    "whisper": ["s i l", "s p n"]
}

def get_category(phoneme):
    for category, phones in phoneme_categories.items():
        if phoneme in phones:
            return category
    return "unknown"

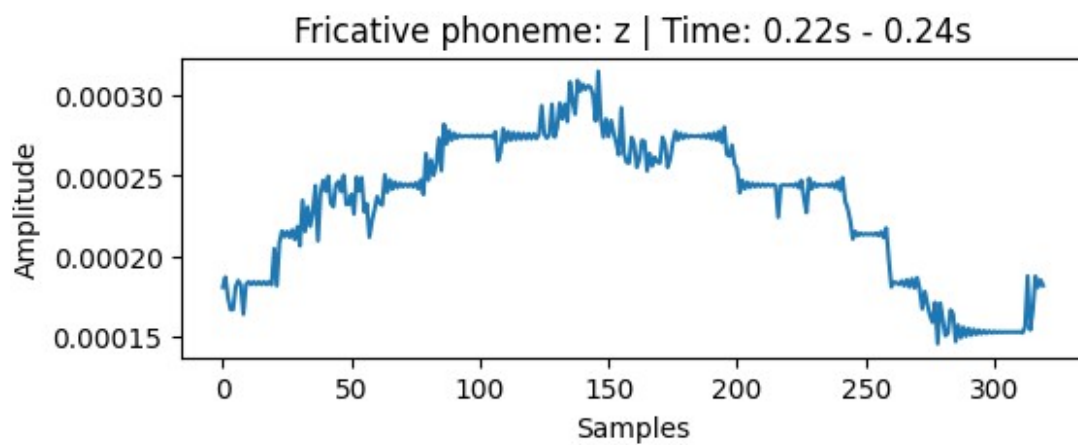
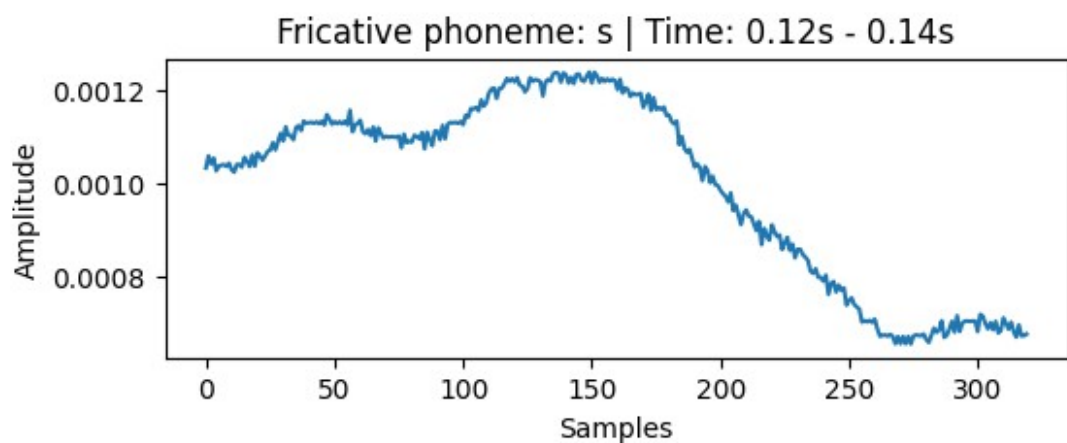
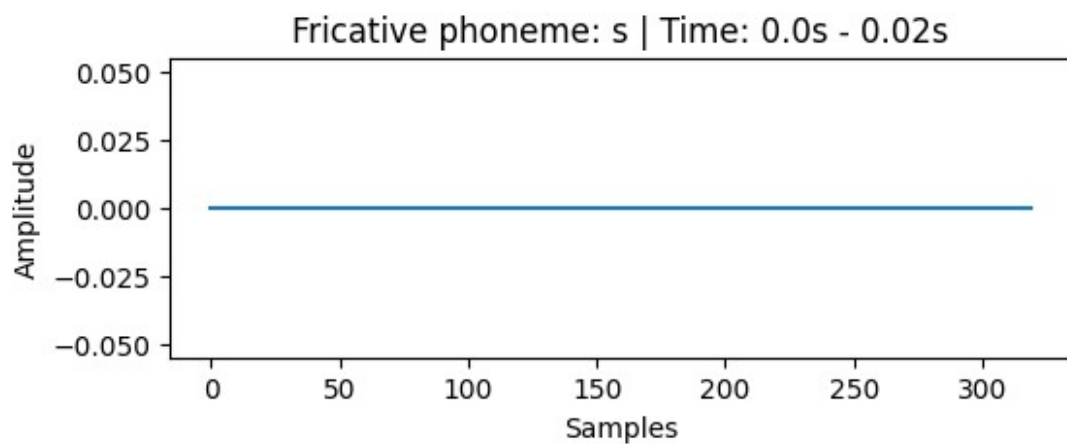
fricative_segments = []
approximant_segments = []

