

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
```

```
/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: multiprocess<0.70.17 in
```

```
/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
```

```
/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-
```

```

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

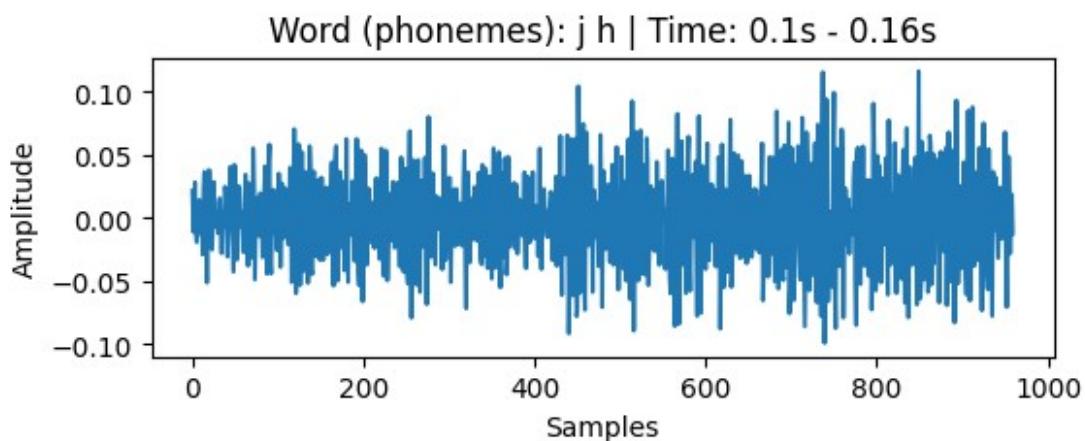
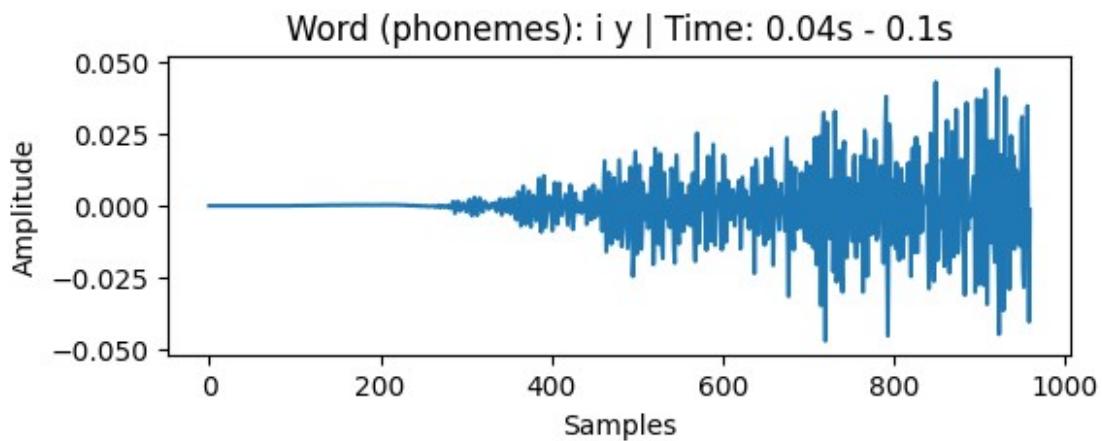
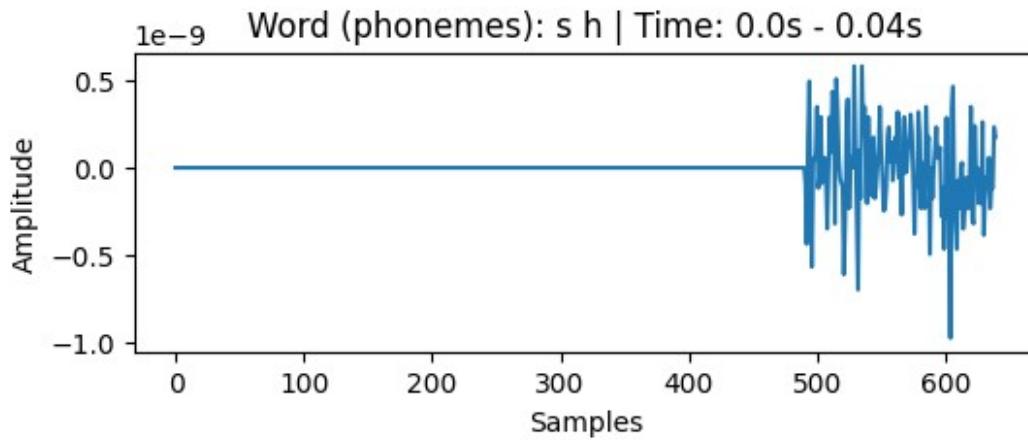
segments = []
current_word = []
start_time = 0.0

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))

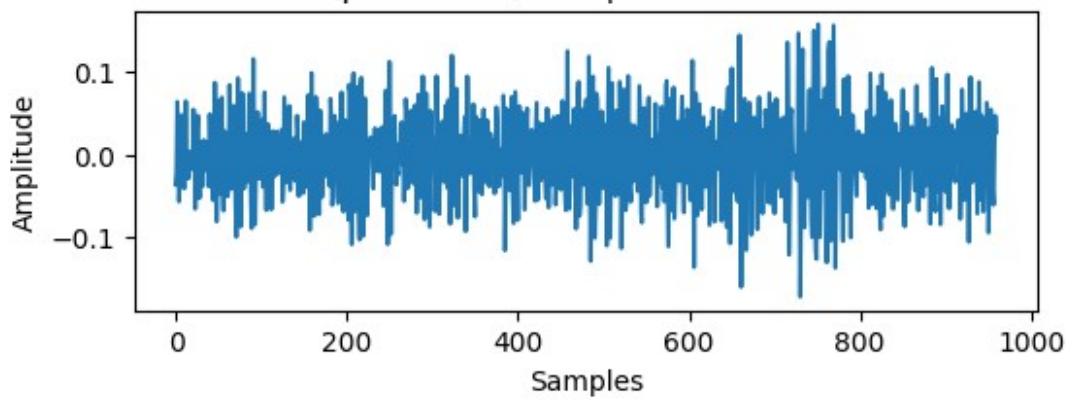
for word, start, end in segments:
    start_sample = int(start * sr)
    end_sample = int(end * sr)
    plt.figure(figsize=(6, 2))
    plt.plot(y[start_sample:end_sample])
    plt.title(f"Word (phonemes): {word} | Time: {round(start,2)}s - "

```

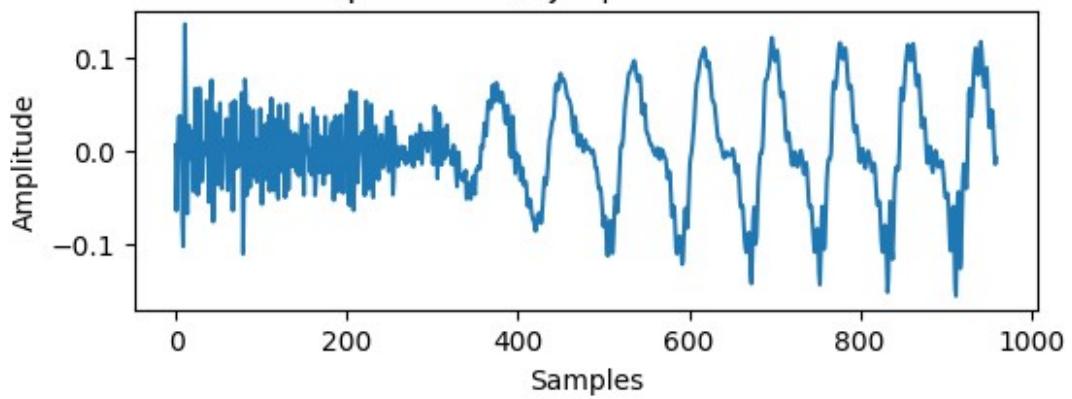
```
{round(end,2)}s")
plt.xlabel("Samples")
plt.ylabel("Amplitude")
plt.show()
```



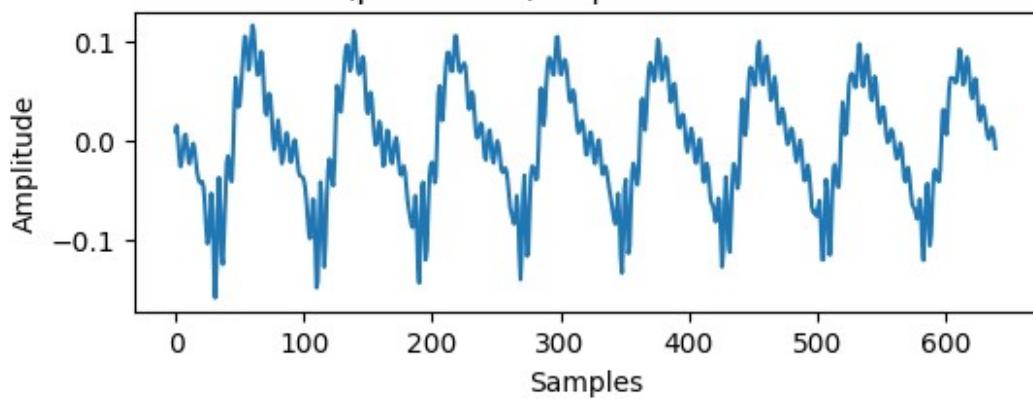
Word (phonemes): a h | Time: 0.16s - 0.22s



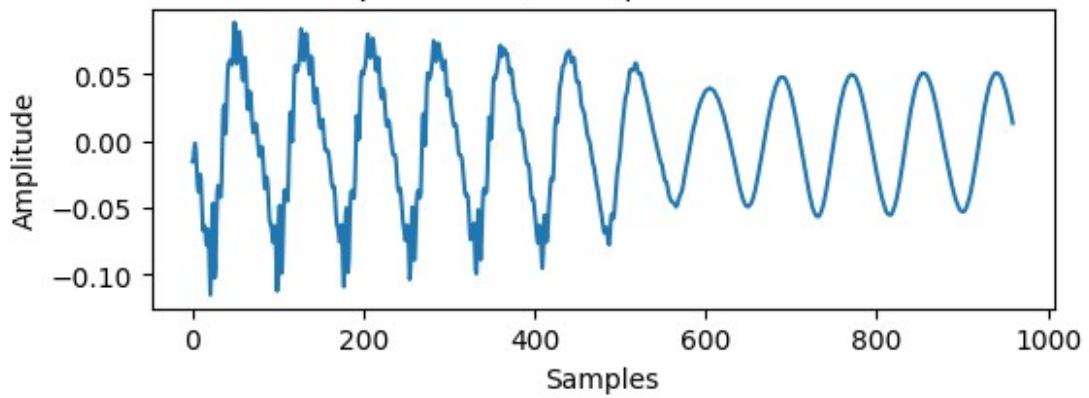
Word (phonemes): j h | Time: 0.22s - 0.28s



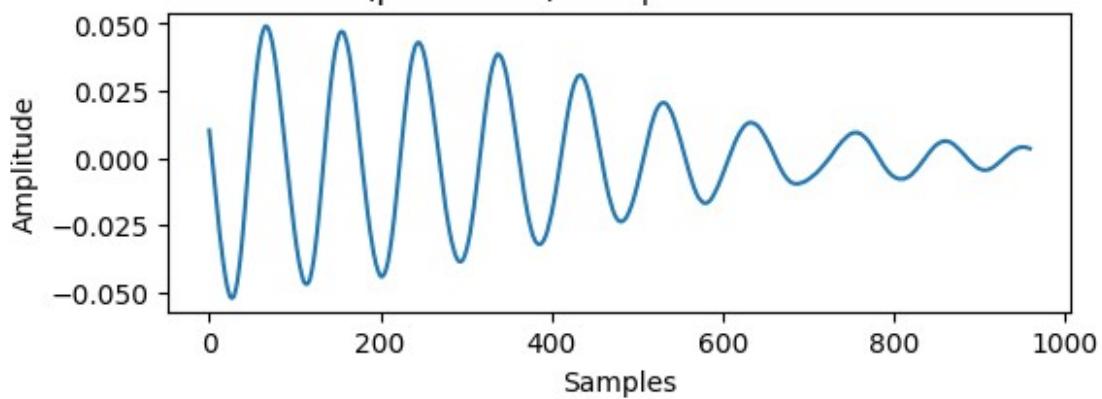
Word (phonemes): d | Time: 0.28s - 0.32s



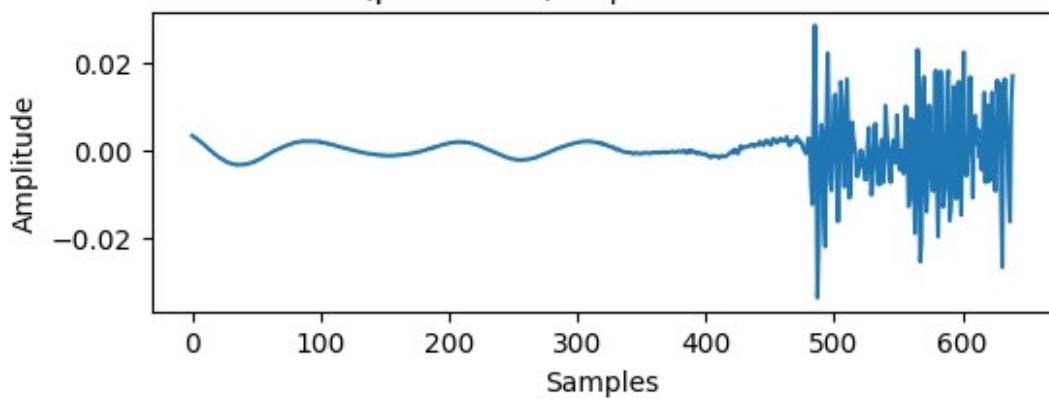
Word (phonemes): d h | Time: 0.32s - 0.38s



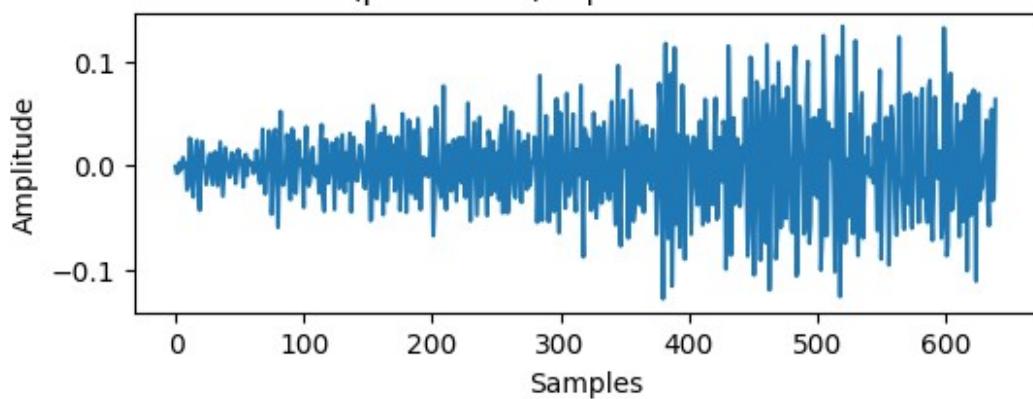
Word (phonemes): a h | Time: 0.38s - 0.44s



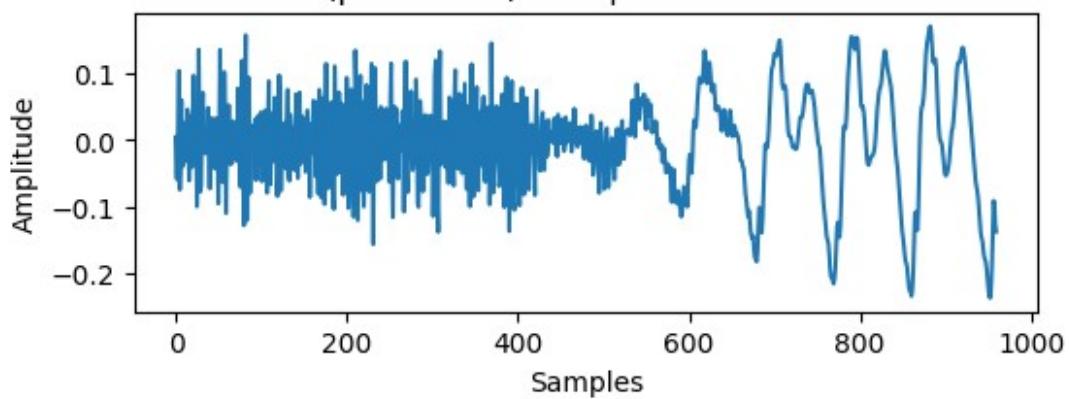
Word (phonemes): b | Time: 0.44s - 0.48s



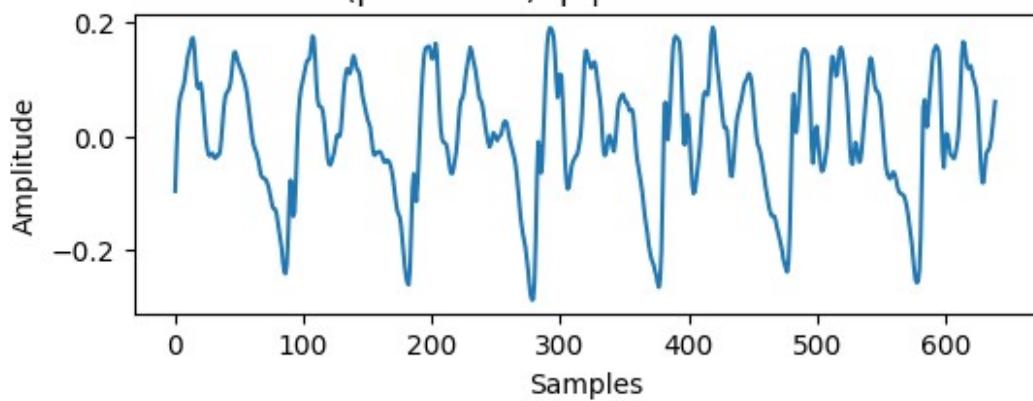
Word (phonemes): I | Time: 0.48s - 0.52s



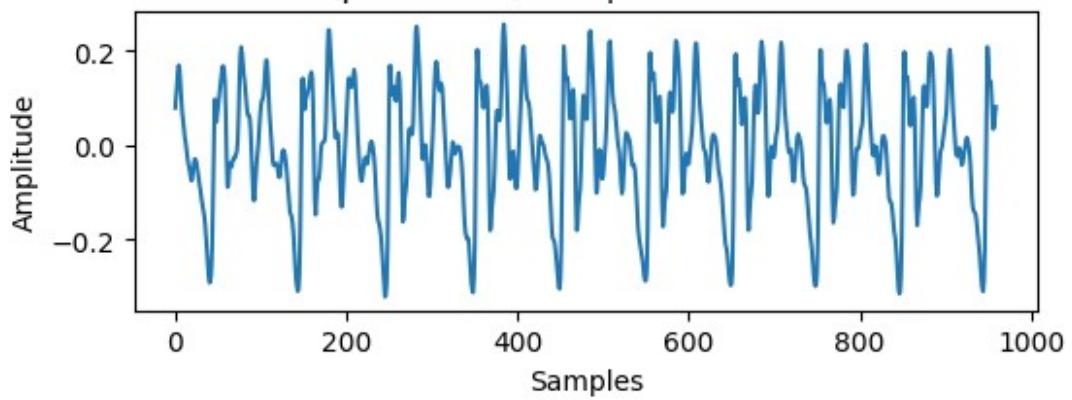
Word (phonemes): u w | Time: 0.52s - 0.58s



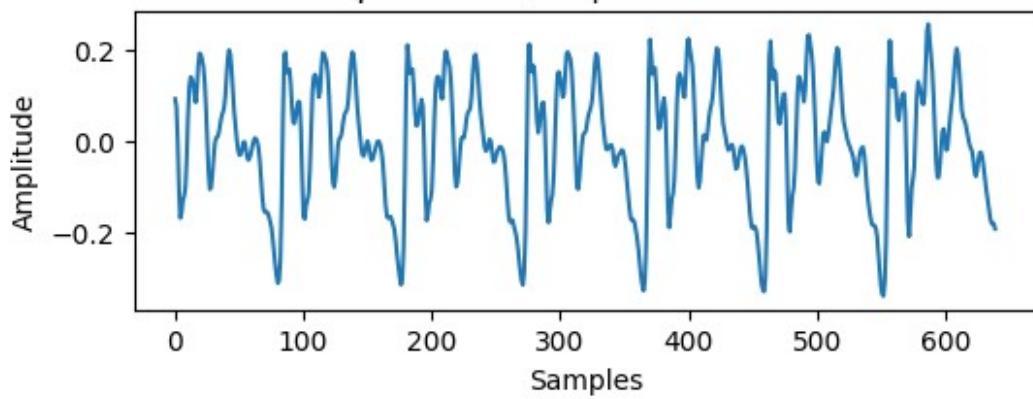
Word (phonemes): p | Time: 0.58s - 0.62s



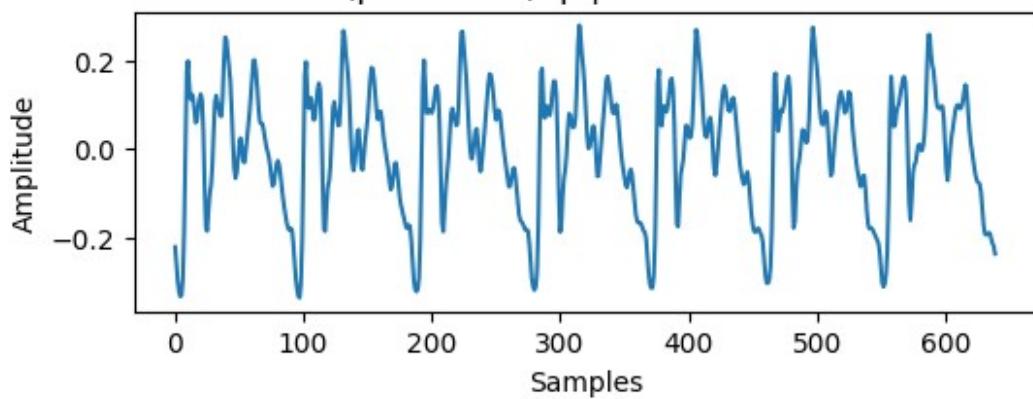
Word (phonemes): e h | Time: 0.62s - 0.68s



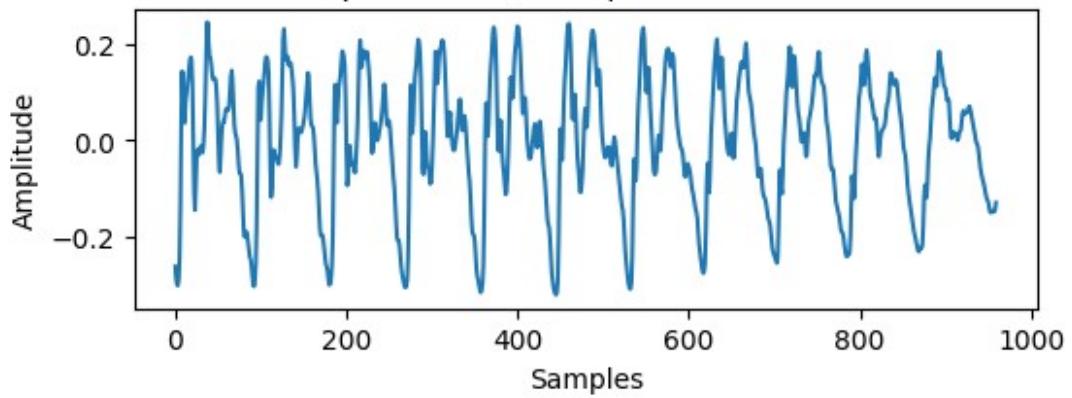
Word (phonemes): n | Time: 0.68s - 0.72s



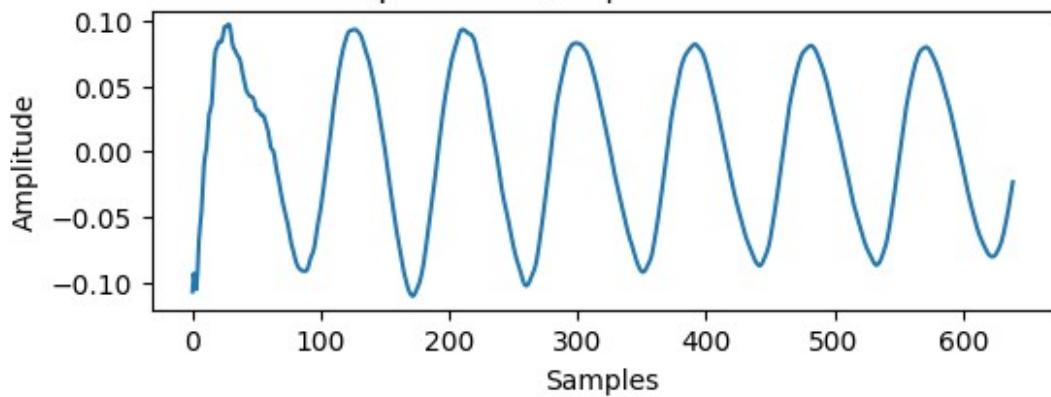
Word (phonemes): p | Time: 0.72s - 0.76s



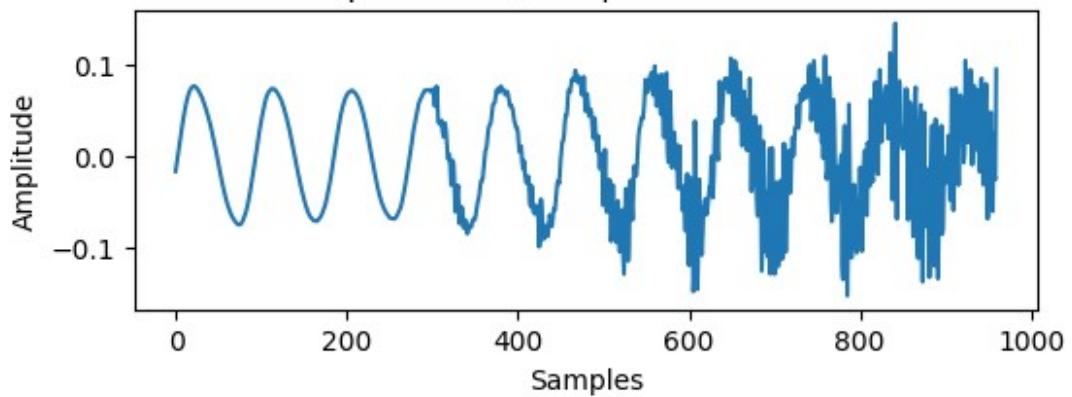
Word (phonemes): u h | Time: 0.76s - 0.82s



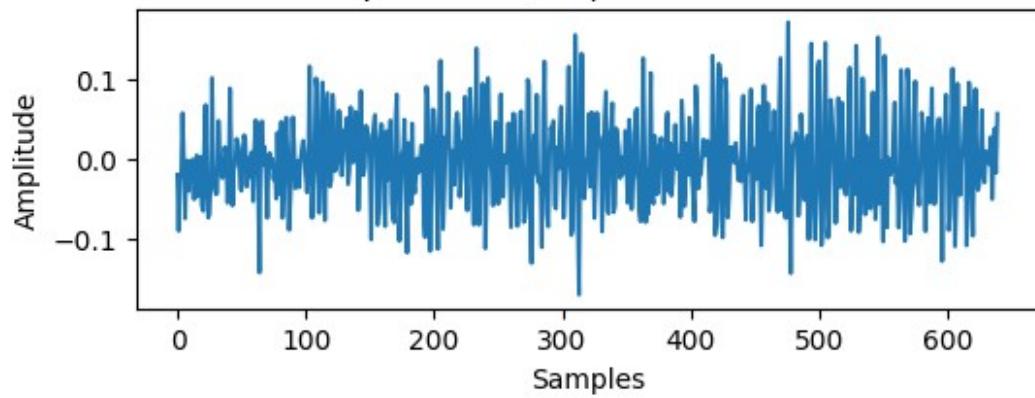
Word (phonemes): t | Time: 0.82s - 0.86s



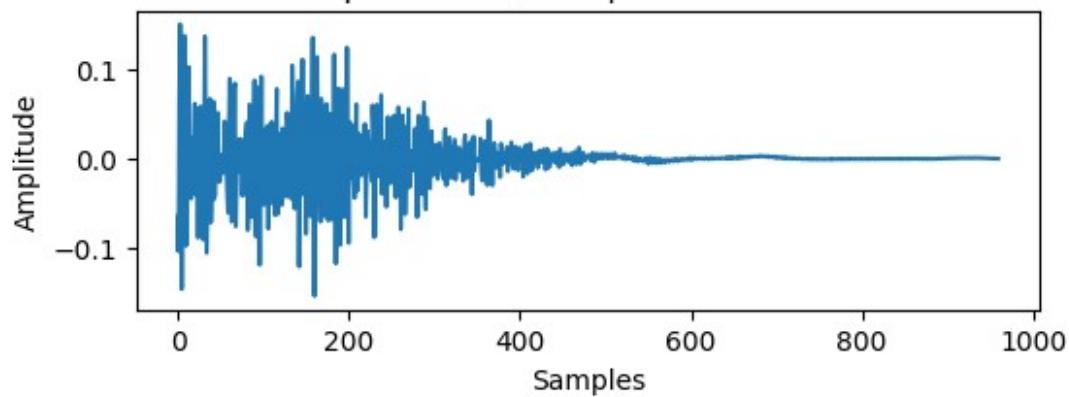
Word (phonemes): i h | Time: 0.86s - 0.92s



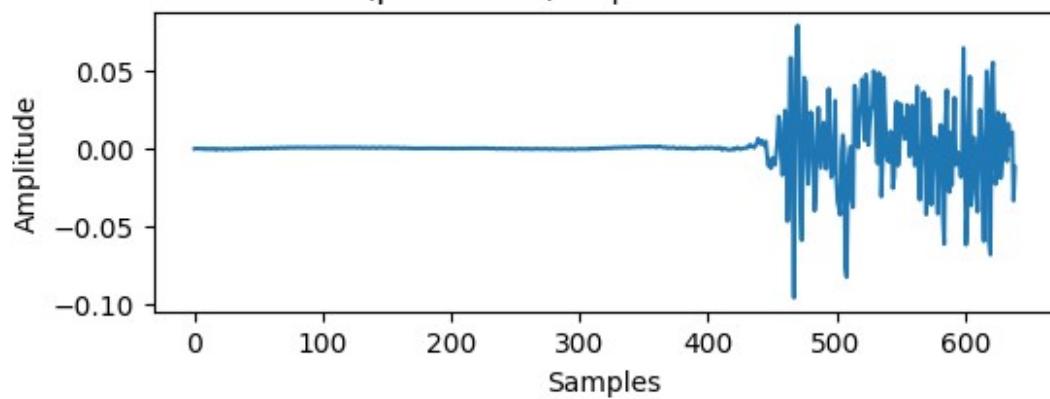
Word (phonemes): t | Time: 0.92s - 0.96s



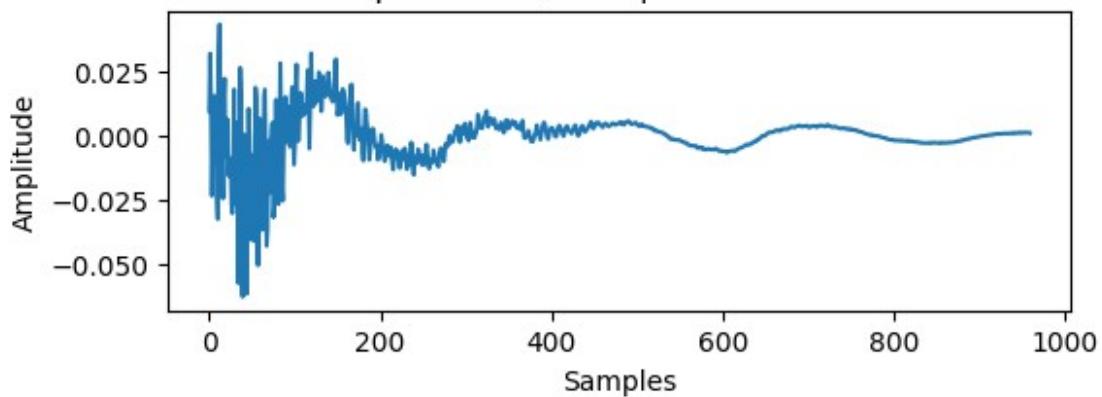
Word (phonemes): a a | Time: 0.96s - 1.02s



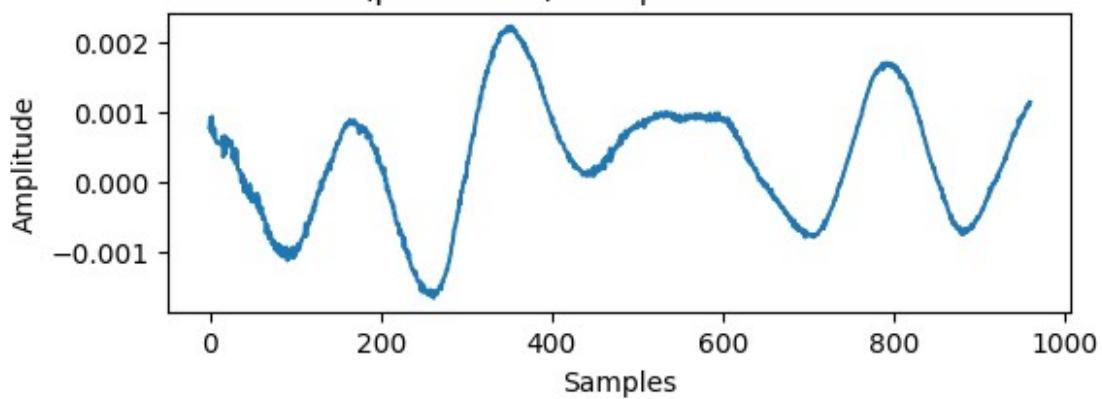
Word (phonemes): n | Time: 1.02s - 1.06s



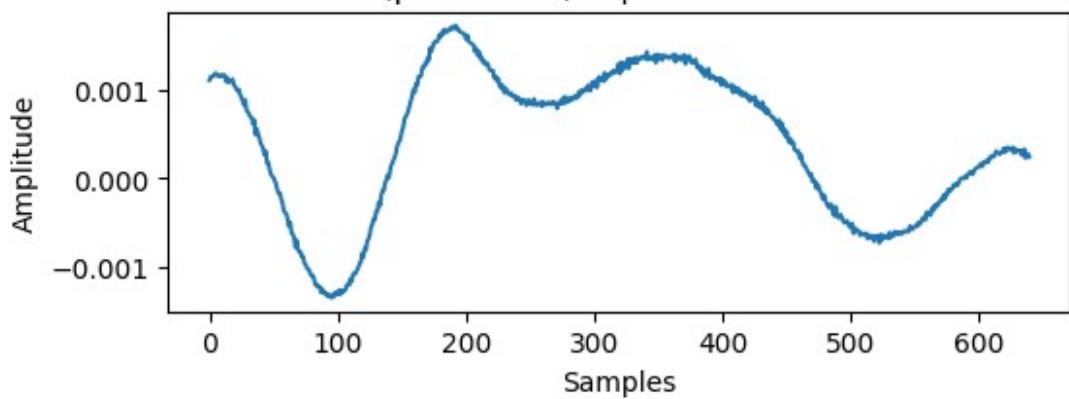
Word (phonemes): d h | Time: 1.06s - 1.12s



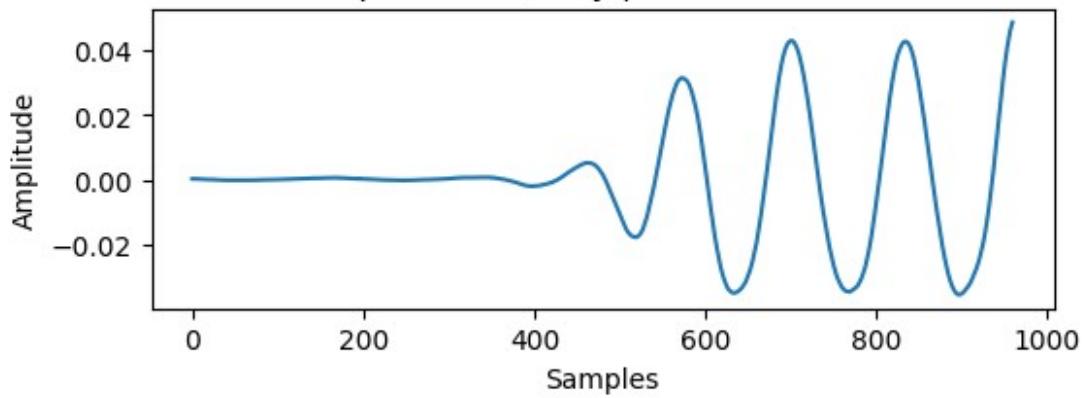
Word (phonemes): a h | Time: 1.12s - 1.18s



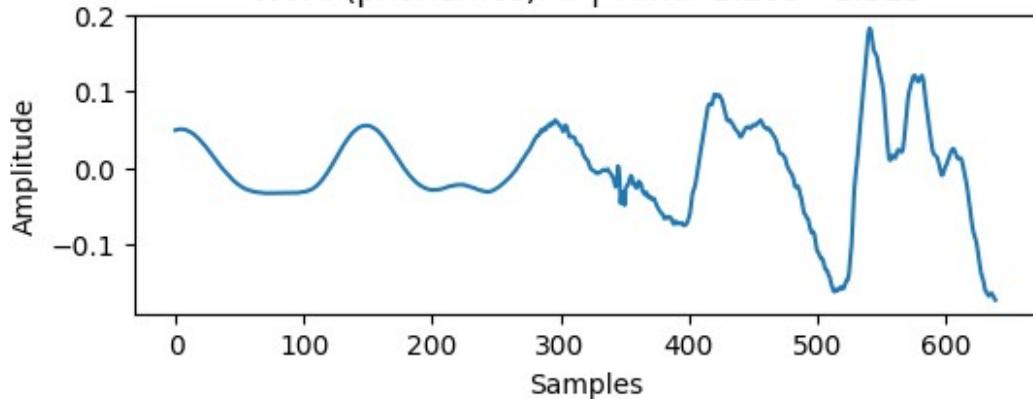
Word (phonemes): t | Time: 1.18s - 1.22s



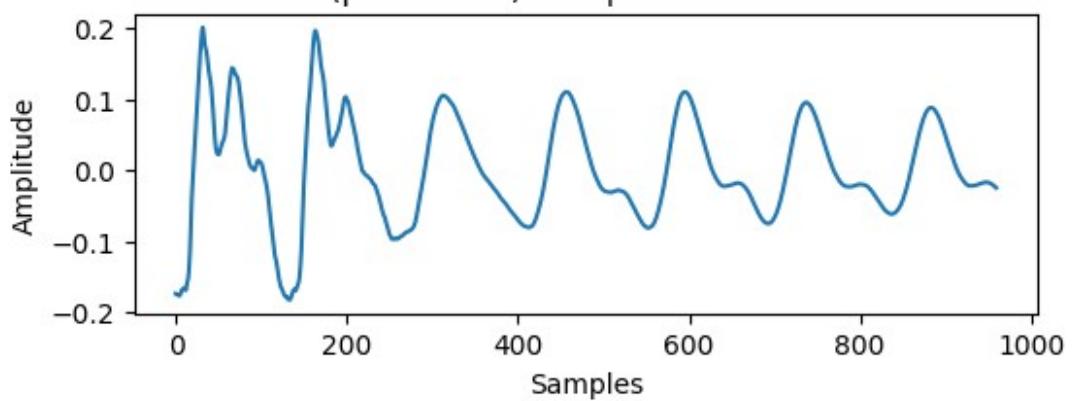
Word (phonemes): e y | Time: 1.22s - 1.28s



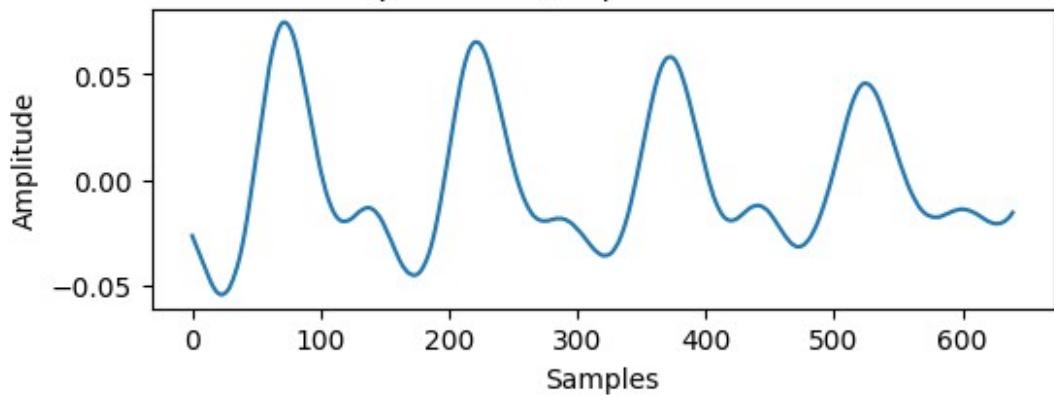
Word (phonemes): b | Time: 1.28s - 1.32s



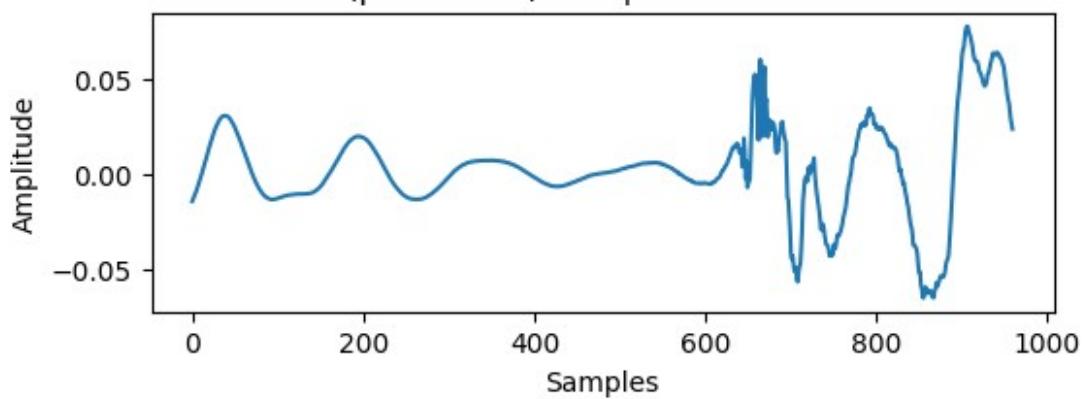
Word (phonemes): a h | Time: 1.32s - 1.38s



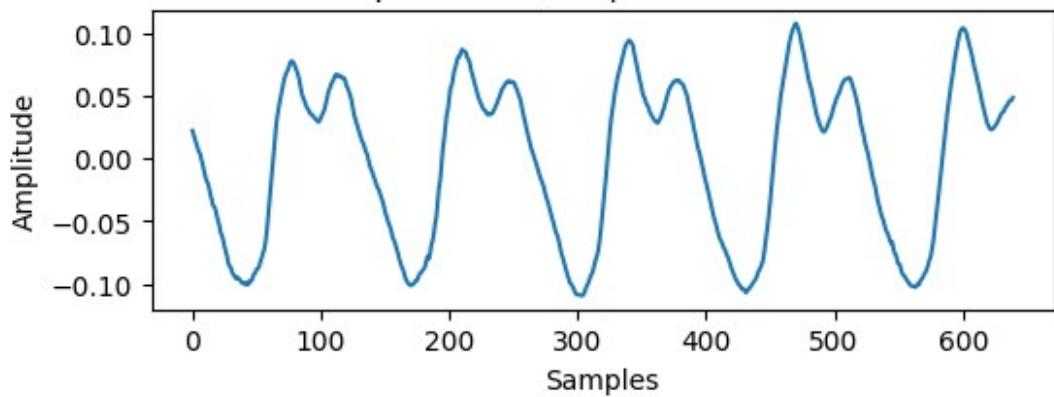
Word (phonemes): I | Time: 1.38s - 1.42s



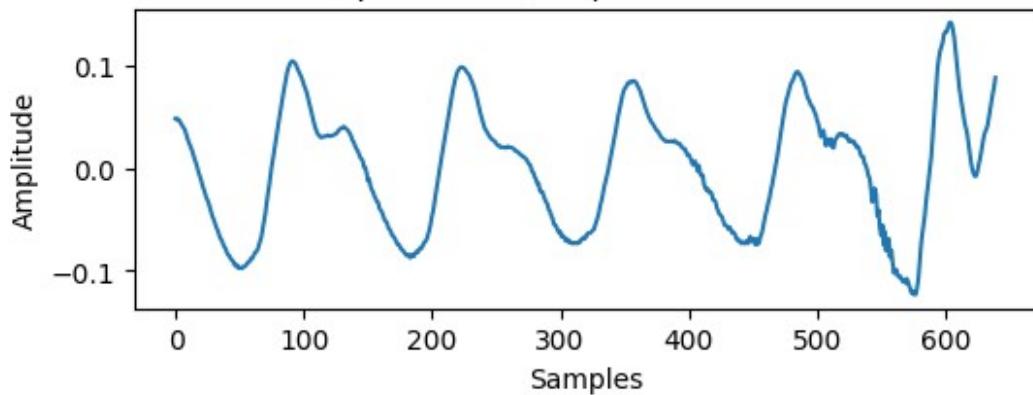
Word (phonemes): a h | Time: 1.42s - 1.48s



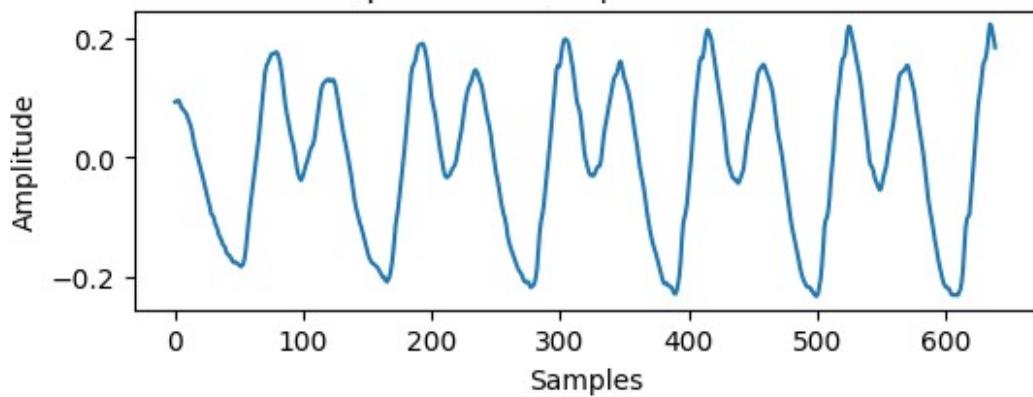
Word (phonemes): n | Time: 1.48s - 1.52s



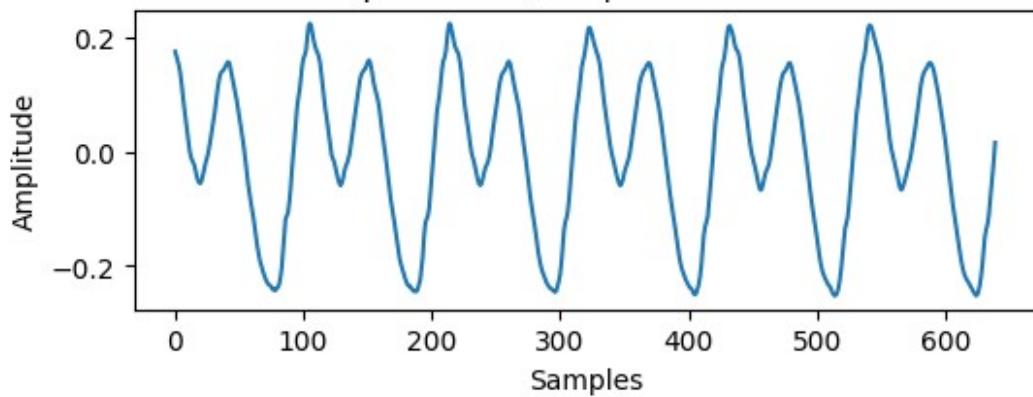
Word (phonemes): d | Time: 1.52s - 1.56s



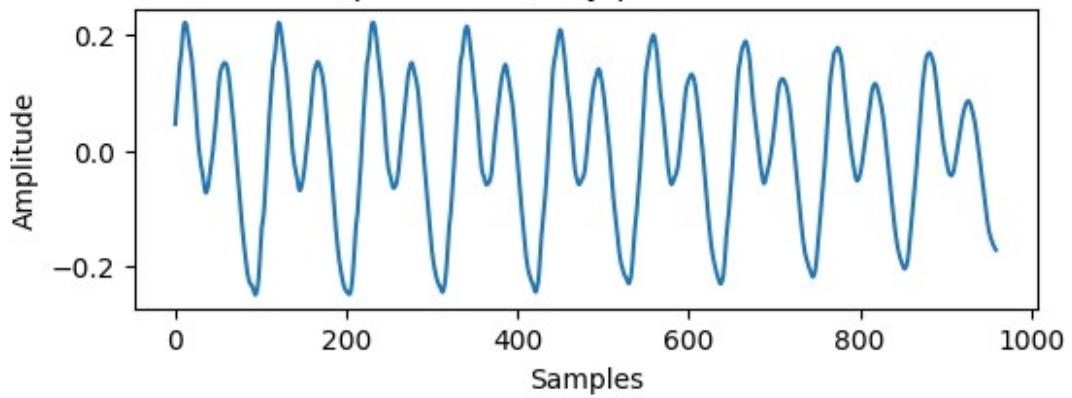
Word (phonemes): k | Time: 1.56s - 1.6s



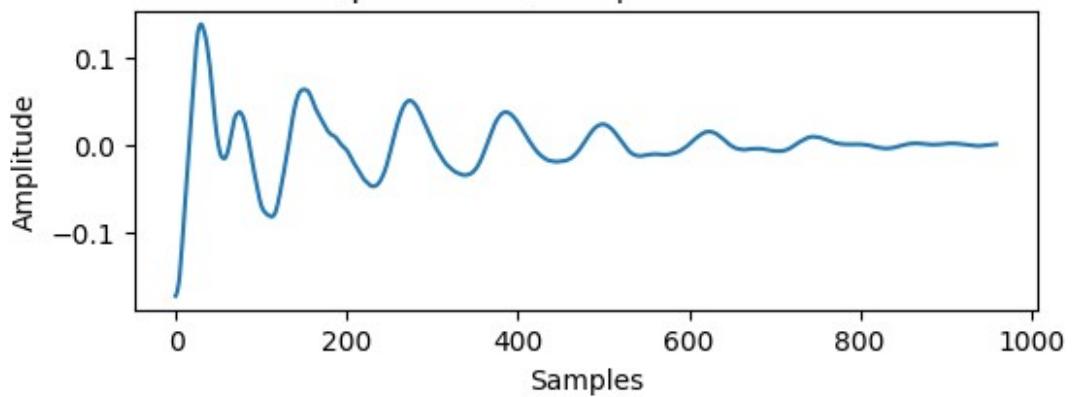
Word (phonemes): w | Time: 1.6s - 1.64s



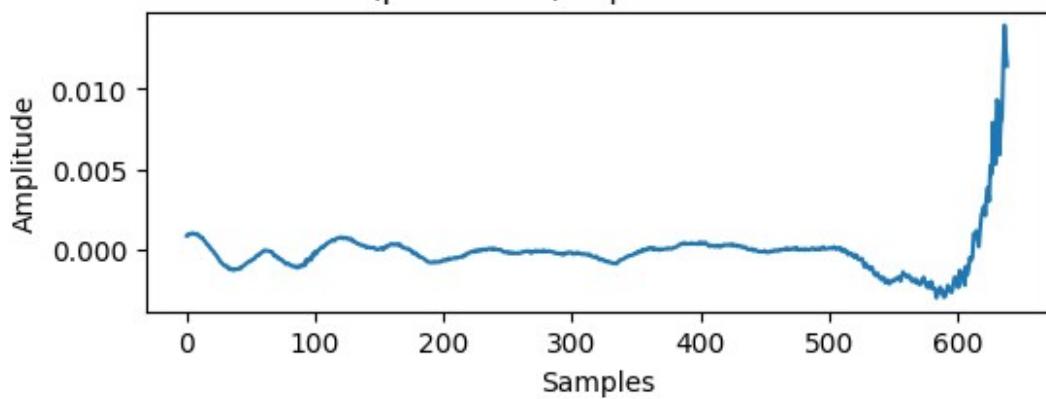
Word (phonemes): a y | Time: 1.64s - 1.7s



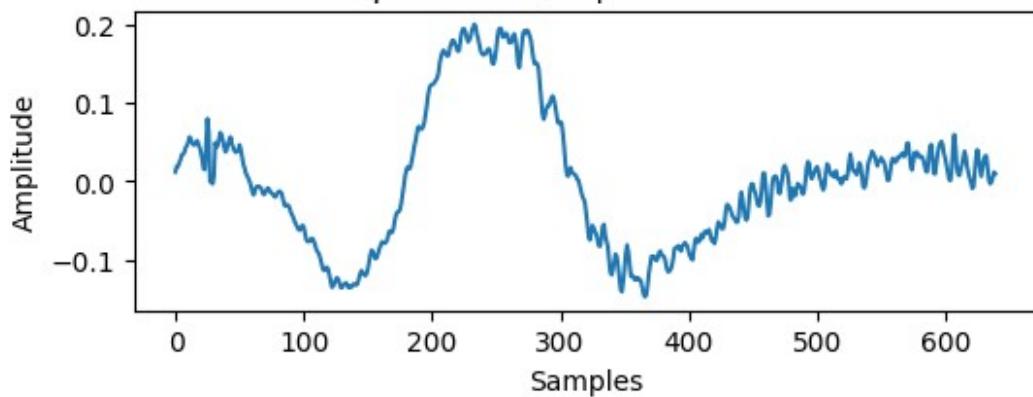
Word (phonemes): a h | Time: 1.7s - 1.76s



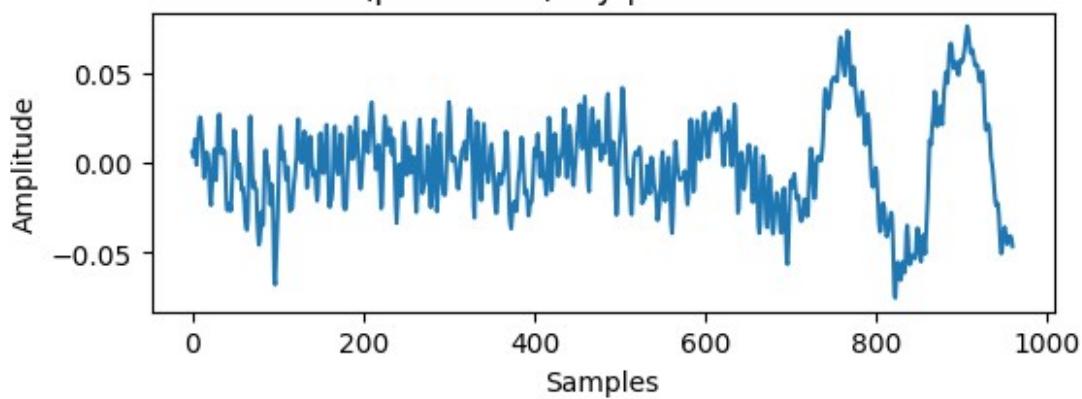
Word (phonemes): t | Time: 1.76s - 1.8s



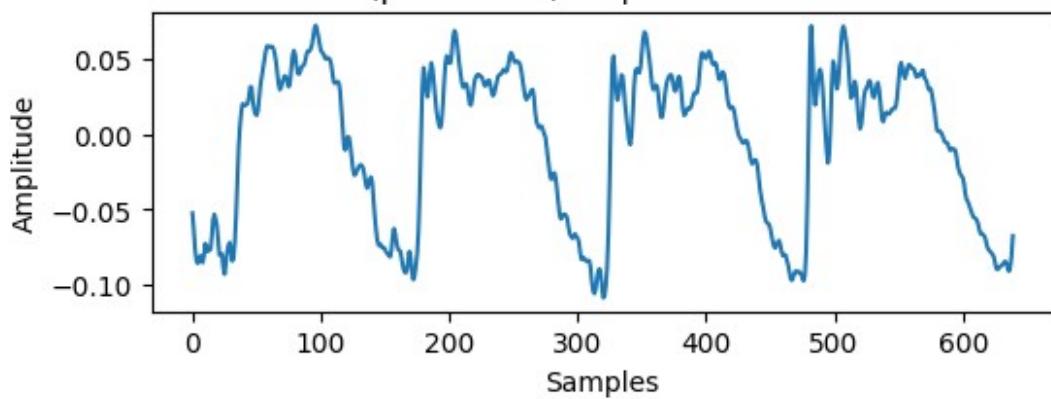
Word (phonemes): I | Time: 1.8s - 1.84s



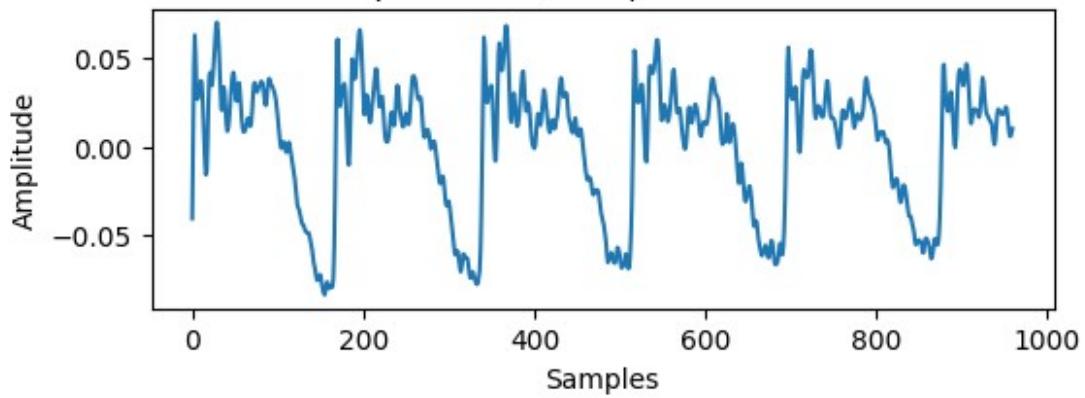
Word (phonemes): i y | Time: 1.84s - 1.9s



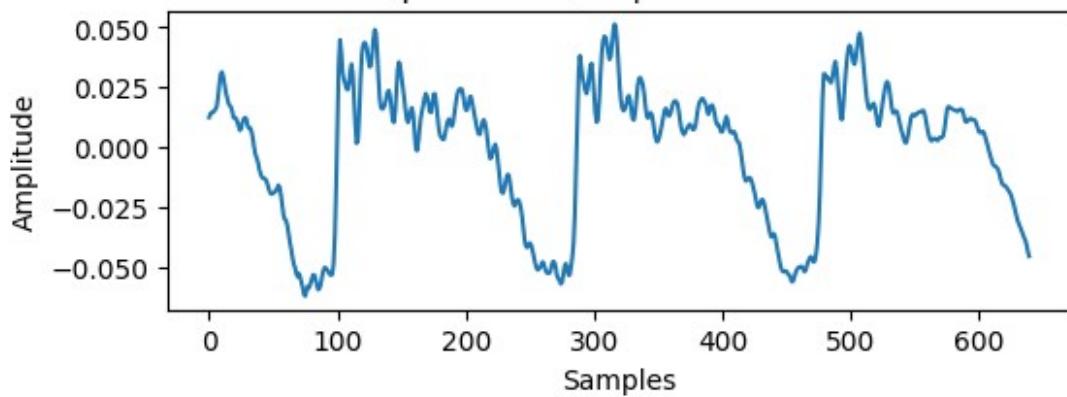
Word (phonemes): w | Time: 1.9s - 1.94s



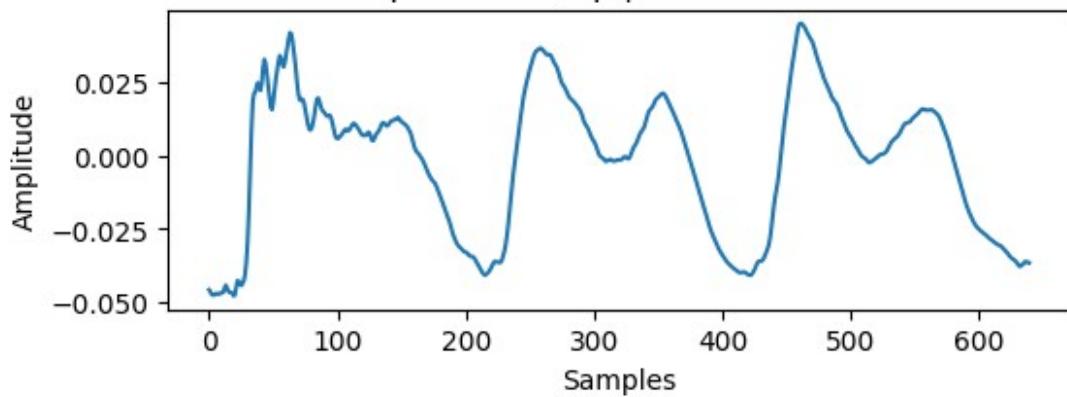
Word (phonemes): i h | Time: 1.94s - 2.0s



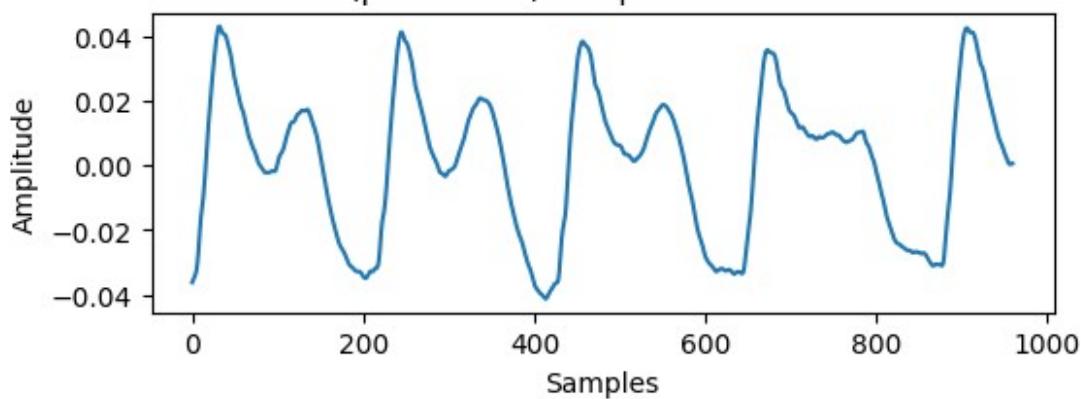
Word (phonemes): s | Time: 2.0s - 2.04s



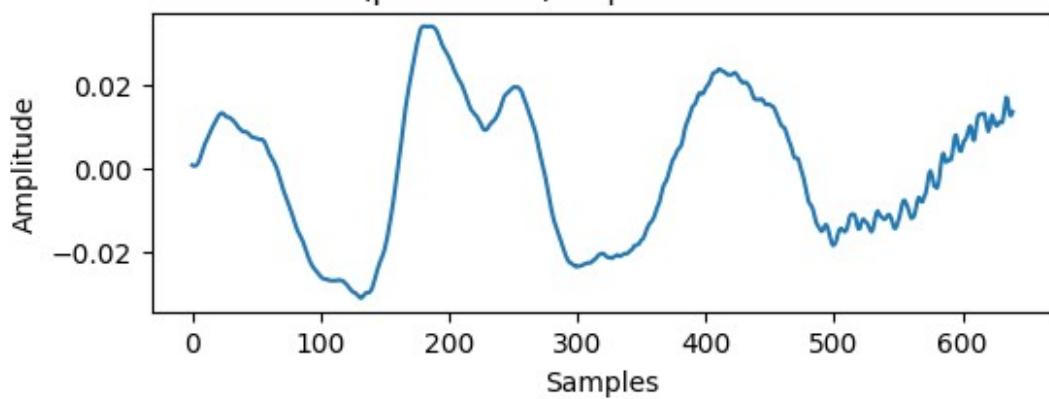
Word (phonemes): p | Time: 2.04s - 2.08s



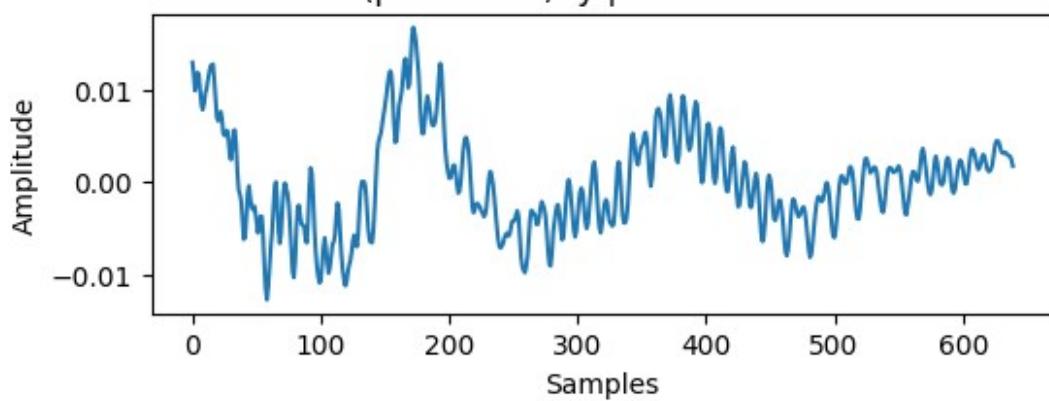
Word (phonemes): e r | Time: 2.08s - 2.14s

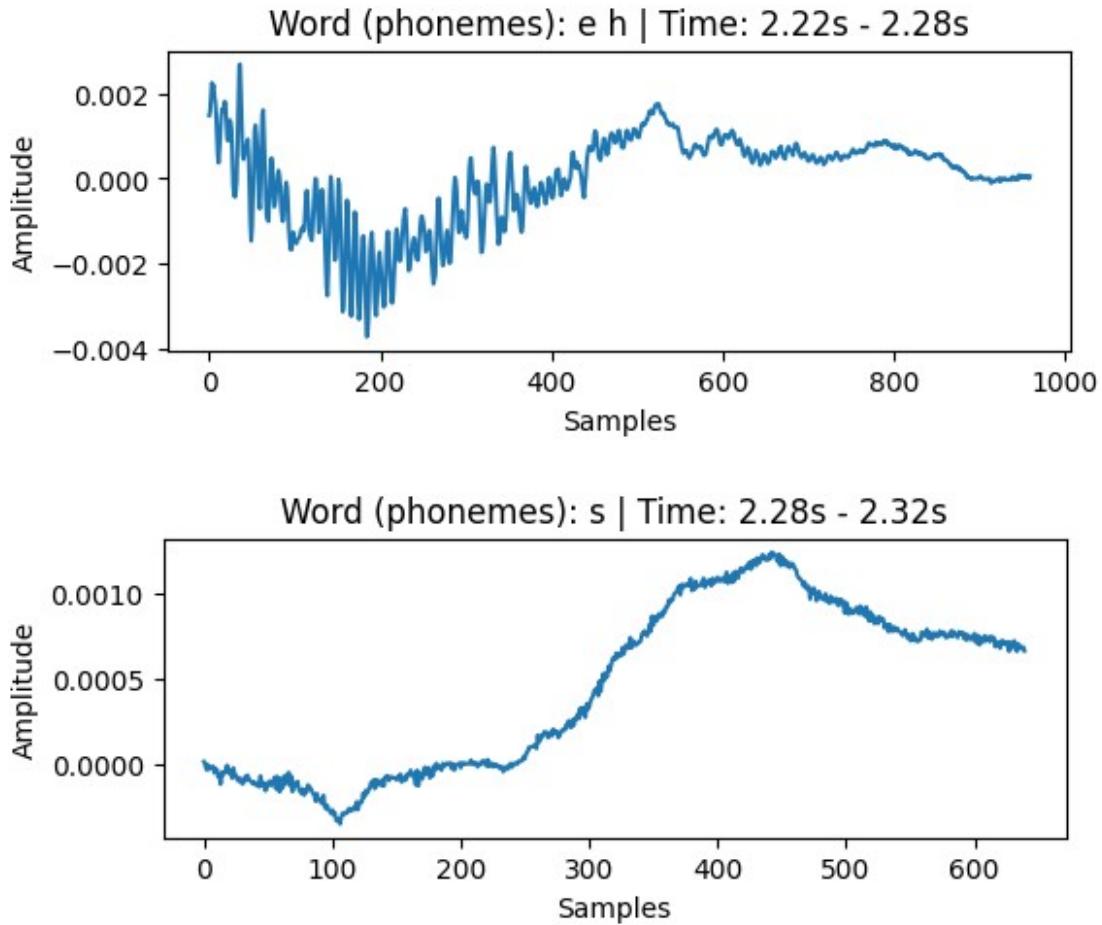


Word (phonemes): d | Time: 2.14s - 2.18s



Word (phonemes): y | Time: 2.18s - 2.22s