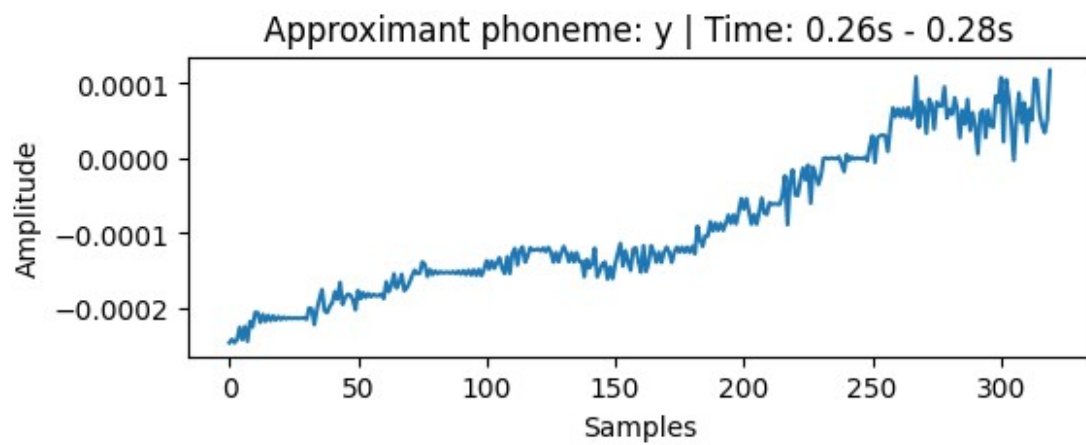
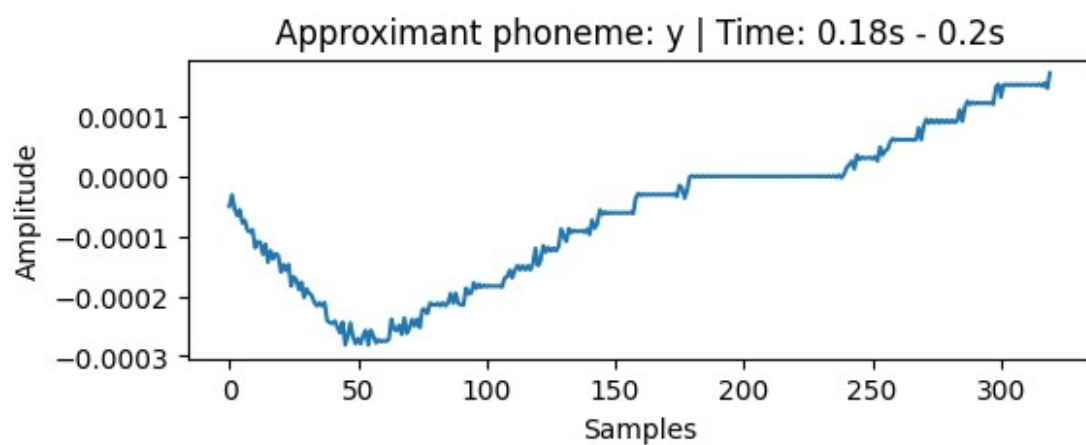
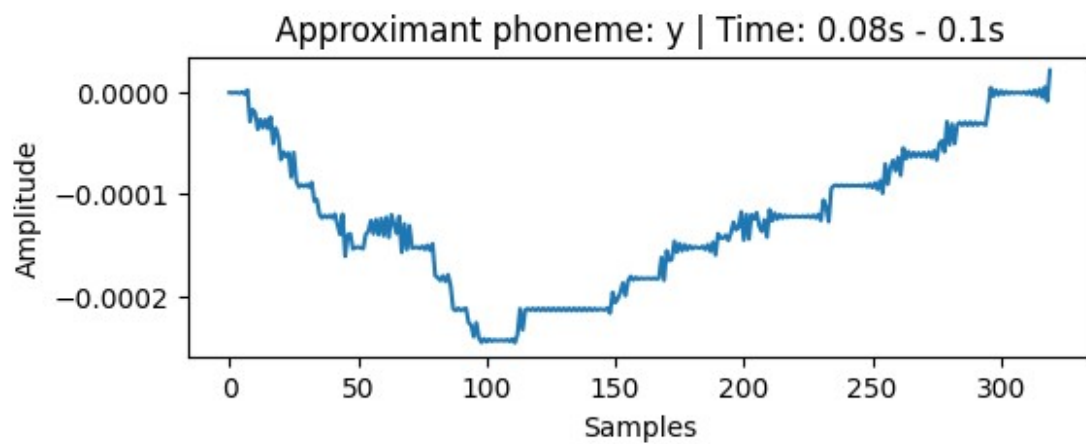
for phoneme, start, end in segments:
    category = get_category(phoneme)
    if category == "fricative":
        fricative_segments.append((phoneme, start, end))
    elif category == "semivowel":
        approximant_segments.append((phoneme, start, end))