```
!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
/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)

```

4

```

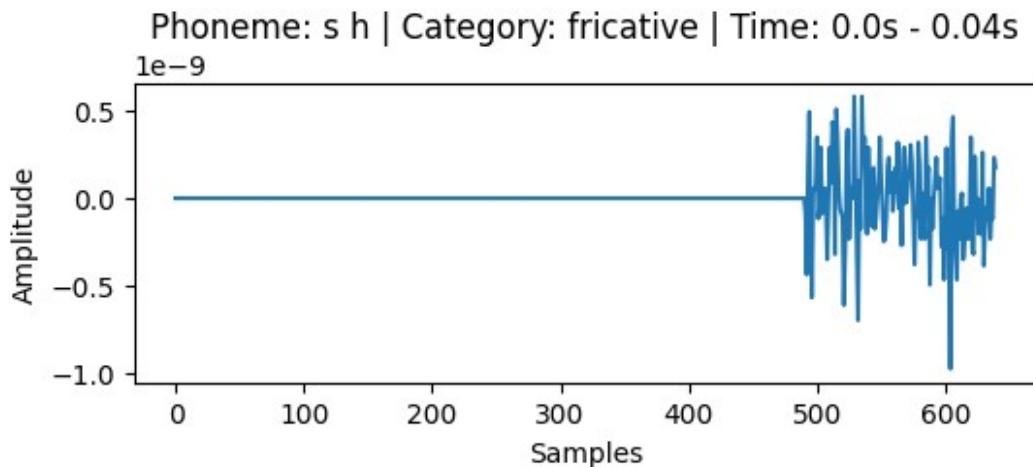
phoneme_categories = {
    "vowel": ["a a", "a e", "a h", "a o", "e h", "e r", "i h", "i y", "u h", "u w"],
    "plosive": ["p", "b", "t", "d", "k", "g"],
}

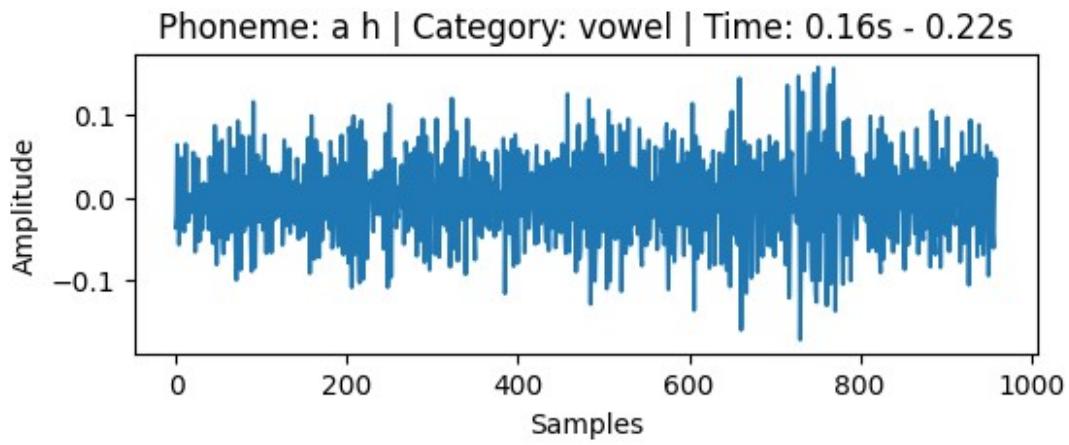
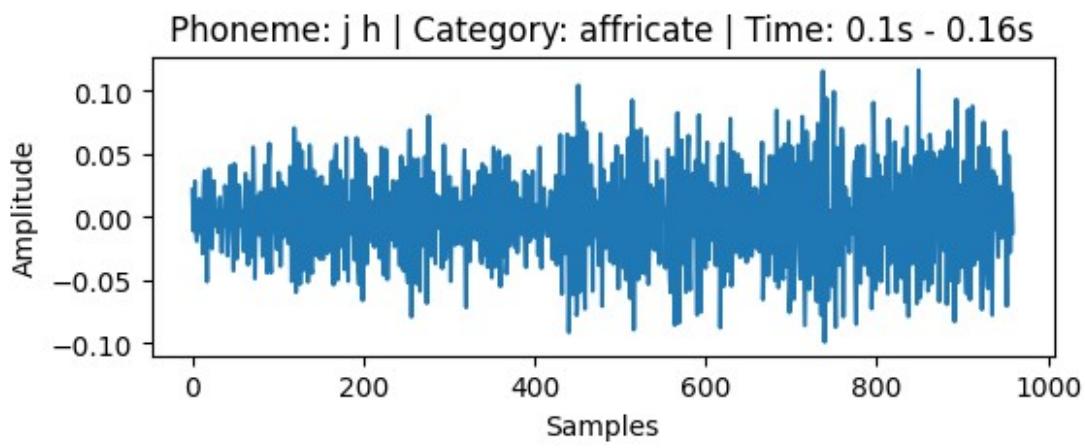
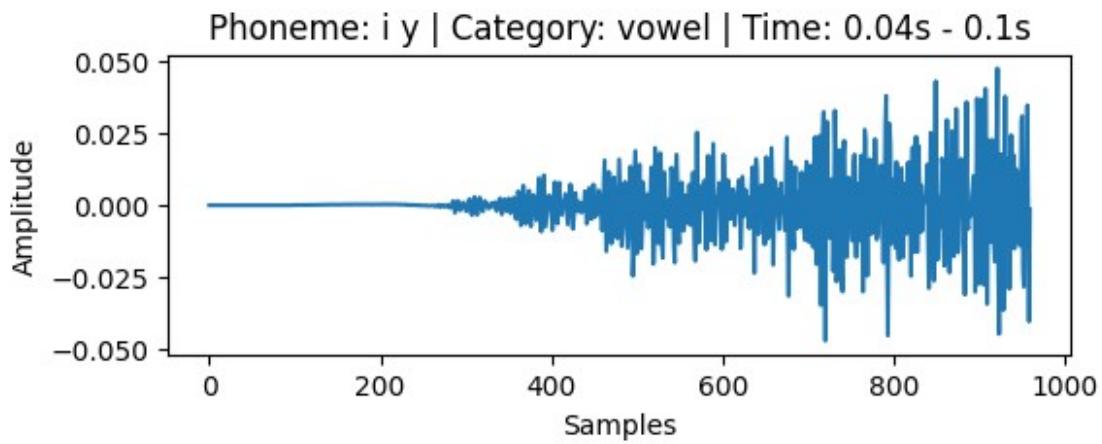
```

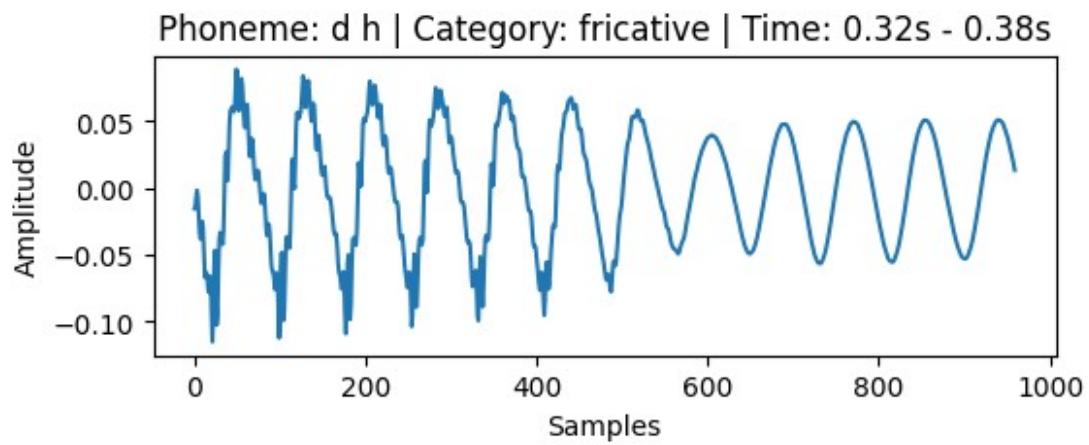
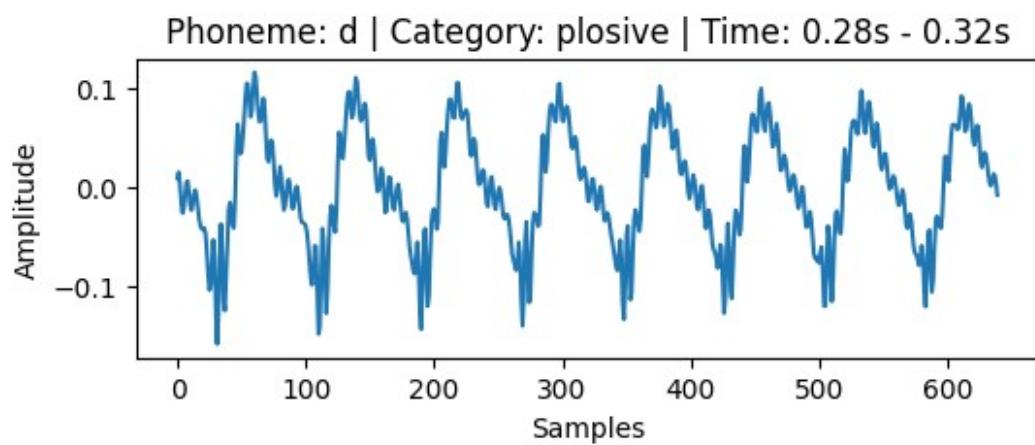
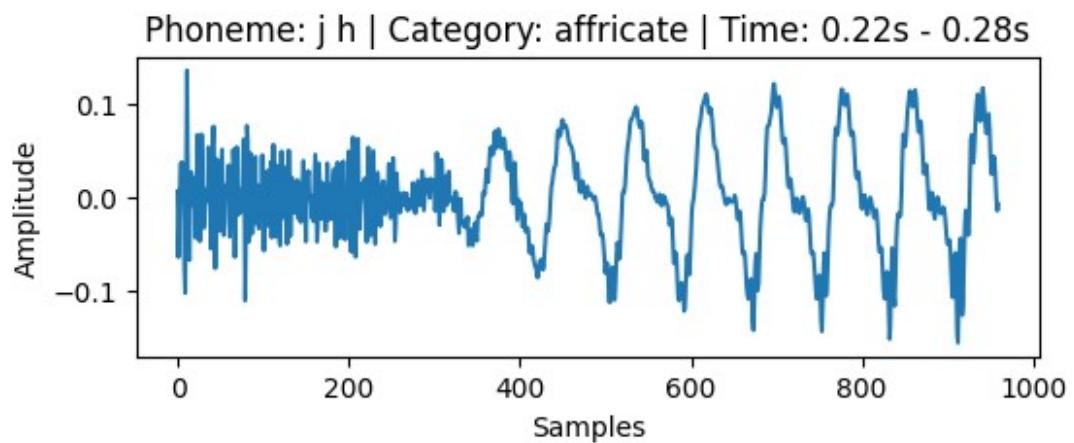
```

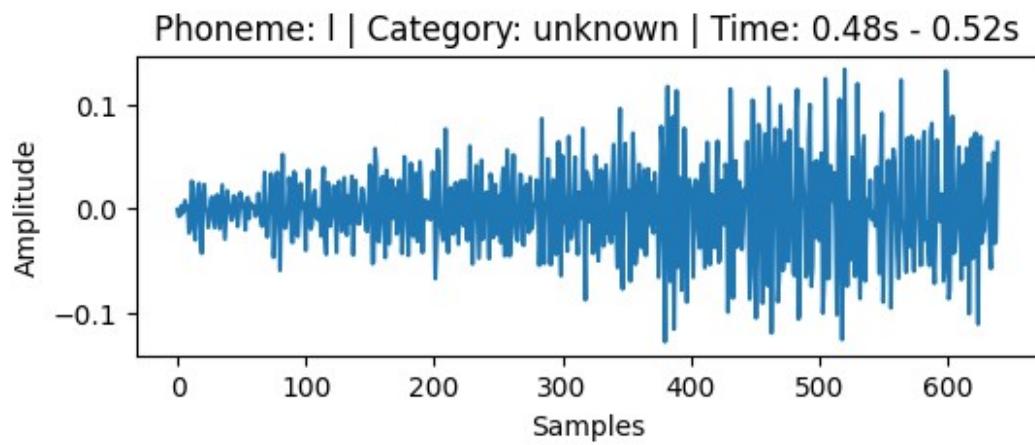
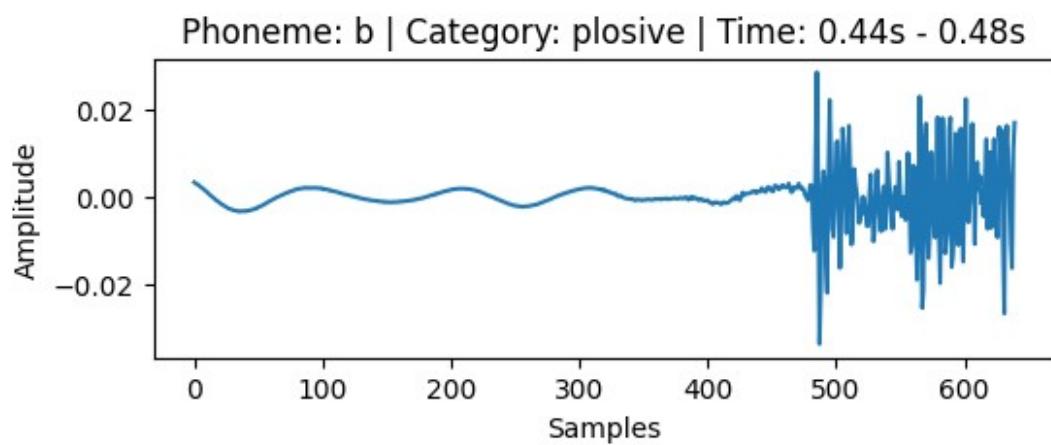
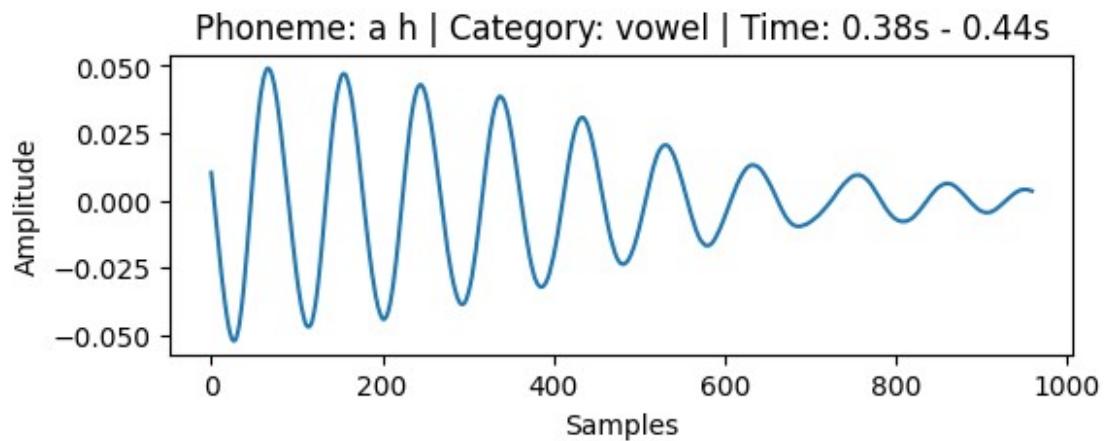
"fricative": ["f", "v", "t h", "d h", "s", "z", "s h", "z h", "h h"],
"affricate": ["c h", "j h"],
"semivowel": ["i", "r", "w", "y"],
"diphthong": ["a y", "e y", "o y", "a w", "o w"],
"whisper": ["s i l", "s p n"]
}
def get_category(phoneme):
    for category, phones in phoneme_categories.items():
        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()