for phoneme, start, end in fricative_segments:
    start_sample = int(start * sr)
    end_sample = int(end * sr)
    plt.figure(figsize=(6, 2))
    plt.plot(y[start_sample:end_sample])
    plt.title(f"Fricative phoneme: {phoneme} | Time: {round(start,2)}s
- {round(end,2)}s")
    plt.xlabel("Samples")
    plt.ylabel("Amplitude")
    plt.show()

for phoneme, start, end in approximant_segments:
    start_sample = int(start * sr)
    end_sample = int(end * sr)
    plt.figure(figsize=(6, 2))
    plt.plot(y[start_sample:end_sample])
    plt.title(f"Approximant phoneme: {phoneme} | Time: {round(start,2)}s
- {round(end,2)}s")
```

```
plt.xlabel("Samples")  
plt.ylabel("Amplitude")  
plt.show()
```









[illegible]

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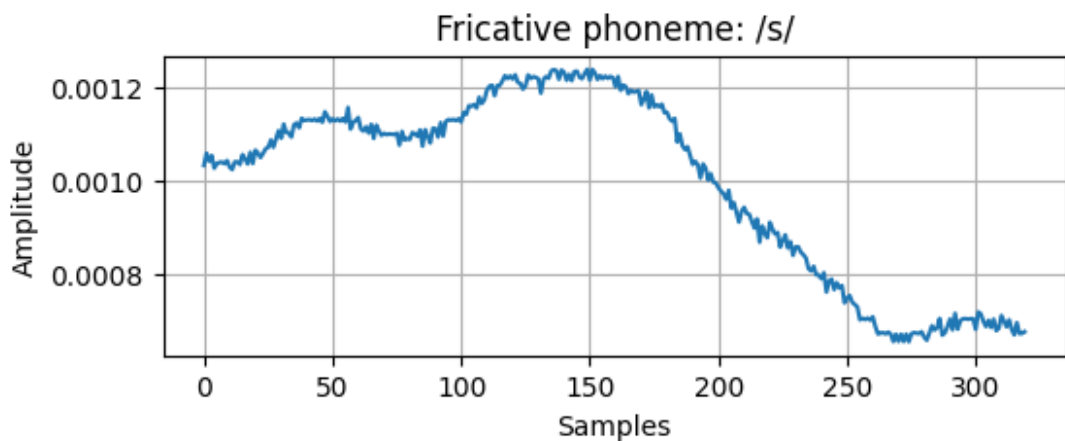
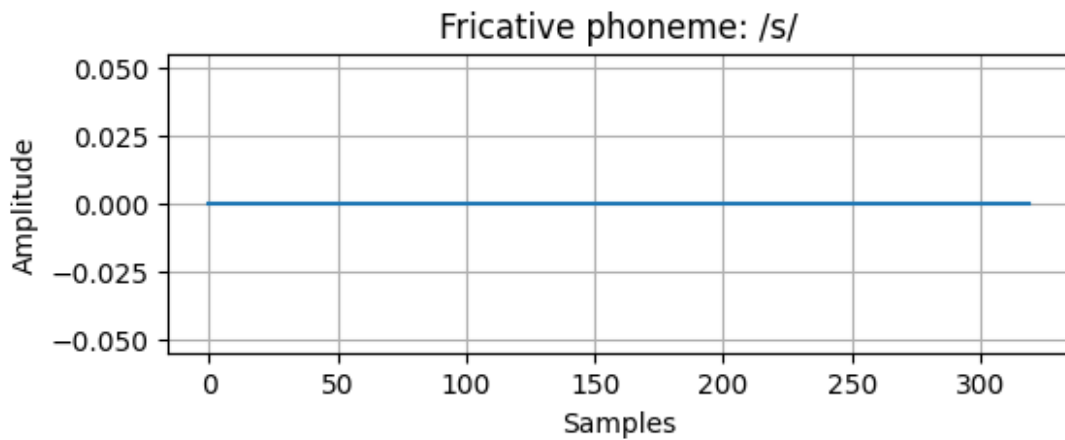
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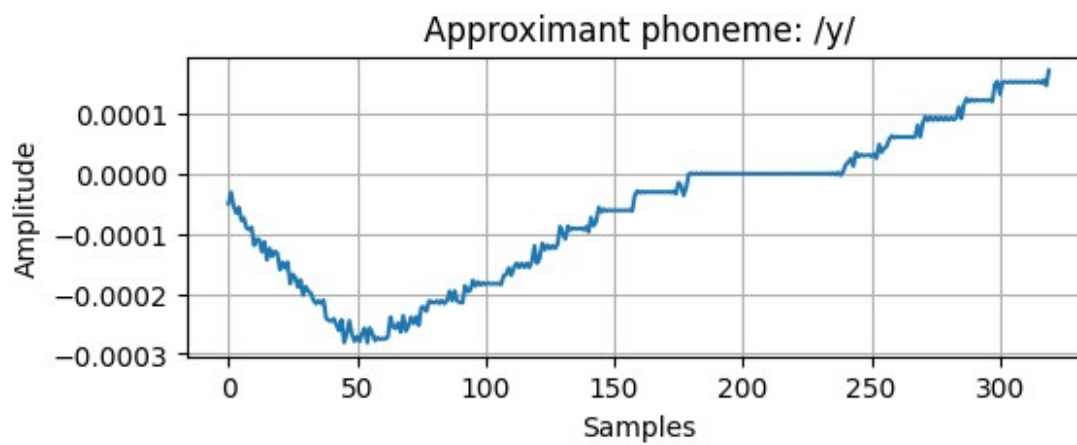
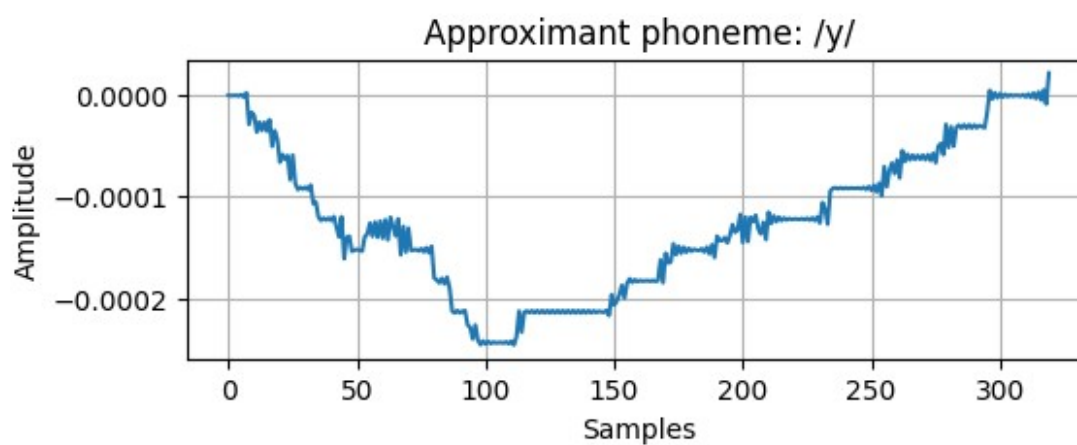
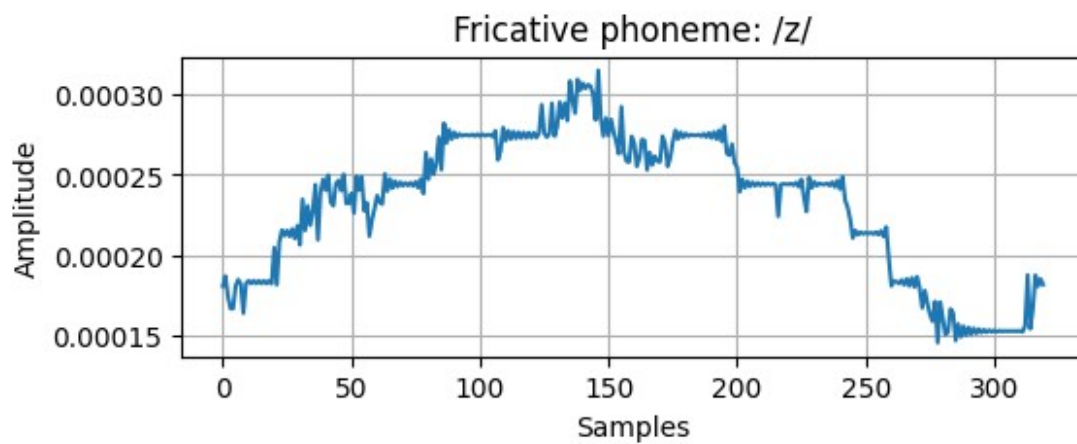
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def plot_segments(segments, title):
    for ph, sig in segments:
        plt.figure(figsize=(6,2))
        plt.plot(sig)
        plt.title(f"{title} phoneme: /{ph}/")
        plt.xlabel("Samples")
        plt.ylabel("Amplitude")
        plt.grid(True)
        plt.show()
plot_segments(fricative_signals, "Fricative")
plot_segments(approximant_signals, "Approximant")

```





Approximant phoneme: /y/