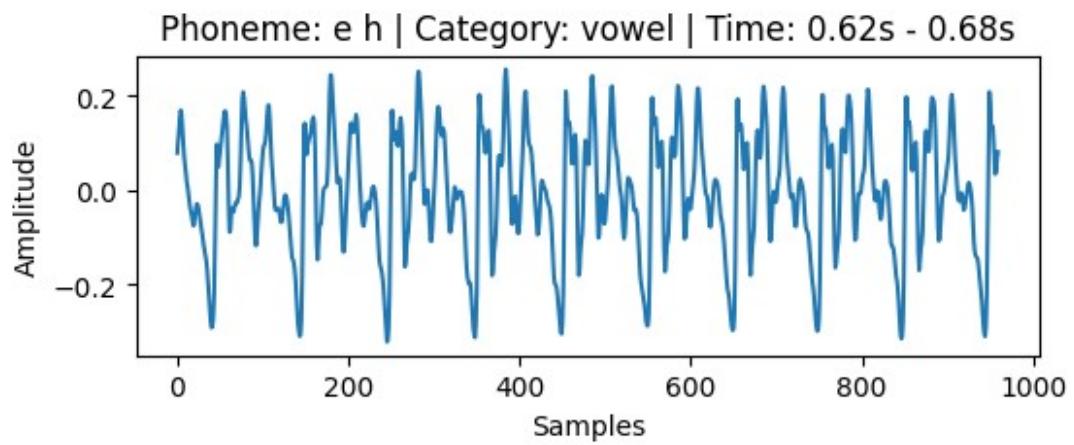
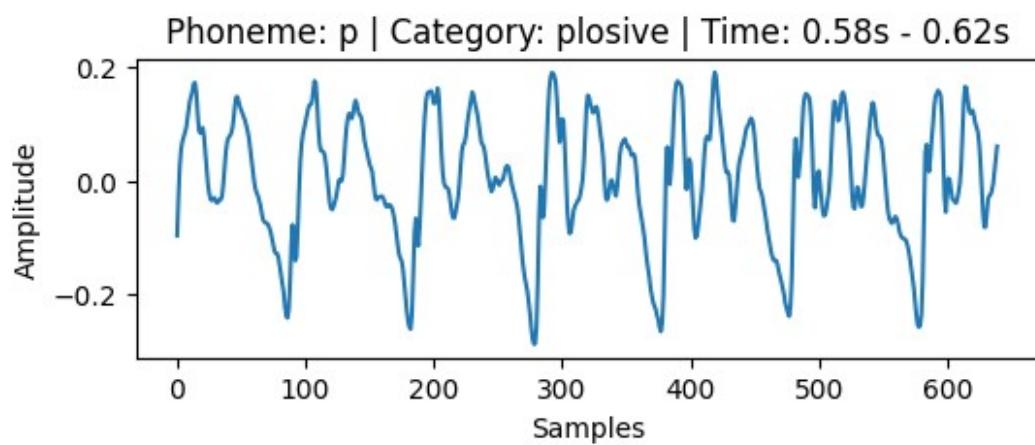
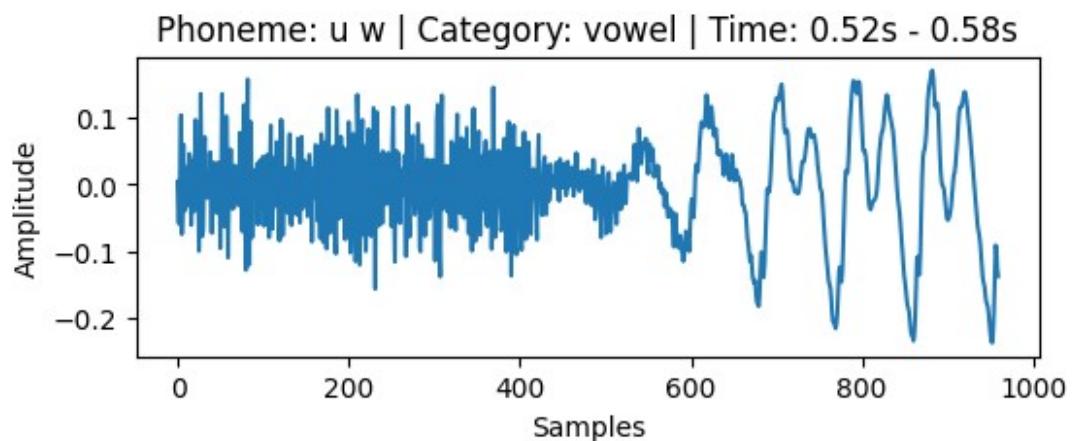
```

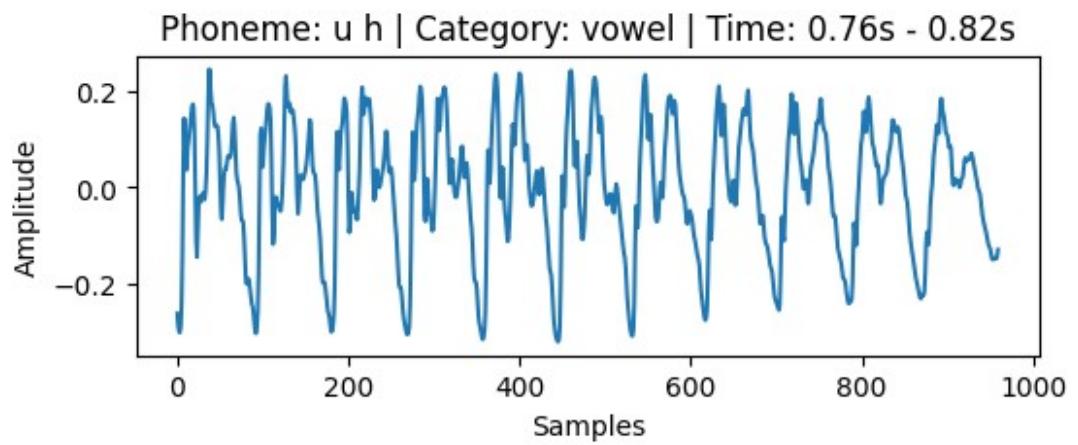
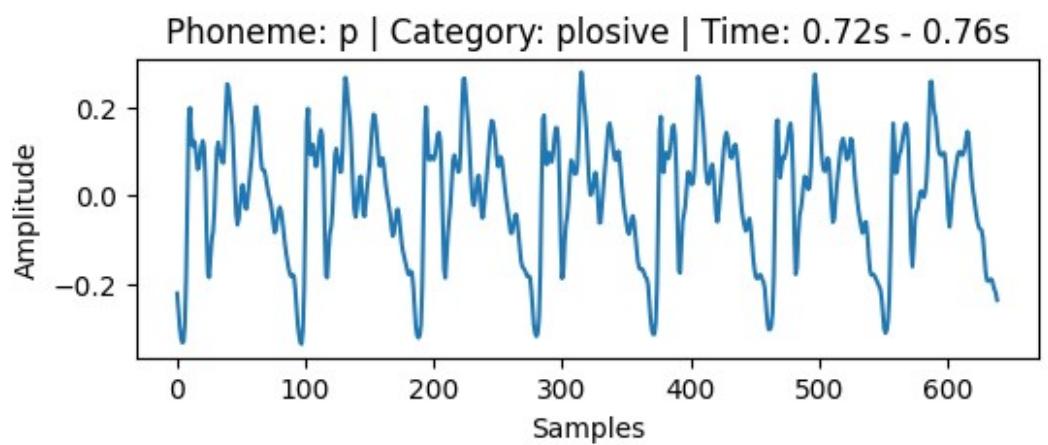
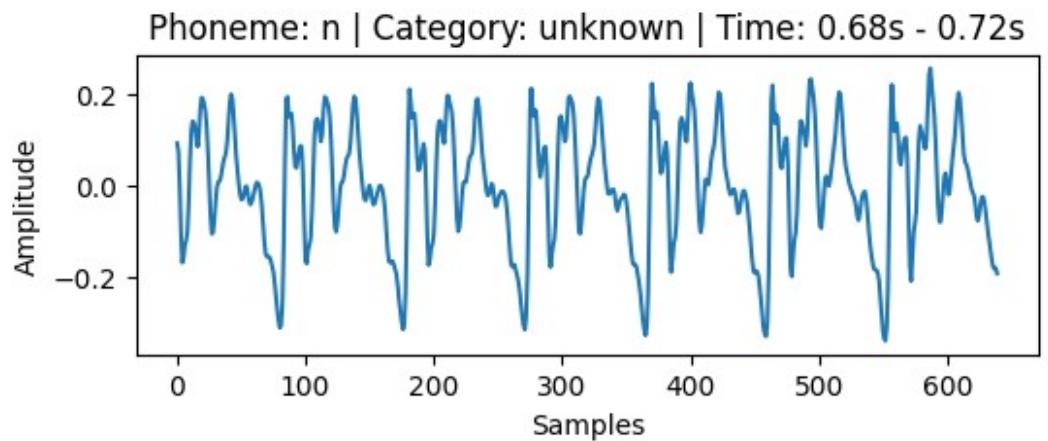


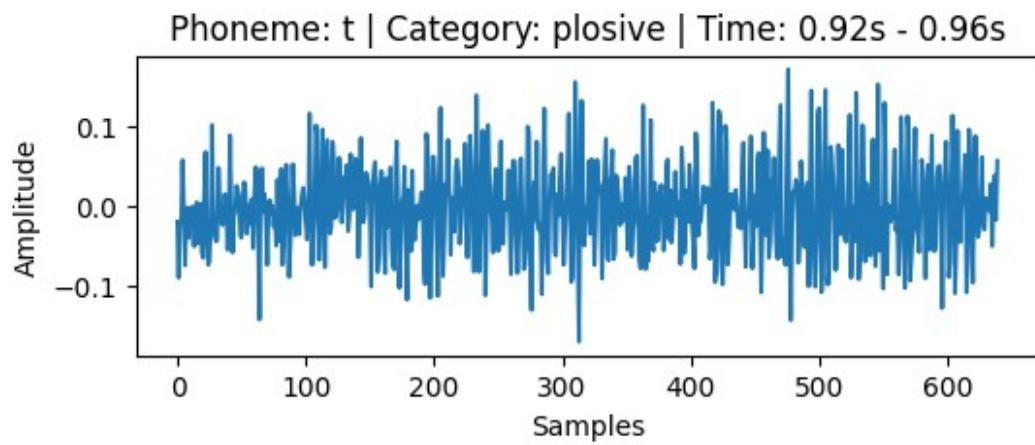
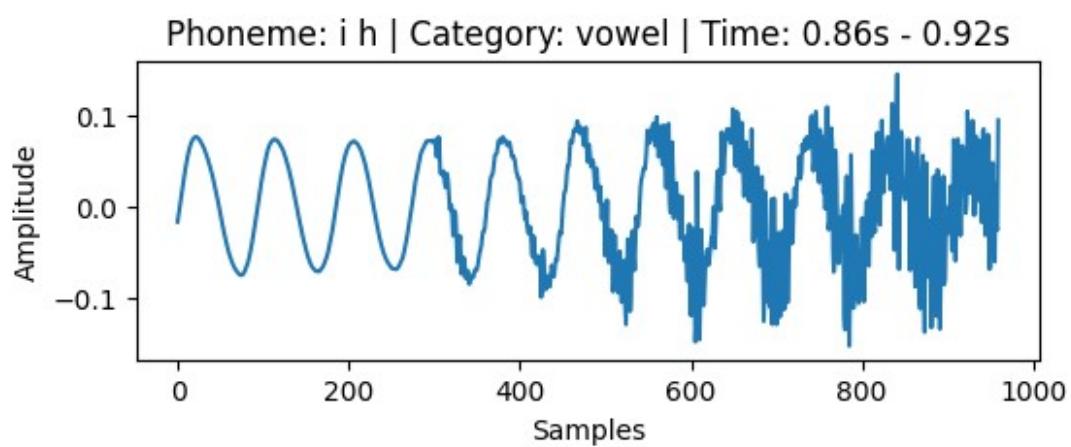
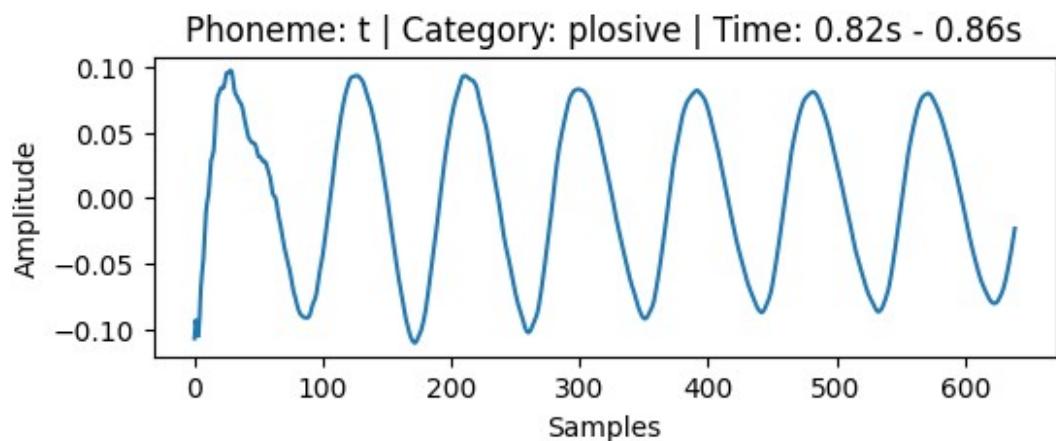




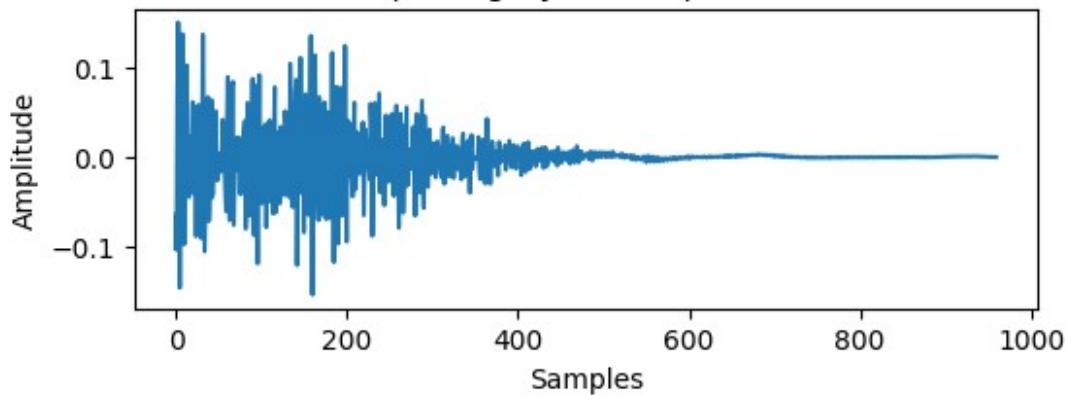




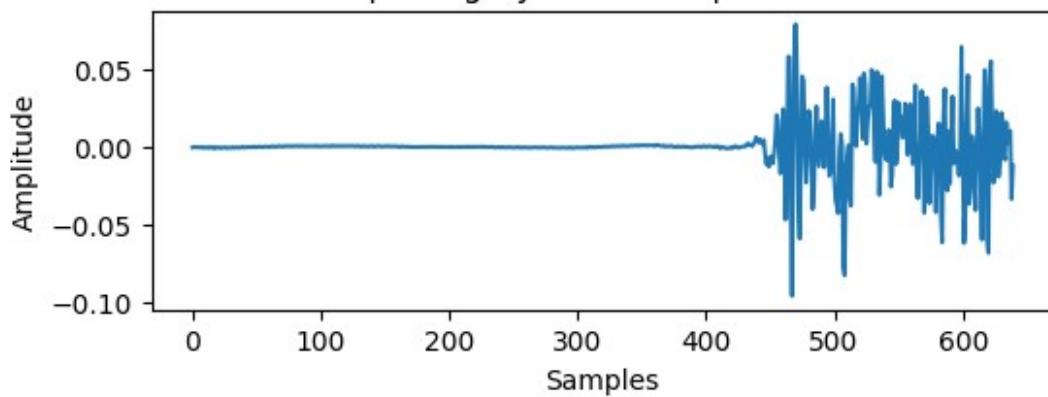




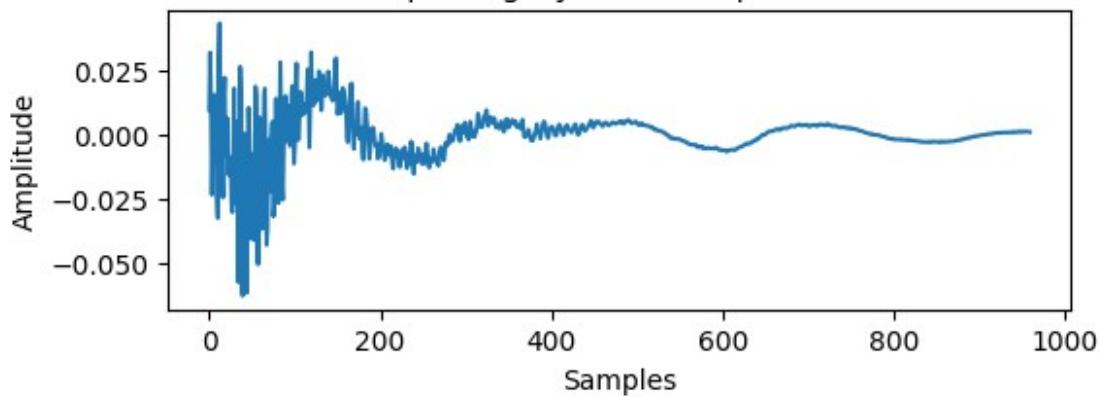
Phoneme: a a | Category: vowel | Time: 0.96s - 1.02s

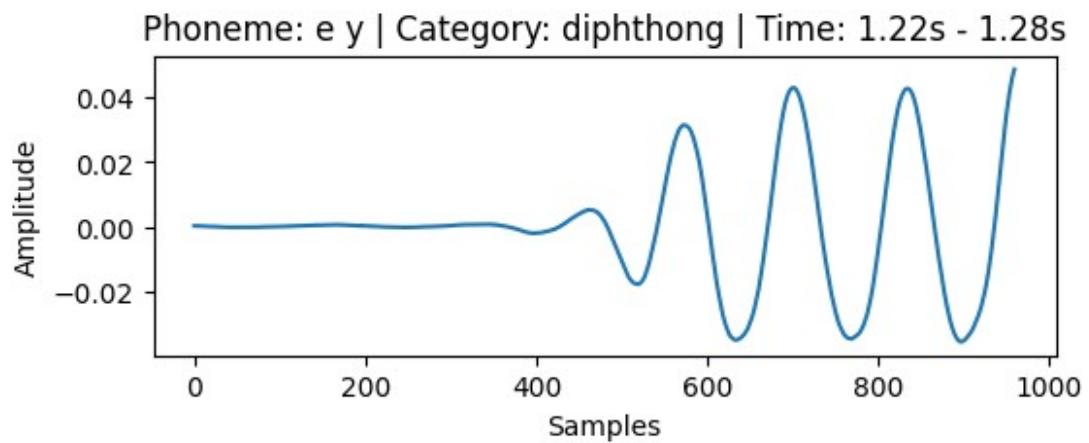
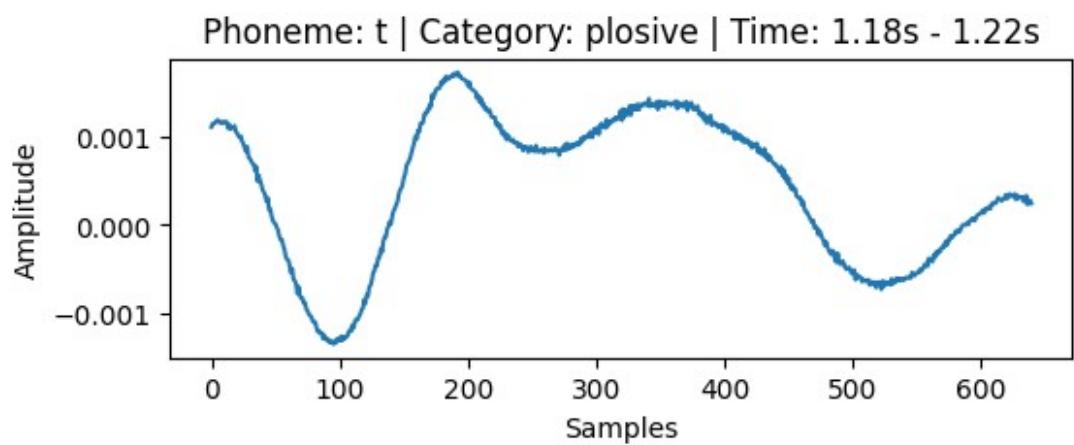
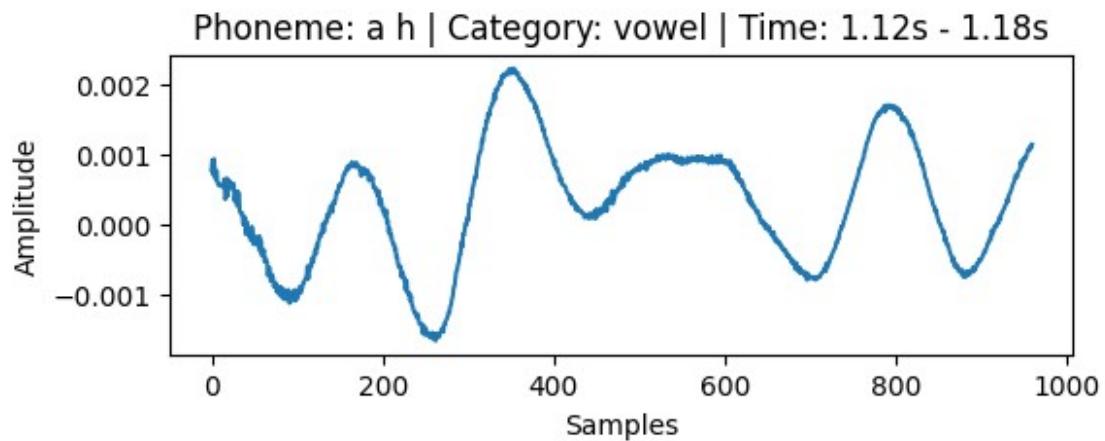


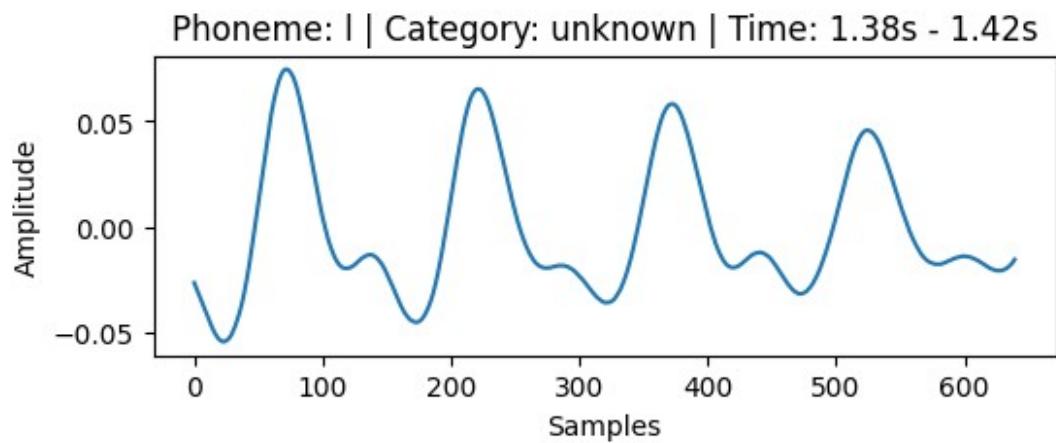
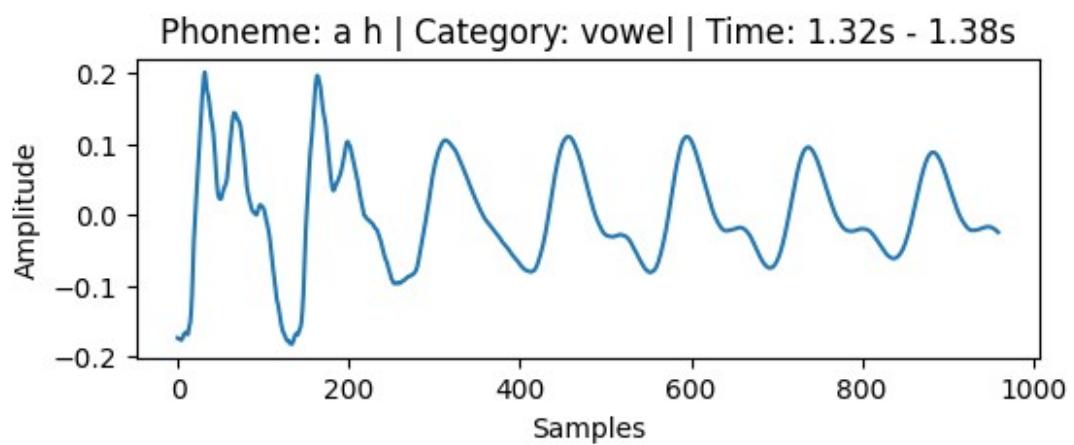
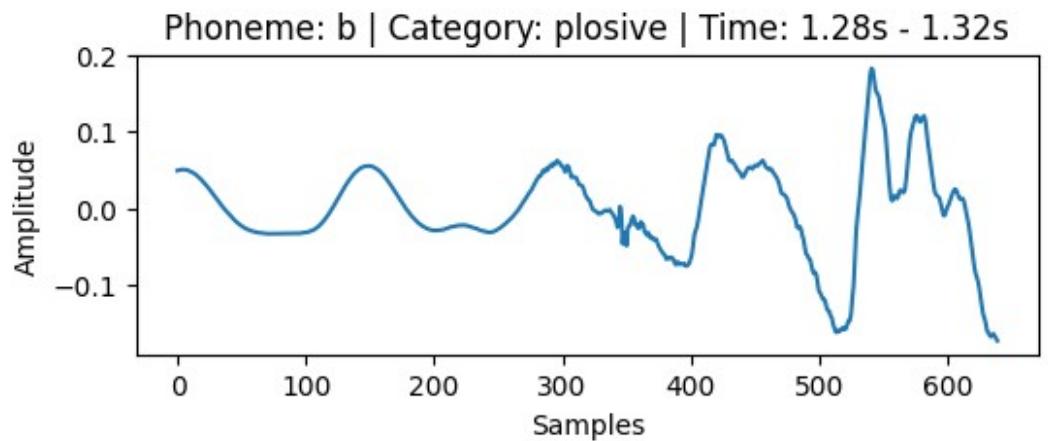
Phoneme: n | Category: unknown | Time: 1.02s - 1.06s

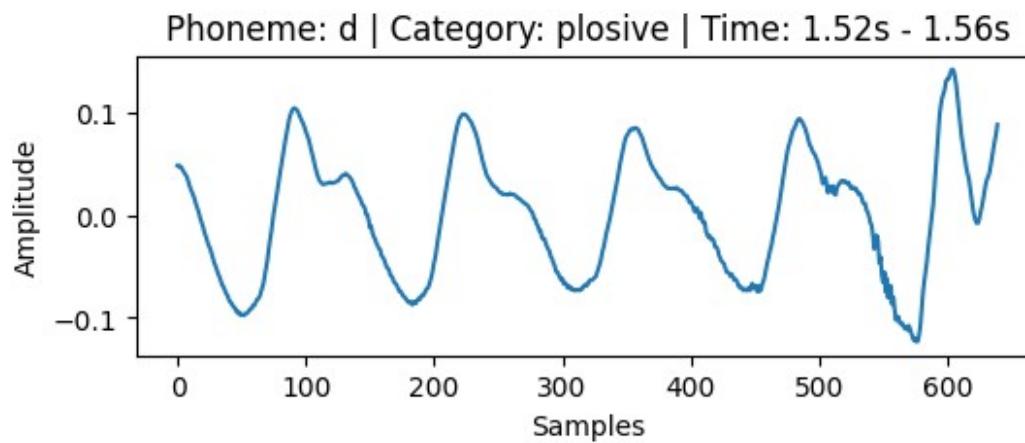
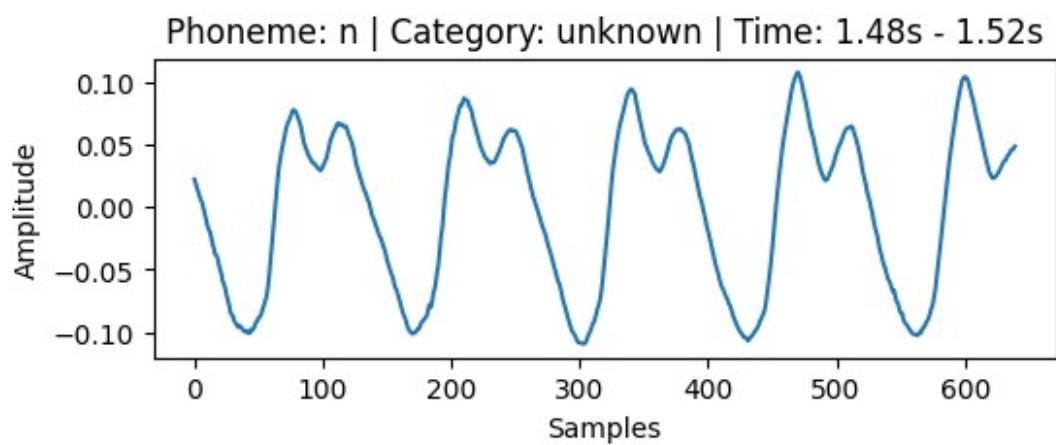
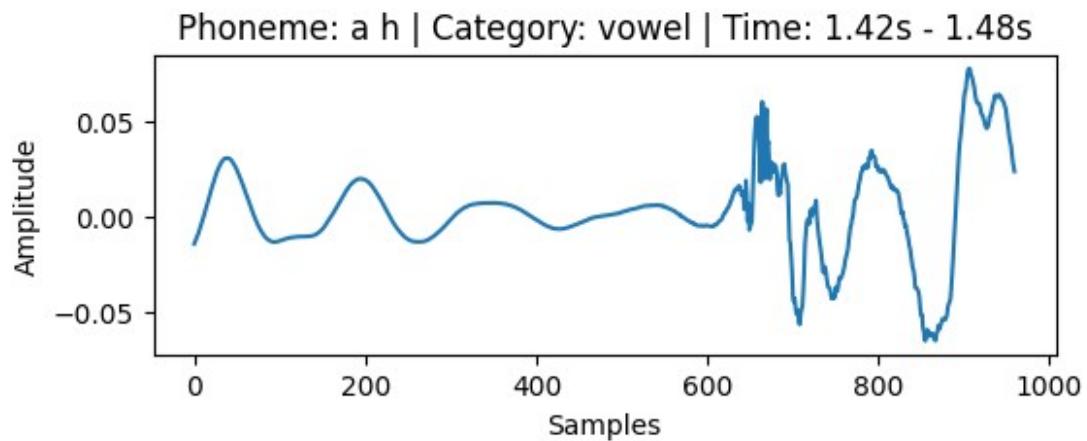


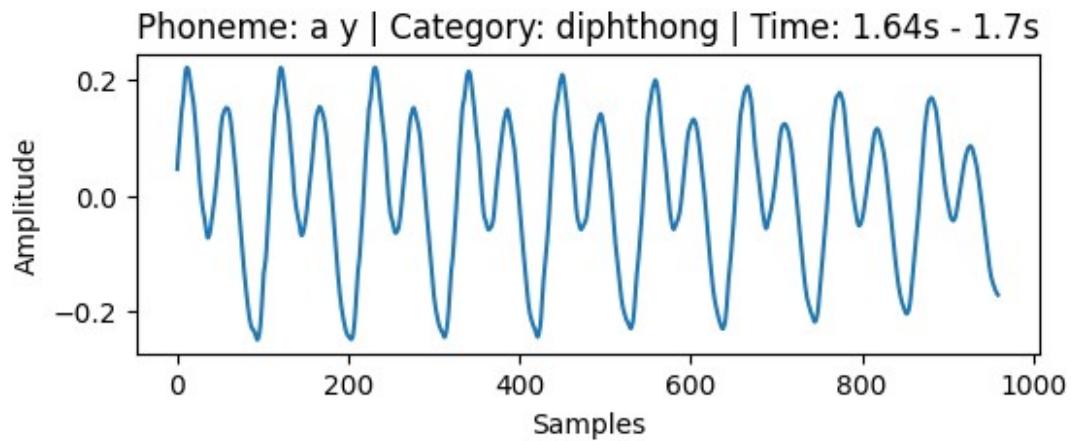
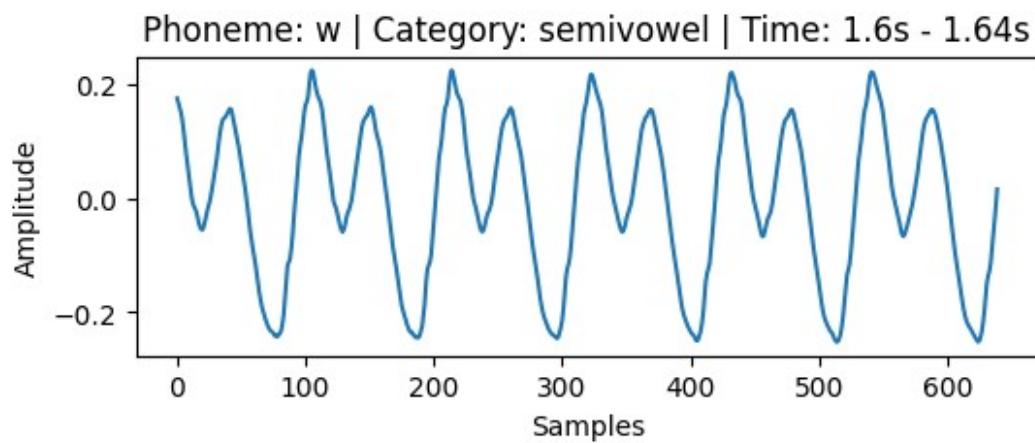
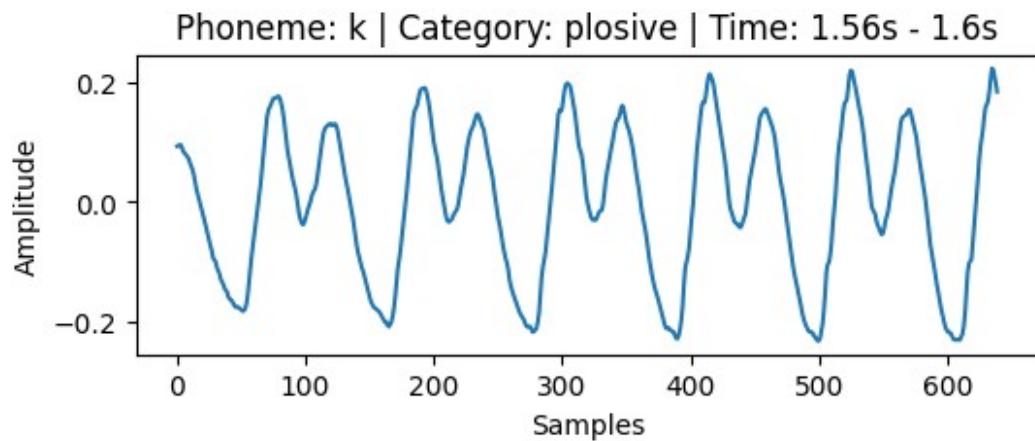
Phoneme: d h | Category: fricative | Time: 1.06s - 1.12s



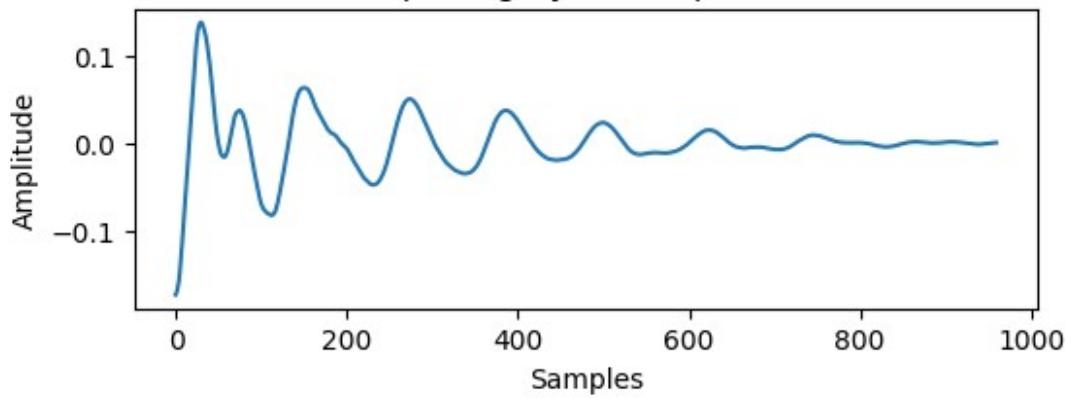




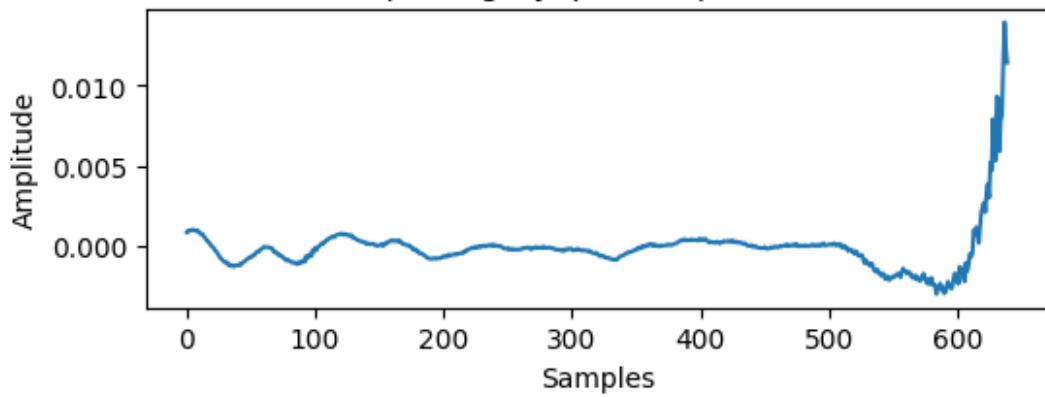




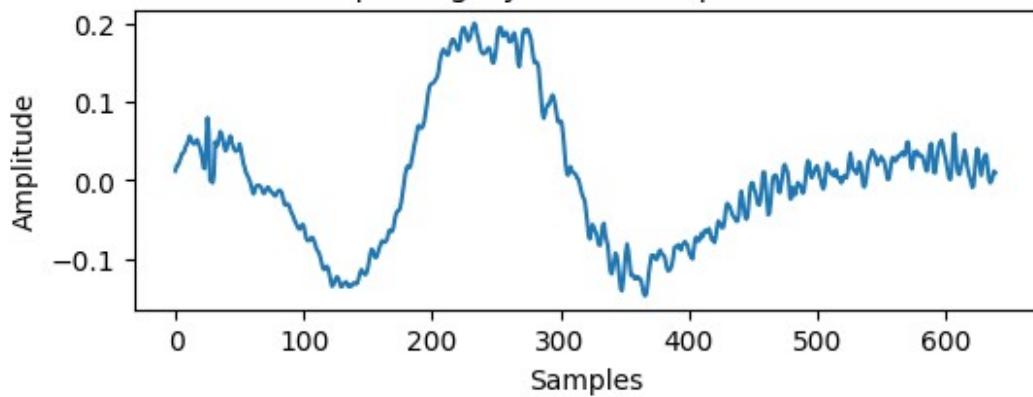
Phoneme: a h | Category: vowel | Time: 1.7s - 1.76s

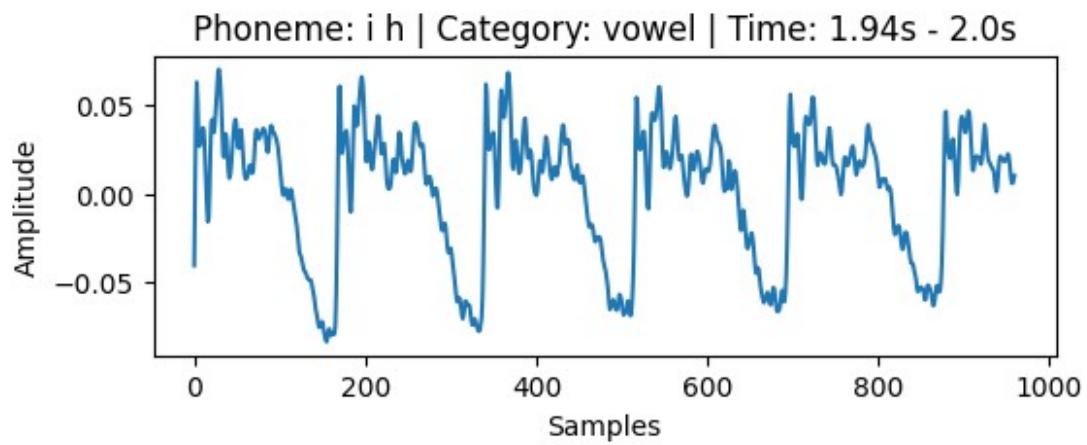
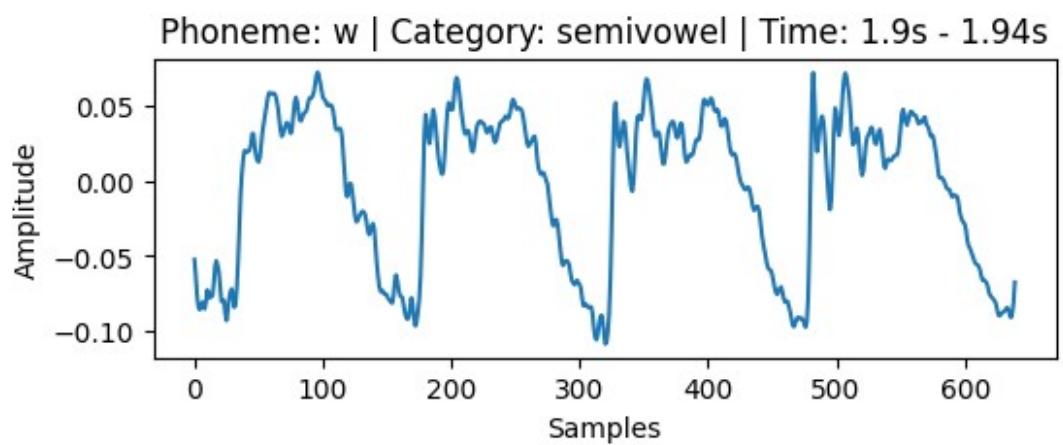
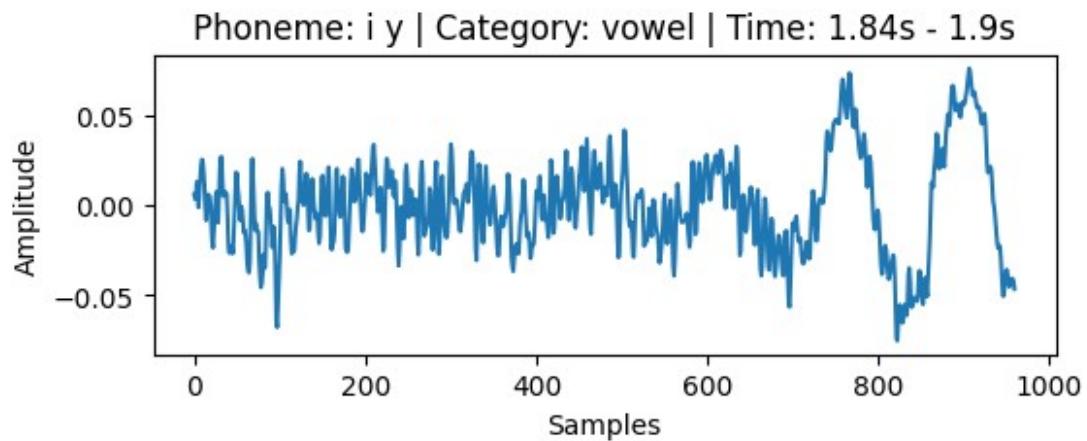


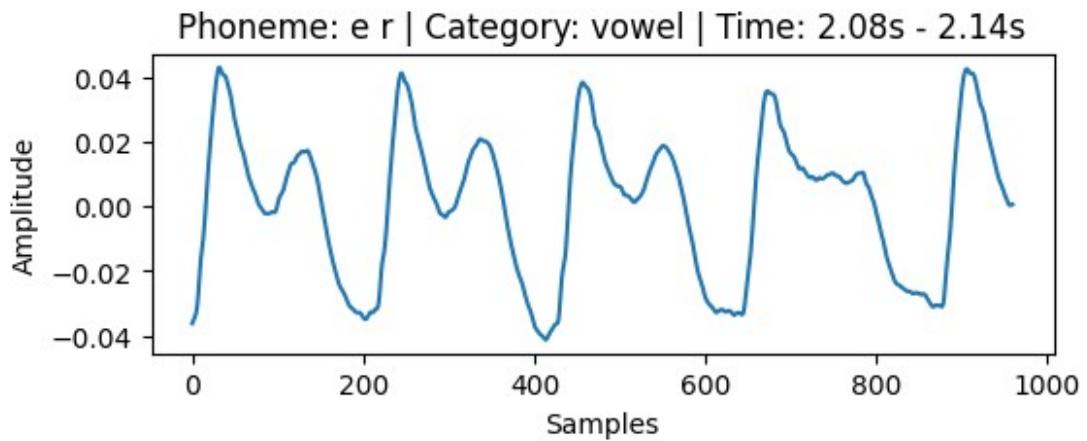
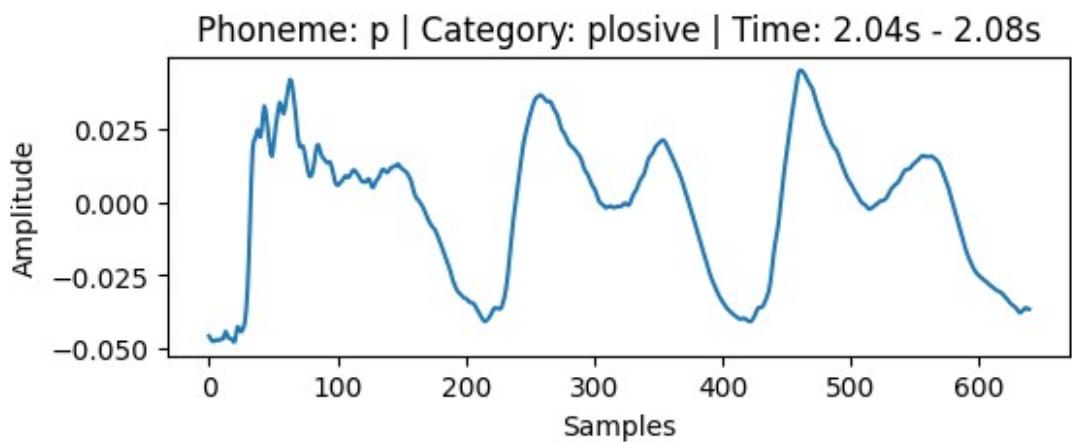
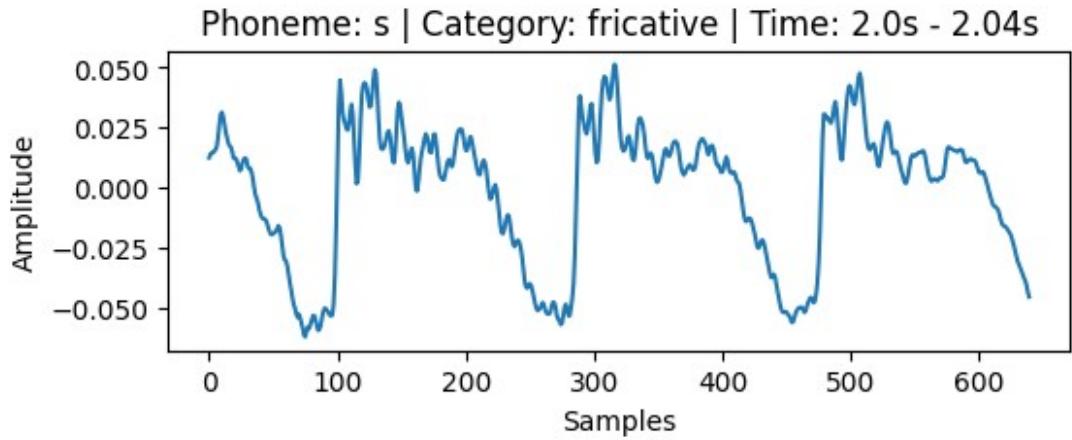
Phoneme: t | Category: plosive | Time: 1.76s - 1.8s



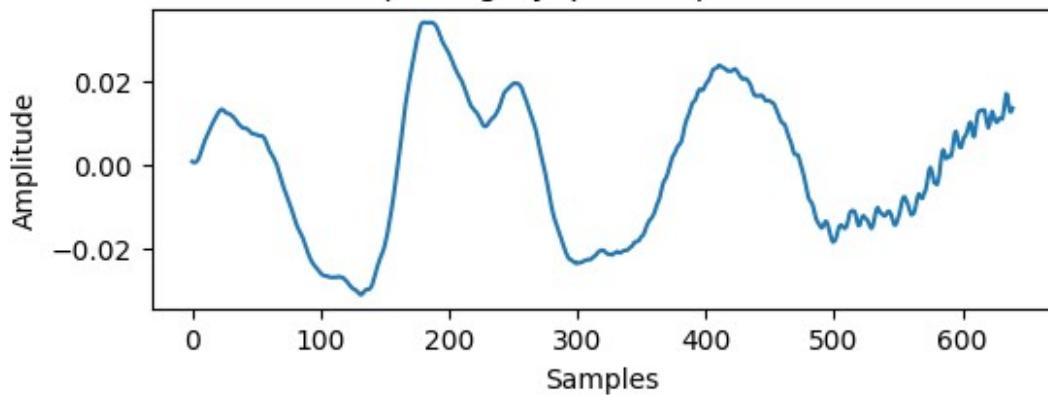
Phoneme: l | Category: unknown | Time: 1.8s - 1.84s



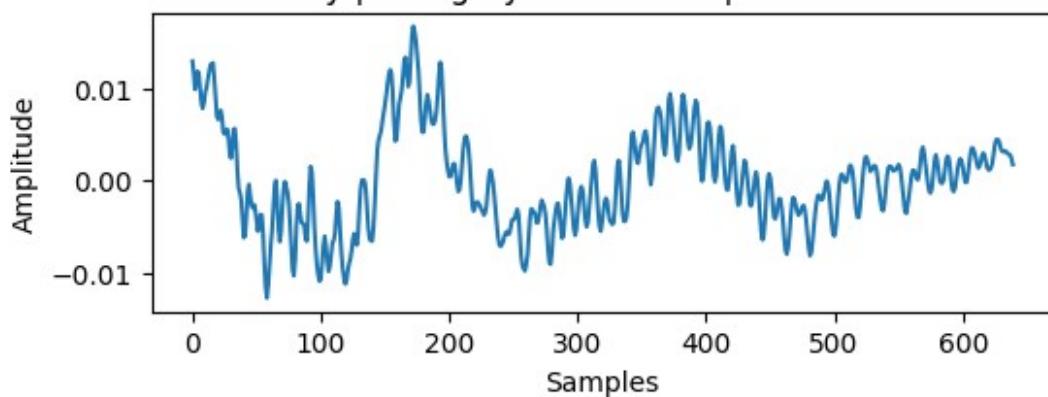




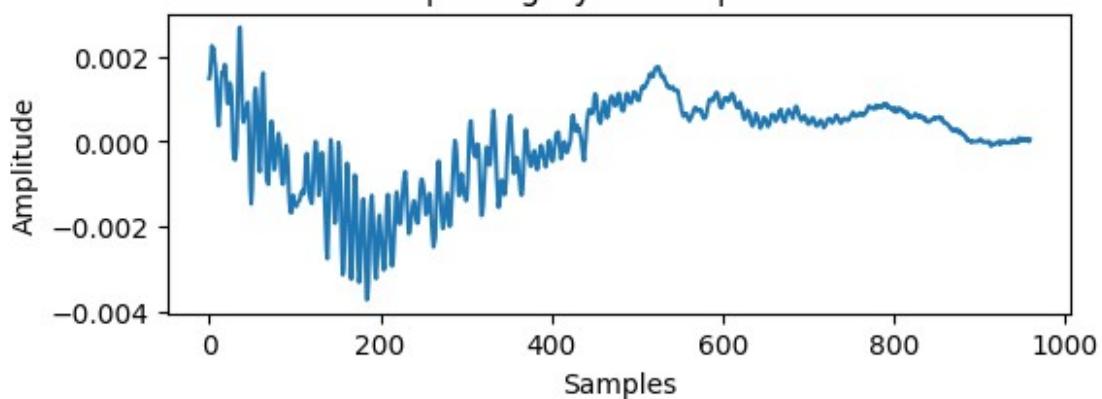
Phoneme: d | Category: plosive | Time: 2.14s - 2.18s

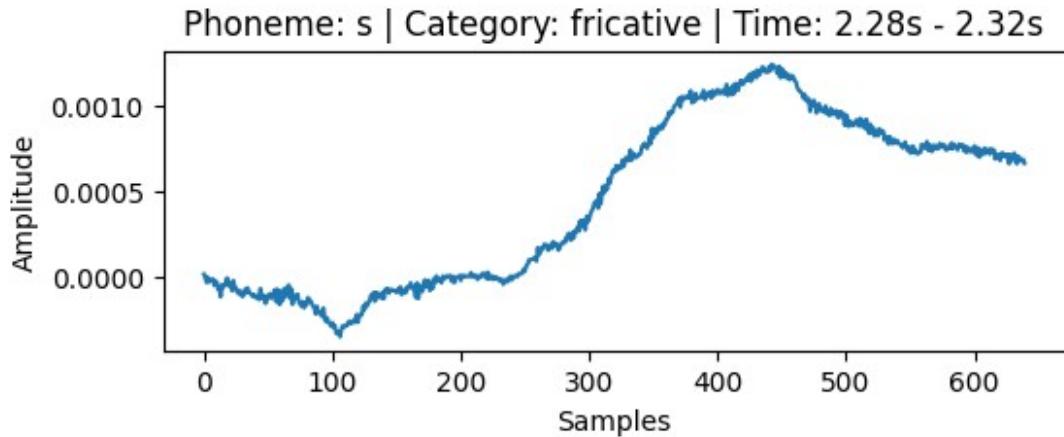


Phoneme: y | Category: semivowel | Time: 2.18s - 2.22s



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





5

```

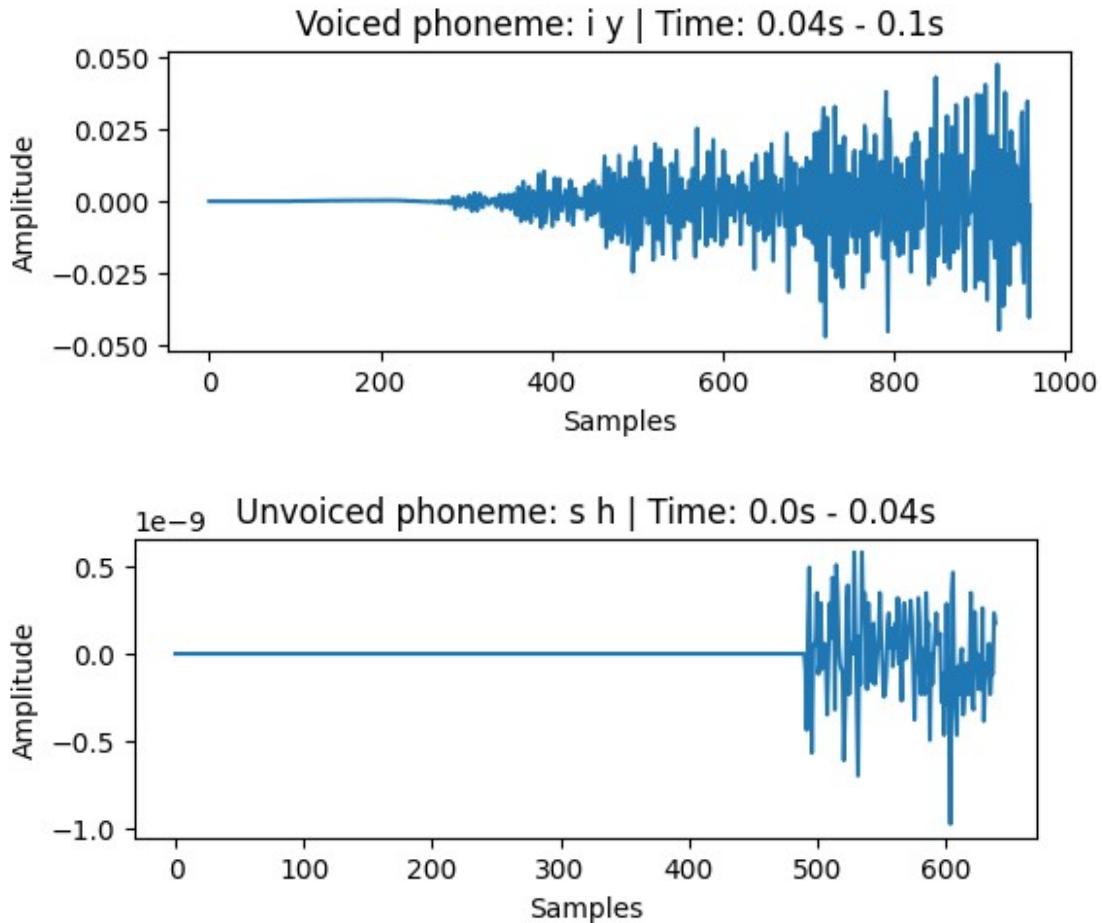
voiced_phonemes = ["a a", "a e", "a h", "a o", "e h", "e r", "i h", "i y", "u
h", "u w", "b", "d", "g", "v", "z", "m", "n", "l", "r", "w", "y", "j h"]
unvoiced_phonemes = ["p", "t", "k", "f", "s", "s h", "t h", "c h", "h h"]

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,"vers
ion_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 = []

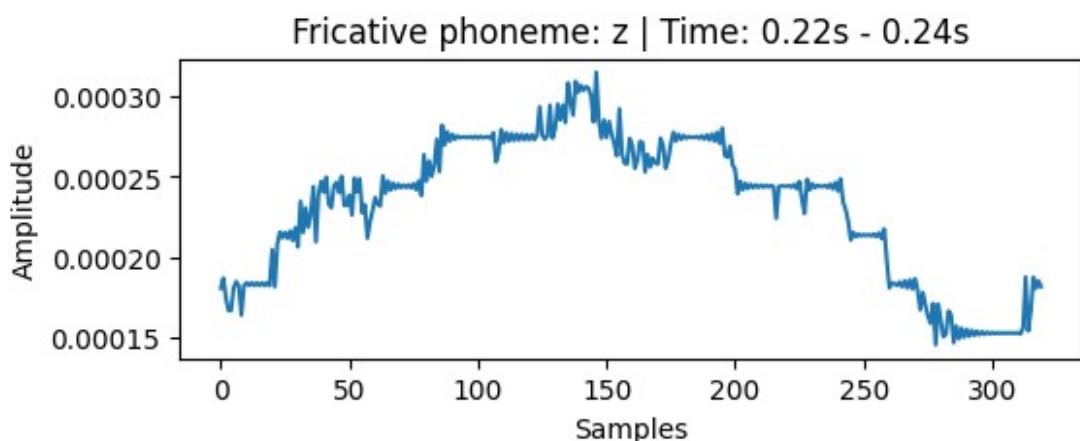
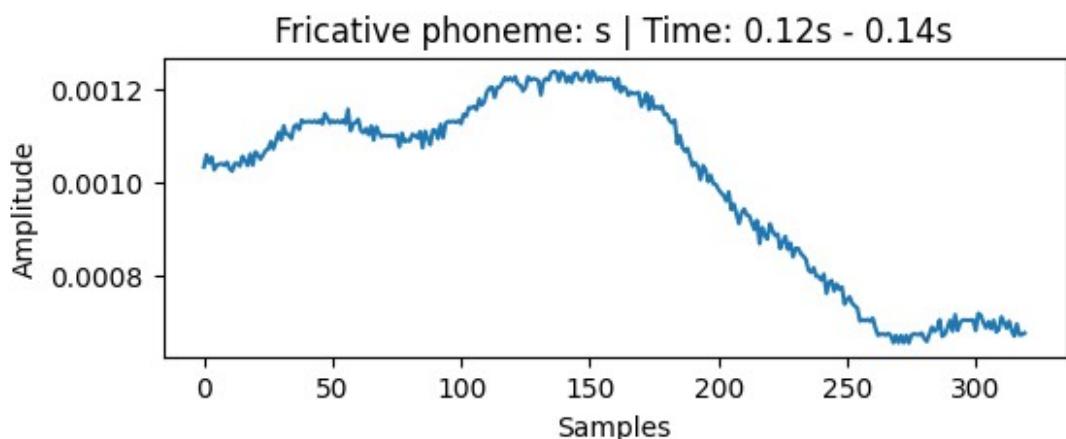
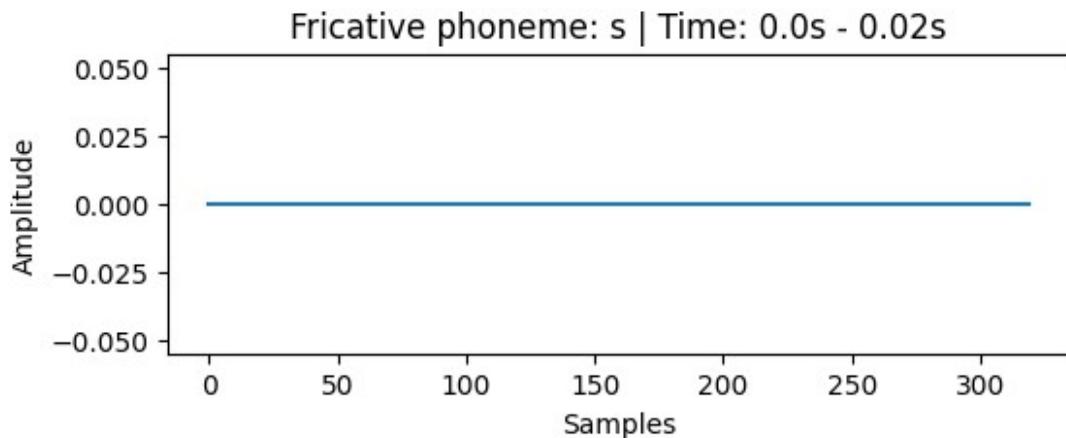
for phoneme, start, end in segments:
    category = get_category(phoneme)
    if category == "fricative":
        fricative_segments.append((phoneme, start, end))
    elif category == "semivowel":
        approximant_segments.append((phoneme, start, end))

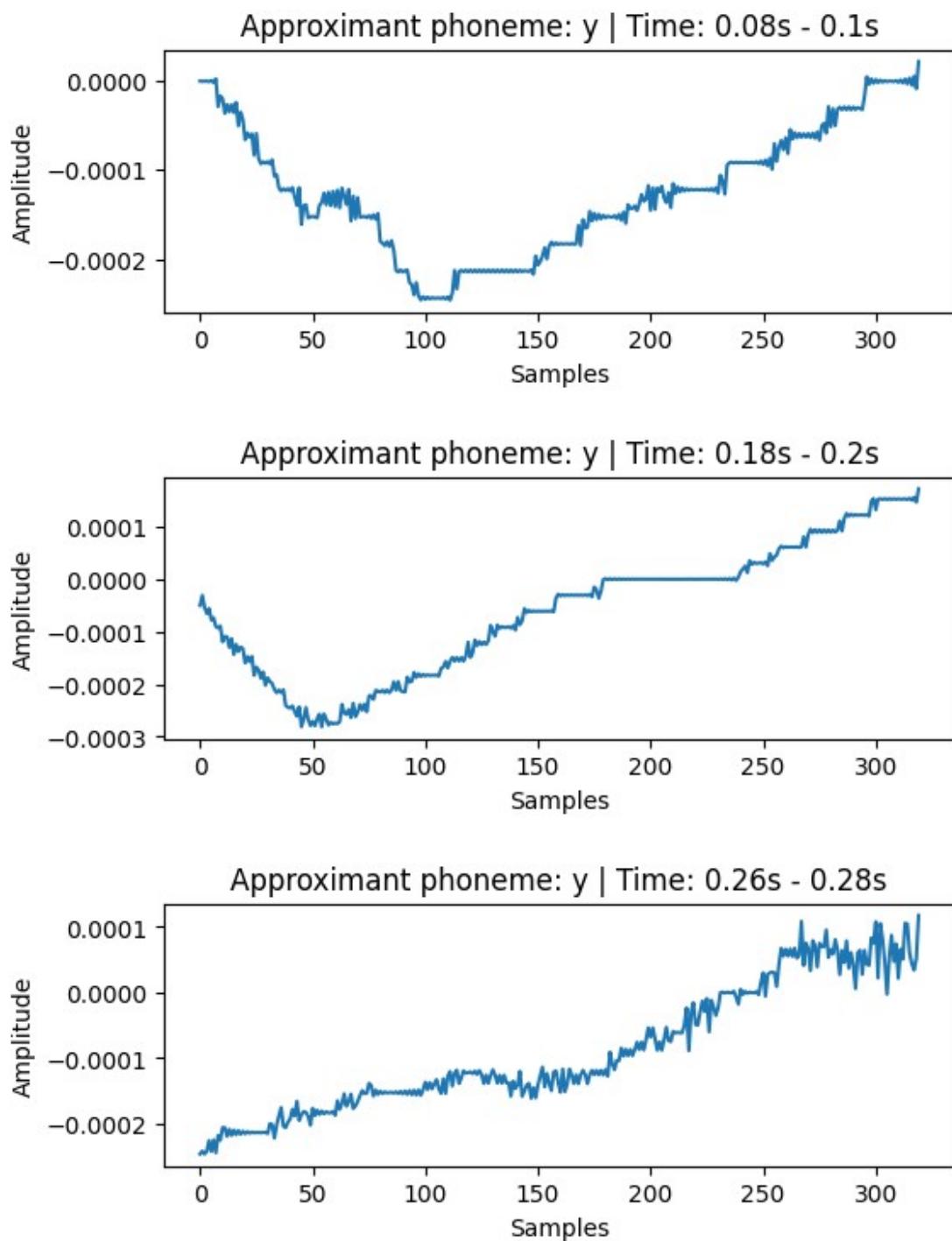
for phoneme, start, end in fricative_segments:
    start_sample = int(start * sr)
    end_sample = int(end * sr)
    plt.figure(figsize=(6, 2))
    plt.plot(y[start_sample:end_sample])
    plt.title(f"Fricative phoneme: {phoneme} | Time: {round(start,2)}s - {round(end,2)}s")
    plt.xlabel("Samples")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

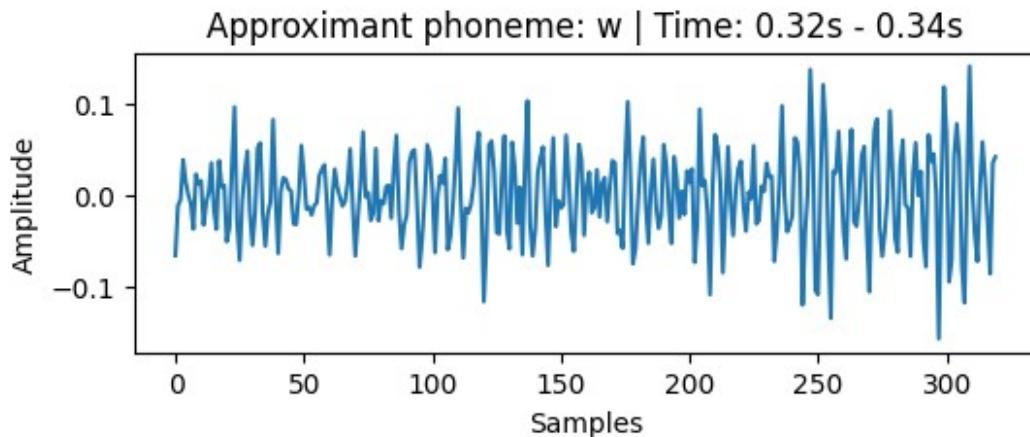
for phoneme, start, end in approximant_segments:
    start_sample = int(start * sr)
    end_sample = int(end * sr)
    plt.figure(figsize=(6, 2))
    plt.plot(y[start_sample:end_sample])
    plt.title(f"Approximant phoneme: {phoneme} | Time: {round(start,2)}s - {round(end,2)}s")

```

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







(iii)

```
fricatives = ['s', 'z', 'sh']
approximants = ['y']

fricative_segments = []
approximant_segments = []

for phoneme, start, end in segments:
    if phoneme in fricatives:
        fricative_segments.append((phoneme, start, end))
    elif phoneme in approximants:
        approximant_segments.append((phoneme, start, end))
print("Fricative Segments:",fricative_segments)
print("Approximant Segments:",approximant_segments)

Fricative Segments: [('s', 0.0, 0.02), ('s', 0.12, 0.14), ('z', 0.22, 0.24)]
Approximant Segments: [('y', 0.08, 0.1), ('y', 0.18, 0.2), ('y', 0.26, 0.28)]
```

(iv)

0.00110016, 0.00109764, 0.00109913, 0.00109871, 0.00109782,
0.00110045, 0.00107502, 0.00110437, 0.00108607, 0.00108902,
0.0010872 , 0.001102 , 0.00109927, 0.00109439, 0.00110767,
0.00107297, 0.00110824, 0.00109333, 0.00107983, 0.00111103,
0.00111052, 0.00109249, 0.00112343, 0.00109467, 0.0011256 ,
0.00112988, 0.0011285 , 0.00113012, 0.00112768, 0.00113142,
0.00112511, 0.00114539, 0.00114135, 0.00115957, 0.0011586 ,
0.00116204, 0.00115489, 0.00117796, 0.00116468, 0.00117232,
0.00119316, 0.0012017 , 0.00120349, 0.00118124, 0.00120263,
0.00120337, 0.00121267, 0.00122414, 0.00121794, 0.00122363,
0.00121706, 0.00122597, 0.00120973, 0.0012078 , 0.00119547,
0.00120228, 0.00122564, 0.00121812, 0.00122206, 0.00122051,
0.00121722, 0.00118668, 0.00121651, 0.00122217, 0.00121843,
0.00123428, 0.00123727, 0.00123489, 0.00121637, 0.00123608,
0.00123139, 0.00121433, 0.00122674, 0.00121365, 0.00123282,
0.00123363, 0.00122084, 0.0012177 , 0.00122912, 0.00123783,
0.00121464, 0.00123744, 0.00122998, 0.0012161 , 0.0012242 ,
0.00121776, 0.00122321, 0.00121863, 0.00122227, 0.00121979,
0.00120032, 0.00122247, 0.00119293, 0.00120396, 0.00120054,
0.00118562, 0.00119279, 0.00118892, 0.00119012, 0.00119218,
0.00116208, 0.00117376, 0.00119017, 0.00115508, 0.00118301,
0.00115742, 0.00116159, 0.00115765, 0.00116284, 0.00114489,
0.0011454 , 0.00113203, 0.00112643, 0.00113239, 0.00108168,
0.00109917, 0.00107392, 0.00106545, 0.00107153, 0.0010531 ,
0.00103378, 0.00104039, 0.00103229, 0.00100434, 0.00103446,
0.00102583, 0.00100019, 0.00101369, 0.00099569, 0.00099384,
0.00098347, 0.00097617, 0.00097038, 0.00095874, 0.00097797,
0.0009398 , 0.00095166, 0.00093033, 0.00090984, 0.00093357,
0.00094131, 0.00092805, 0.00092647, 0.00091098, 0.00089694,
0.00091671, 0.00086672, 0.00090151, 0.00088602, 0.00087623,
0.00090917, 0.00089464, 0.00088427, 0.00088733, 0.00085615,
0.0008701 , 0.00088237, 0.00085443, 0.0008675 , 0.00083832,
0.00085634, 0.00085672, 0.0008455 , 0.00083979, 0.00083285,
0.00081012, 0.00080502, 0.00081481, 0.00079669, 0.00079614,
0.00078838, 0.00080096, 0.00075955, 0.00078305, 0.00078721,
0.00076483, 0.0007794 , 0.00076849, 0.00077344, 0.00073654,
0.00074607, 0.00075205, 0.00073781, 0.00073258, 0.00072778,
0.00070009, 0.00070316, 0.00070058, 0.00070363, 0.00069939,
0.00070621, 0.00068537, 0.00066964, 0.0006713 , 0.00067233,
0.0006699 , 0.00067327, 0.00066921, 0.00065342, 0.00066888,
0.00065359, 0.00066887, 0.00065344, 0.0006692 , 0.00065293,
0.00066991, 0.00067231, 0.00067122, 0.00067045, 0.00067425,
0.00066258, 0.00065628, 0.0006713 , 0.00068704, 0.00067799,
0.00068337, 0.0007028 , 0.00066712, 0.0006718 , 0.00068499,
0.00070153, 0.00067836, 0.00071367, 0.00067993, 0.00069748,
0.00070202, 0.00070249, 0.00070126, 0.0007023 , 0.00070215,
0.00067954, 0.00071654, 0.00071247, 0.00069649, 0.00068552,
0.00069885, 0.00068366, 0.00070136, 0.00067676, 0.00068178,
0.00070904, 0.00069703, 0.00068507, 0.00069989, 0.00067932,

```
    0.00066772, 0.00069388, 0.0006705 , 0.0006708 , 0.00067425]])),  
('z', array([0.00018061, 0.00018685, 0.00017433, 0.00016661,  
0.00016668,  
    0.00018093, 0.00018462, 0.00018191, 0.00016378, 0.00018218,  
    0.00018398, 0.00018225, 0.00018395, 0.00018226, 0.00018396,  
    0.00018225, 0.00018397, 0.00018223, 0.000184 , 0.00018216,  
    0.00020455, 0.00018148, 0.0002084 , 0.00021557, 0.00021206,  
    0.00021529, 0.00021162, 0.00021616, 0.00021029, 0.00021824,  
    0.00020642, 0.00023467, 0.00021534, 0.0002306 , 0.00021851,  
    0.00022726, 0.00024378, 0.00020949, 0.00023928, 0.0002471 ,  
    0.00024033, 0.00024974, 0.00023292, 0.00023071, 0.00024433,  
    0.00024647, 0.00024013, 0.00025024, 0.00023215, 0.00023227,  
    0.00023839, 0.00022624, 0.00024915, 0.00024048, 0.00024878,  
    0.00022749, 0.00023267, 0.00021179, 0.00022179, 0.00022886,  
    0.00023702, 0.00023298, 0.00023179, 0.00025047, 0.00023975,  
    0.00024742, 0.00024162, 0.00024609, 0.00024262, 0.00024533,  
    0.00024317, 0.00024498, 0.00024334, 0.00024503, 0.00024303,  
    0.00024565, 0.00024197, 0.00024747, 0.00023831, 0.00026375,  
    0.00024731, 0.00025972, 0.00025023, 0.0002571 , 0.00027341,  
    0.00025324, 0.00028215, 0.00026984, 0.00027809, 0.00027216,  
    0.00027646, 0.00027341, 0.00027546, 0.00027423, 0.00027478,  
    0.00027479, 0.00027434, 0.00027513, 0.00027409, 0.00027527,  
    0.00027404, 0.00027521, 0.00027423, 0.00027486, 0.00027484,  
    0.00027374, 0.0002774 , 0.00025926, 0.00026486, 0.00027937,  
    0.00027124, 0.00027746, 0.00027222, 0.00027686, 0.00027263,  
    0.00027655, 0.00027286, 0.00027638, 0.000273 , 0.00027627,  
    0.00027308, 0.00027619, 0.00027316, 0.00027611, 0.00029362,  
    0.00027595, 0.0002735 , 0.00027558, 0.00029452, 0.00027408,  
    0.00027996, 0.00029522, 0.00028543, 0.00029457, 0.00028379,  
    0.00030848, 0.00029664, 0.00028846, 0.00030936, 0.00030271,  
    0.00030698, 0.00030378, 0.00030609, 0.00030531, 0.00030035,  
    0.00028415, 0.00031508, 0.00028539, 0.00027406, 0.00028533,  
    0.00027442, 0.0002845 , 0.00027658, 0.00027061, 0.00026311,  
    0.00029238, 0.0002643 , 0.00025839, 0.00025794, 0.00027394,  
    0.00026951, 0.00025526, 0.00026023, 0.00027203, 0.00027136,  
    0.00025306, 0.0002639 , 0.0002561 , 0.0002616 , 0.00025851,  
    0.00025794, 0.00027402, 0.00026941, 0.00025524, 0.00026066,  
    0.00027051, 0.00027773, 0.00027229, 0.00027649, 0.00027327,  
    0.00027567, 0.00027397, 0.00027504, 0.00027455, 0.00027451,  
    0.00027505, 0.00027403, 0.00027553, 0.00027354, 0.00027604,  
    0.00027299, 0.00027667, 0.00027223, 0.00027767, 0.00027076,  
    0.00028026, 0.00026331, 0.00026222, 0.00026913, 0.00025746,  
    0.00025463, 0.00023937, 0.00024725, 0.00024186, 0.00024592,  
    0.0002427 , 0.00024533, 0.00024313, 0.00024502, 0.00024337,  
    0.00024482, 0.00024353, 0.00024469, 0.00024365, 0.00024457,  
    0.00024377, 0.0002241 , 0.00024391, 0.00024427, 0.00024412,  
    0.00024401, 0.00024446, 0.00024355, 0.00024512, 0.00024251,  
    0.00024712, 0.00023602, 0.00022714, 0.0002484 , 0.00024182,  
    0.00024559, 0.00024324, 0.00024462, 0.00024402, 0.00024393,
```

```

    0.00024468, 0.00024327, 0.00024538, 0.00024248, 0.00024635,
    0.00024112, 0.00024869, 0.00023415, 0.00022967, 0.00022206,
    0.00021056, 0.00021525, 0.00021267, 0.00021422, 0.00021323,
    0.00021392, 0.00021334, 0.00021396, 0.00021316, 0.00021428,
    0.00021267, 0.00021502, 0.00021148, 0.00021748, 0.00019761,
    0.00018076, 0.00018368, 0.00018337, 0.00018228, 0.00018439,
    0.00018142, 0.00018515, 0.00018071, 0.00018583, 0.00018004,
    0.00018652, 0.00017928, 0.00016711, 0.0001779 , 0.00016994,
    0.00016299, 0.00015871, 0.00017102, 0.00014535, 0.00017065,
    0.00016019, 0.00015036, 0.00015195, 0.00016634, 0.00016375,
    0.00014673, 0.00015695, 0.00014902, 0.00015561, 0.00014998,
    0.00015485, 0.00015063, 0.00015428, 0.00015113, 0.00015384,
    0.00015153, 0.00015348, 0.00015184, 0.0001532 , 0.00015208,
    0.000153 , 0.00015226, 0.00015285, 0.00015238, 0.00015275,
    0.00015246, 0.00015269, 0.00015251, 0.00015265, 0.00015253,
    0.00015272, 0.00015208, 0.00015605, 0.00018754, 0.00015398,
    0.00016637, 0.00018738, 0.00018053, 0.00018503, 0.00018152)])
pproximant segments [(['y', array([
  2.02358933e-07, -9.25938366e-08, -
  4.16766852e-08, 2.15004547e-07,
  -4.54514520e-07, 8.17351975e-07, -1.44407386e-06,
  2.80200038e-06,
  -2.84037524e-05, -1.65790843e-05, -1.97905320e-05, -
  3.60753766e-05,
  -2.61548557e-05, -3.45265289e-05, -2.64092814e-05, -
  3.52476491e-05,
  -2.38965295e-05, -5.01644390e-05, -3.47239402e-05, -
  4.31625376e-05,
  -6.58359131e-05, -5.82103530e-05, -6.30978830e-05, -
  5.92992437e-05,
  -8.30837525e-05, -5.88715193e-05, -8.68748466e-05, -
  9.28900845e-05,
  -9.07066133e-05, -9.23679472e-05, -9.05281995e-05, -
  9.31167888e-05,
  -8.84686160e-05, -1.06577696e-04, -1.05268657e-04, -
  1.20072189e-04,
  -1.23484264e-04, -1.20939760e-04, -1.23085090e-04, -
  1.21004967e-04,
  -1.23464415e-04, -1.19622884e-04, -1.29437627e-04, -
  1.39757409e-04,
  -1.19790653e-04, -1.61115255e-04, -1.40313132e-04, -
  1.39030468e-04,
  -1.53900066e-04, -1.52754830e-04, -1.52091758e-04, -
  1.52820052e-04,
  -1.53719957e-04, -1.39595300e-04, -1.36820396e-04, -
  1.26079089e-04,
  -1.39099240e-04, -1.24909522e-04, -1.40004093e-04, -
  1.24032391e-04,
  -1.40974938e-04, -1.22847705e-04, -1.42589066e-04, -
  1.20186349e-04,
])])

```

-1.29593958e-04, -1.38767646e-04, -1.21853169e-04, -
1.57304705e-04,
-1.29289838e-04, -1.54517867e-04, -1.31061694e-04, -
1.53154120e-04,
-1.52559020e-04, -1.52129054e-04, -1.53501082e-04, -
1.51240311e-04,
-1.54365713e-04, -1.50354230e-04, -1.55378017e-04, -
1.48856081e-04,
-1.80416711e-04, -1.82059652e-04, -1.85046476e-04, -
1.80660689e-04,
-1.86016448e-04, -1.79412396e-04, -1.90341656e-04, -
2.13082865e-04,
-2.14734173e-04, -2.12444924e-04, -2.14592728e-04, -
2.13221298e-04,
-2.12451123e-04, -2.26812277e-04, -2.29076017e-04, -
2.40528156e-04,
-2.26671822e-04, -2.41740810e-04, -2.46166426e-04, -
2.42440205e-04,
-2.45541334e-04, -2.43024173e-04, -2.44982832e-04, -
2.43565155e-04,
-2.44454830e-04, -2.44083712e-04, -2.43941235e-04, -
2.44600378e-04,
-2.43405229e-04, -2.45192845e-04, -2.42657727e-04, -
2.46449490e-04,
-2.38188863e-04, -2.13028601e-04, -2.33785817e-04, -
2.14154570e-04,
-2.12886560e-04, -2.14494343e-04, -2.12658852e-04, -
2.14651795e-04,
-2.12550309e-04, -2.14724510e-04, -2.12504237e-04, -
2.14750995e-04,
-2.12491548e-04, -2.14754808e-04, -2.12492465e-04, -
2.14752523e-04,
-2.12493207e-04, -2.14755361e-04, -2.12485524e-04, -
2.14768253e-04,
-2.12467887e-04, -2.14789325e-04, -2.12445768e-04, -
2.14809159e-04,
-2.12432540e-04, -2.14810338e-04, -2.12450192e-04, -
2.14765634e-04,
-2.12532032e-04, -2.14633750e-04, -2.12731029e-04, -
2.14343600e-04,
-2.13149207e-04, -2.13734485e-04, -2.14072614e-04, -
2.12200044e-04,
-2.17237975e-04, -1.96702342e-04, -2.06965648e-04, -
2.03148535e-04,
-1.96772293e-04, -1.87494850e-04, -2.00166352e-04, -
1.85664947e-04,
-1.81098745e-04, -1.84653181e-04, -1.81956770e-04, -
1.83899392e-04,
-1.82628137e-04, -1.83303448e-04, -1.83146331e-04, -

1.82872507e-04,
-1.83472468e-04, -1.82680029e-04, -1.83482654e-04, -
1.82943826e-04,
-1.62394135e-04, -1.84783508e-04, -1.55813759e-04, -
1.65490172e-04,
-1.64202633e-04, -1.46375838e-04, -1.57265720e-04, -
1.48746651e-04,
-1.55820599e-04, -1.49877538e-04, -1.54803958e-04, -
1.50865904e-04,
-1.53800138e-04, -1.51911008e-04, -1.52695735e-04, -
1.53091270e-04,
-1.51419226e-04, -1.54494643e-04, -1.49835731e-04, -
1.56361581e-04,
-1.47454062e-04, -1.59929885e-04, -1.38932723e-04, -
1.43095414e-04,
-1.43294572e-04, -1.40352029e-04, -1.45555066e-04, -
1.38156174e-04,
-1.27641368e-04, -1.35070441e-04, -1.32519344e-04, -
1.17541815e-04,
-1.45225669e-04, -1.20019889e-04, -1.44182355e-04, -
1.20213779e-04,
-1.24469749e-04, -1.18220400e-04, -1.31480512e-04, -
1.36634888e-04,
-1.25222083e-04, -1.42264093e-04, -1.15336443e-04, -
1.26469298e-04,
-1.18796015e-04, -1.24617334e-04, -1.20065932e-04, -
1.23635080e-04,
-1.20878016e-04, -1.22938131e-04, -1.21489051e-04, -
1.22396625e-04,
-1.21971476e-04, -1.21965248e-04, -1.22358906e-04, -
1.21613237e-04,
-1.22686324e-04, -1.21294084e-04, -1.23024103e-04, -
1.20889512e-04,
-1.23594858e-04, -1.19901088e-04, -1.25924009e-04, -
1.05780462e-04,
-1.12804293e-04, -1.27020234e-04, -9.44739440e-05, -
9.16161516e-05,
-9.11009265e-05, -9.20843740e-05, -9.10219969e-05, -
9.20456368e-05,
-9.11228417e-05, -9.18944133e-05, -9.13248514e-05, -
9.16380377e-05,
-9.16412682e-05, -9.12550022e-05, -9.20986640e-05, -
9.07132635e-05,
-9.27388901e-05, -8.99525185e-05, -9.36562428e-05, -
8.88128416e-05,
-9.51510156e-05, -8.66461196e-05, -9.90513945e-05, -
7.02205580e-05,
-9.01128515e-05, -7.42843258e-05, -6.67222776e-05, -
7.71225896e-05,

```

-6.35929755e-05, -8.13524239e-05, -5.44079230e-05, -
6.52507297e-05,
-5.79106272e-05, -6.35521719e-05, -5.88711700e-05, -
6.30095019e-05,
-5.91303105e-05, -6.29686983e-05, -5.89825795e-05, -
6.32986776e-05,
-5.84493391e-05, -6.41037477e-05, -5.71875717e-05, -
6.64204708e-05,
-5.01880422e-05, -4.74731205e-05, -5.83173824e-05, -
2.85198330e-05,
-5.13283303e-05, -3.08256131e-05, -5.00726164e-05, -
3.16358637e-05,
-2.91679753e-05, -3.20264371e-05, -2.89081945e-05, -
3.21742846e-05,
-2.88649462e-05, -3.21116531e-05, -2.90460302e-05, -
3.17801605e-05,
-2.96042417e-05, -3.07822484e-05, -3.18731763e-05, -
1.71186985e-05,
5.05911885e-06, -3.38949030e-06, 2.65886774e-06, -
2.19262438e-06,
1.83144584e-06, -1.51863787e-06, 1.22998608e-06, -
9.51986294e-07,
6.77886419e-07, -4.01807483e-07, 1.20839104e-07,
1.69151463e-07,
-4.71191015e-07, 7.89645128e-07, -1.12864655e-06,
1.49564585e-06,
-1.89978164e-06, 2.35578045e-06, -2.88803130e-06,
3.54199437e-06,
-4.40812437e-06, 5.71645796e-06, -8.30349745e-06,
2.21281662e-05]), ('y', array([-5.00890019e-05, -3.08479939e-05, -
5.37438318e-05, -6.53449679e-05,
-5.59686450e-05, -7.76202651e-05, -7.35665672e-05, -
9.02966131e-05,
-9.28817608e-05, -8.91872915e-05, -1.19253848e-04, -
1.09140441e-04,
-1.09882181e-04, -1.29916065e-04, -1.13401416e-04, -
1.43508048e-04,
-1.24254468e-04, -1.37767143e-04, -1.29122753e-04, -
1.32290705e-04,
-1.59663963e-04, -1.47442333e-04, -1.57287432e-04, -
1.47219049e-04,
-1.83014490e-04, -1.67664955e-04, -1.73267967e-04, -
1.88700069e-04,
-1.76668982e-04, -2.02199357e-04, -1.88004284e-04, -
1.95016386e-04,
-1.98810973e-04, -2.10084894e-04, -2.16382236e-04, -
2.11191451e-04,
-2.16054672e-04, -2.10644299e-04, -2.40455207e-04, -
2.44151073e-04,

```

```

-2.45268631e-04, -2.41530332e-04, -2.52017984e-04, -
2.60951289e-04,
-2.43214512e-04, -2.81053071e-04, -2.66340387e-04, -
2.44555005e-04,
-2.67164607e-04, -2.78849766e-04, -2.70808931e-04, -
2.79157743e-04,
-2.65760405e-04, -2.57372099e-04, -2.81345507e-04, -
2.56931060e-04,
-2.66664545e-04, -2.77735468e-04, -2.72876932e-04, -
2.75743630e-04,
-2.74037622e-04, -2.75150378e-04, -2.71728553e-04, -
2.38562701e-04,
-2.54880462e-04, -2.57487438e-04, -2.48351018e-04, -
2.63728958e-04,
-2.36504304e-04, -2.61734938e-04, -2.53284379e-04, -
2.38854846e-04,
-2.49337667e-04, -2.38067412e-04, -2.52453727e-04, -
2.22441391e-04,
-2.21986091e-04, -2.28779681e-04, -2.11827937e-04, -
2.13180581e-04,
-2.15067877e-04, -2.11610080e-04, -2.15977459e-04, -
2.11076229e-04,
-2.16246524e-04, -2.11023929e-04, -1.95754517e-04, -
2.11374208e-04,
-1.95171844e-04, -2.12264189e-04, -2.14129614e-04, -
2.14750471e-04,
-1.86568985e-04, -1.96067049e-04, -1.94386797e-04, -
1.77471375e-04,
-1.86996709e-04, -1.80216652e-04, -1.85269484e-04, -
1.81522773e-04,
-1.84200951e-04, -1.82419404e-04, -1.83461307e-04, -
1.82980279e-04,
-1.83154116e-04, -1.82819131e-04, -1.84619363e-04, -
1.69920851e-04,
-1.67309685e-04, -1.56866328e-04, -1.69087041e-04, -
1.56237889e-04,
-1.49056592e-04, -1.56022637e-04, -1.49247120e-04, -
1.55838978e-04,
-1.49379193e-04, -1.56028691e-04, -1.46349426e-04, -
1.20223427e-04,
-1.48815248e-04, -1.40971169e-04, -1.15872899e-04, -
1.26309198e-04,
-1.18746684e-04, -1.24800150e-04, -1.19743694e-04, -
1.24349666e-04,
-1.17218602e-04, -8.81332962e-05, -9.96808230e-05, -
1.08592620e-04,
-8.73333775e-05, -9.37034711e-05, -9.04343833e-05, -
9.19261438e-05,
-9.18381993e-05, -9.05907582e-05, -9.33194387e-05, -

```

| | | |
|-----------------|--|--|
| 8.86264097e-05, | | |
| | -9.68072272e-05, -7.29021485e-05, -8.66725532e-05, - | |
| 7.92943538e-05, | | |
| | -5.61089473e-05, -6.37407866e-05, -5.93325676e-05, - | |
| 6.21463842e-05, | | |
| | -6.03152585e-05, -6.14823439e-05, -6.07794209e-05, - | |
| 6.11616560e-05, | | |
| | -6.09847484e-05, -6.10606367e-05, -6.09771378e-05, - | |
| 6.12056683e-05, | | |
| | -6.06022950e-05, -6.21592117e-05, -3.60267804e-05, - | |
| 2.85595379e-05, | | |
| | -3.17483355e-05, -2.96092039e-05, -3.12285993e-05, - | |
| 2.99490348e-05, | | |
| | -3.09745301e-05, -3.01500404e-05, -3.08156450e-05, - | |
| 3.02675180e-05, | | |
| | -3.07455339e-05, -3.02771514e-05, -3.08201707e-05, - | |
| 3.00732936e-05, | | |
| | -3.12488701e-05, -2.91725009e-05, -3.35401564e-05, - | |
| 1.50460255e-05, | | |
| | -2.04633106e-05, -3.62127757e-05, -2.25729746e-05, - | |
| 6.99714292e-07, | | |
| | 1.03052298e-06, -1.05706567e-06, 1.01048499e-06, - | |
| 9.40141035e-07, | | |
| | 8.60803993e-07, -7.77872629e-07, 6.93878974e-07, - | |
| 6.10336429e-07, | | |
| | 5.28365490e-07, -4.48941137e-07, 3.72921932e-07, - | |
| 3.00977263e-07, | | |
| | 2.33965693e-07, -1.72381988e-07, 1.16822775e-07, - | |
| 6.77246135e-08, | | |
| | 2.52912287e-08, 1.02154445e-08, -3.88245098e-08, | |
| 6.06087269e-08, | | |
| | -7.56554073e-08, 8.44884198e-08, -8.73405952e-08, | |
| 8.48376658e-08, | | |
| | -7.75035005e-08, 6.60220394e-08, -5.11863618e-08, | |
| 3.36149242e-08, | | |
| | -1.43918442e-08, -5.92262950e-09, 2.63898983e-08, - | |
| 4.61732270e-08, | | |
| | 6.45668479e-08, -8.07922333e-08, 9.40926839e-08, - | |
| 1.03798811e-07, | | |
| | 1.09328539e-07, -1.10128894e-07, 1.05734216e-07, - | |
| 9.56206350e-08, | | |
| | 7.95698725e-08, -5.71017154e-08, 2.80851964e-08, | |
| 7.98900146e-09, | | |
| | -5.12518454e-08, 1.02227204e-07, -1.61075150e-07, | |
| 2.28727004e-07, | | |
| | -3.05619324e-07, 3.93149094e-07, -4.92800609e-07, | |
| 6.06902177e-07, | | |
| | -7.38727977e-07, 8.93458491e-07, -1.07854430e-06, | |
| 1.30652916e-06, | | |

```

-1.59825868e-06, 1.99296483e-06, -2.57304782e-06,
3.55188968e-06,
1.46086531e-05, 1.90232095e-05, 2.49281511e-05,
1.25150837e-05,
3.51894487e-05, 2.81069879e-05, 3.18333186e-05,
2.99484964e-05,
3.04549176e-05, 3.12178672e-05, 2.90534081e-05,
3.31051269e-05,
2.56294734e-05, 4.87858488e-05, 3.57824028e-05,
4.24040554e-05,
4.59596486e-05, 5.80311680e-05, 6.29746937e-05,
5.97644030e-05,
6.18215126e-05, 6.06292306e-05, 6.11283904e-05,
6.12043659e-05,
6.06463436e-05, 6.16008329e-05, 6.03440712e-05,
6.17754267e-05,
8.07395700e-05, 6.11455907e-05, 8.46527473e-05,
9.50499889e-05,
8.86453781e-05, 9.42604311e-05, 8.89376461e-05,
9.41082762e-05,
8.90518495e-05, 9.39906458e-05, 8.91938107e-05,
9.38110752e-05,
8.94220939e-05, 9.35214412e-05, 8.97925929e-05,
9.30308815e-05,
1.10847875e-04, 9.17468642e-05, 1.15407965e-04,
1.25014456e-04,
1.20023768e-04, 1.23619247e-04, 1.20900506e-04,
1.22906640e-04,
1.21549972e-04, 1.22276659e-04, 1.22191792e-04,
1.21579542e-04,
1.23044709e-04, 1.20217177e-04, 1.47962652e-04,
1.53538829e-04,
1.32111192e-04, 1.52335400e-04, 1.53069952e-04,
1.51959321e-04,
1.53305387e-04, 1.51828426e-04, 1.53347384e-04,
1.51868517e-04,
1.53227767e-04, 1.52067849e-04, 1.52945897e-04,
1.52438093e-04,
1.52476641e-04, 1.53025001e-04, 1.51738961e-04,
1.53975445e-04,
1.50447973e-04, 1.55916903e-04, 1.46805076e-04,
1.72033557e-04]), ('y', array([-2.46282492e-04, -2.41896516e-04, -
2.46419688e-04, -2.41908187e-04,
-2.25871452e-04, -2.42389317e-04, -2.24911812e-04, -
2.44438881e-04,
-2.18132816e-04, -2.25327938e-04, -2.06015451e-04, -
2.06348428e-04,
-2.19320136e-04, -2.08786281e-04, -2.17849651e-04, -
2.09895486e-04,
-2.16907414e-04, -2.10750863e-04, -2.16102038e-04, -
```

2.11523235e-04,
-2.15355656e-04, -2.12244850e-04, -2.14661588e-04, -
2.12905361e-04,
-2.14044136e-04, -2.13465231e-04, -2.13565654e-04, -
2.13818887e-04,
-2.13428939e-04, -2.13497551e-04, -2.15115928e-04, -
2.00018112e-04,
-2.01318238e-04, -2.22037605e-04, -2.02323456e-04, -
1.88176389e-04,
-1.75496069e-04, -2.04051321e-04, -2.06081429e-04, -
1.97876478e-04,
-1.92755688e-04, -1.78262795e-04, -1.88295031e-04, -
1.65894482e-04,
-1.95214365e-04, -1.86217687e-04, -1.81681971e-04, -
1.82767399e-04,
-1.88800361e-04, -2.02408715e-04, -1.76638147e-04, -
1.87552156e-04,
-1.79612922e-04, -1.85949379e-04, -1.80804549e-04, -
1.84883116e-04,
-1.81888696e-04, -1.83661861e-04, -1.83410113e-04, -
1.81504729e-04,
-1.87275378e-04, -1.65138117e-04, -1.78241389e-04, -
1.69377003e-04,
-1.54463749e-04, -1.73298293e-04, -1.66554935e-04, -
1.55135349e-04,
-1.76764181e-04, -1.73060558e-04, -1.65857899e-04, -
1.57115457e-04,
-1.49604501e-04, -1.54070149e-04, -1.53513814e-04, -
1.38533738e-04,
-1.41854602e-04, -1.57861345e-04, -1.48962587e-04, -
1.55271293e-04,
-1.50587686e-04, -1.54029767e-04, -1.51633707e-04, -
1.53098284e-04,
-1.52491484e-04, -1.52291643e-04, -1.53260131e-04, -
1.51553337e-04,
-1.53972403e-04, -1.50865133e-04, -1.54636888e-04, -
1.50225183e-04,
-1.55250629e-04, -1.49639760e-04, -1.55805290e-04, -
1.49118103e-04,
-1.56292546e-04, -1.48665247e-04, -1.56713941e-04, -
1.48266990e-04,
-1.36762625e-04, -1.47837418e-04, -1.37320545e-04, -
1.46903680e-04,
-1.39555501e-04, -1.32898684e-04, -1.46713981e-04, -
1.53852408e-04,
-1.31611130e-04, -1.53755405e-04, -1.27377542e-04, -
1.20687284e-04,
-1.42467907e-04, -1.23334059e-04, -1.18491698e-04, -
1.38756717e-04,

```

-1.30139917e-04, -1.19525554e-04, -1.22882586e-04, -
1.22290803e-04,
-1.21079596e-04, -1.23693026e-04, -1.19907389e-04, -
1.24701022e-04,
-1.19035671e-04, -1.25448321e-04, -1.38753167e-04, -
1.25957784e-04,
-1.38361225e-04, -1.26233121e-04, -1.17855045e-04, -
1.26285042e-04,
-1.38247240e-04, -1.26160536e-04, -1.38396048e-04, -
1.26148589e-04,
-1.37554453e-04, -1.37674200e-04, -1.58019378e-04, -
1.35049617e-04,
-1.46453429e-04, -1.40950535e-04, -1.20251469e-04, -
1.58249124e-04,
-1.50297885e-04, -1.41532713e-04, -1.38751726e-04, -
1.61302713e-04,
-1.44900085e-04, -1.60540236e-04, -1.41029261e-04, -
1.27651787e-04,
-1.13775066e-04, -1.43917598e-04, -1.23480131e-04, -
1.38557720e-04,
-1.49542087e-04, -1.21235185e-04, -1.19613745e-04, -
1.37725699e-04,
-1.51966524e-04, -1.16757699e-04, -1.51151529e-04, -
1.39445576e-04,
-1.16733529e-04, -1.26029525e-04, -1.38850795e-04, -
1.25501916e-04,
-1.39026772e-04, -1.25446488e-04, -1.18700184e-04, -
1.25430262e-04,
-1.39073149e-04, -1.25387742e-04, -1.18780634e-04, -
1.25336912e-04,
-1.18809505e-04, -1.25363134e-04, -1.18671567e-04, -
1.25718521e-04,
-1.17868221e-04, -1.27633932e-04, -9.07501599e-05, -
1.08907741e-04,
-1.17604068e-04, -1.03472827e-04, -1.03777616e-04, -
8.47273841e-05,
-9.70325564e-05, -8.66073970e-05, -9.62701597e-05, -
8.69197829e-05,
-9.61715632e-05, -8.69199939e-05, -7.58496608e-05, -
8.69454670e-05,
-7.56561276e-05, -8.76710837e-05, -7.16986542e-05, -
5.37313608e-05,
-6.79120858e-05, -5.37971573e-05, -7.15542410e-05, -
8.79280851e-05,
-7.51964326e-05, -8.79358995e-05, -7.16996728e-05, -
5.29031895e-05,
-7.31831533e-05, -7.48023522e-05, -5.92929282e-05, -
6.15408644e-05,
-6.07274560e-05, -6.13116717e-05, -6.14426244e-05, -

```

| | | |
|-----------------|--|--|
| 4.97667934e-05, | | |
| | -2.33801038e-05, -8.87067290e-05, -2.98719169e-05, - | |
| 1.54730296e-05, | | |
| | -4.87499929e-05, -4.95630375e-05, -2.98245432e-05, - | |
| 1.29778637e-05, | | |
| | -2.88208394e-05, -9.18513251e-06, -5.98661427e-05, - | |
| 1.17198942e-05, | | |
| | -2.25018521e-05, -3.49425318e-05, -2.33602113e-05, - | |
| 2.02744559e-07, | | |
| | 6.72545866e-07, -7.02639227e-07, 5.18324669e-07, - | |
| 1.31287379e-07, | | |
| | -5.63086360e-07, 1.99244823e-06, -7.24381243e-06, - | |
| 1.77624170e-05, | | |
| | 4.89068771e-06, -2.81927350e-06, 1.81605719e-06, - | |
| 1.13129499e-06, | | |
| | 5.69969416e-07, -3.73693183e-08, -5.56465238e-07, | |
| 1.40722841e-06, | | |
| | -3.25799920e-06, 1.58175826e-05, 2.99948733e-05, - | |
| 5.27361408e-06, | | |
| | 2.78751832e-05, 3.02181579e-05, 3.11001204e-05, | |
| 3.01826512e-05, | | |
| | 9.28132795e-06, 4.30197688e-05, 6.74624462e-05, | |
| 5.57634048e-05, | | |
| | 6.61343802e-05, 5.58085740e-05, 6.65569678e-05, | |
| 5.50583936e-05, | | |
| | 6.77506905e-05, 5.26487129e-05, 5.70113771e-05, | |
| 1.08642038e-04, | | |
| | 4.13791277e-05, 7.54587818e-05, 6.73059840e-05, | |
| 3.35425138e-05, | | |
| | 7.91312195e-05, 7.16489740e-05, 3.91863286e-05, | |
| 7.50748441e-05, | | |
| | 7.02280086e-05, 7.00765522e-05, 9.55071300e-05, | |
| 5.35538420e-05, | | |
| | 6.56533521e-05, 5.88311814e-05, 8.09172634e-05, | |
| 6.52661547e-05, | | |
| | 2.75624916e-05, 6.41616061e-05, 4.59877774e-05, | |
| 7.88103789e-05, | | |
| | 3.73078510e-05, 6.09364361e-05, 4.18387353e-05, | |
| 6.24731183e-06, | | |
| | 6.06714748e-05, 6.45462424e-05, 2.78092921e-05, | |
| 6.42938539e-05, | | |
| | 4.33940440e-05, 4.16999683e-05, 8.33980739e-05, | |
| 7.54343346e-05, | | |
| | 1.07874977e-04, 2.22595409e-05, 1.05183106e-04, | |
| 8.17866530e-05, | | |
| | 4.64478508e-05, -2.45845877e-06, 5.38646709e-05, | |
| 8.73673707e-05, | | |
| | 4.75668348e-05, 7.41481781e-05, 2.18735076e-05, | |
| 6.62505627e-05, | | |

```

5.09228557e-05, 1.05835963e-04, 1.04693230e-04,
5.98717015e-05,
4.41018492e-05, 3.43886204e-05, 5.23831695e-05,
1.17620453e-04)])

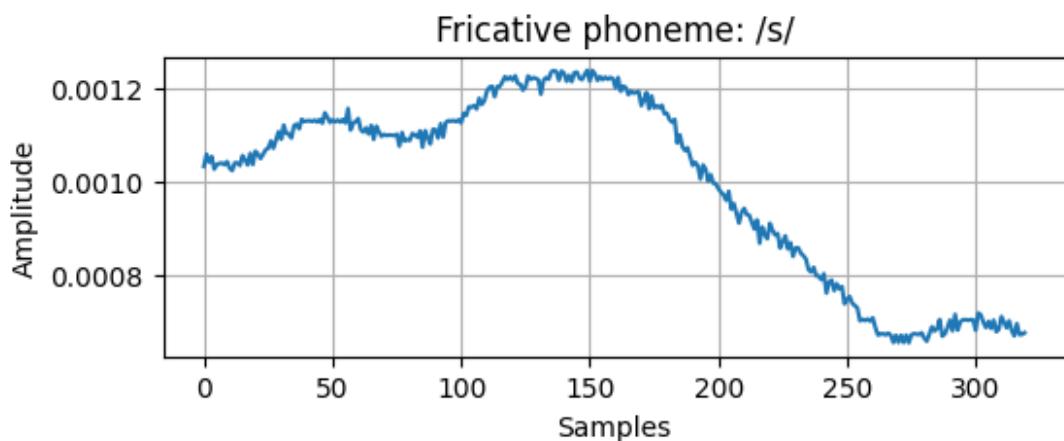
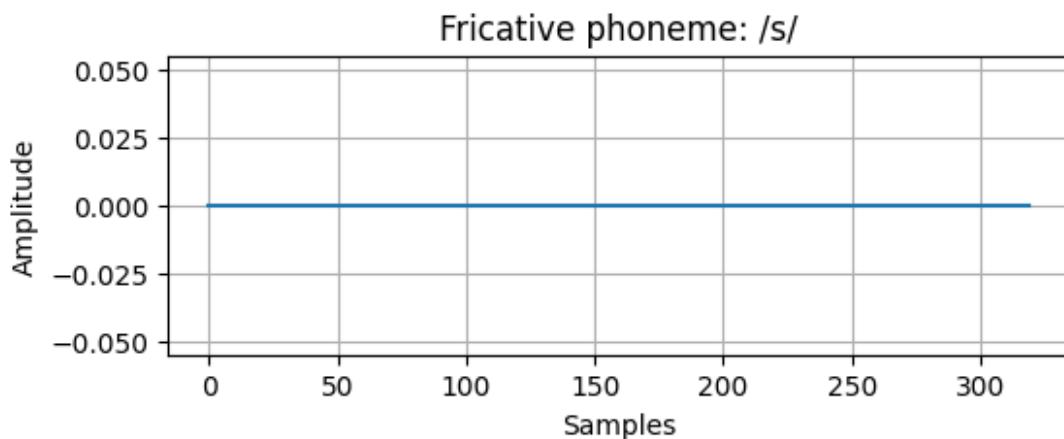
```

(v)

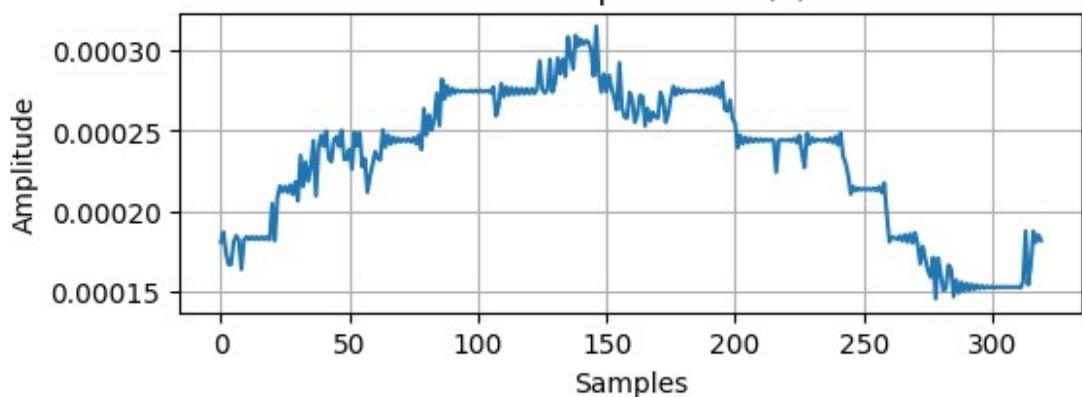
```

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")

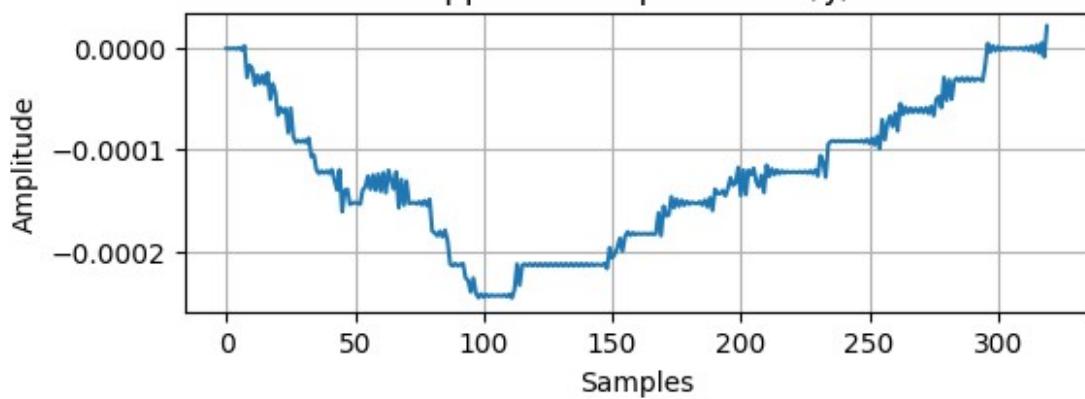
```



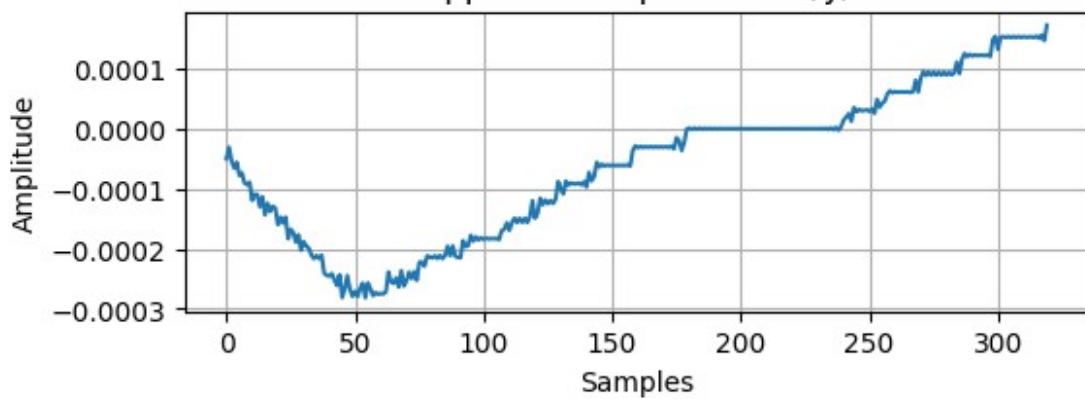
Fricative phoneme: /z/



Approximant phoneme: /y/



Approximant phoneme: /y/



Approximant phoneme: /y/

