In [ ]:
```python
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib.ticker as mtick
from UliEngineering.EngineerIO import format_value
from si_prefix import si_format
import plecs_helper as helper
%matplotlib
%matplotlib inline
```

```
Using matplotlib backend: TkAgg
```

Lab 4 Report

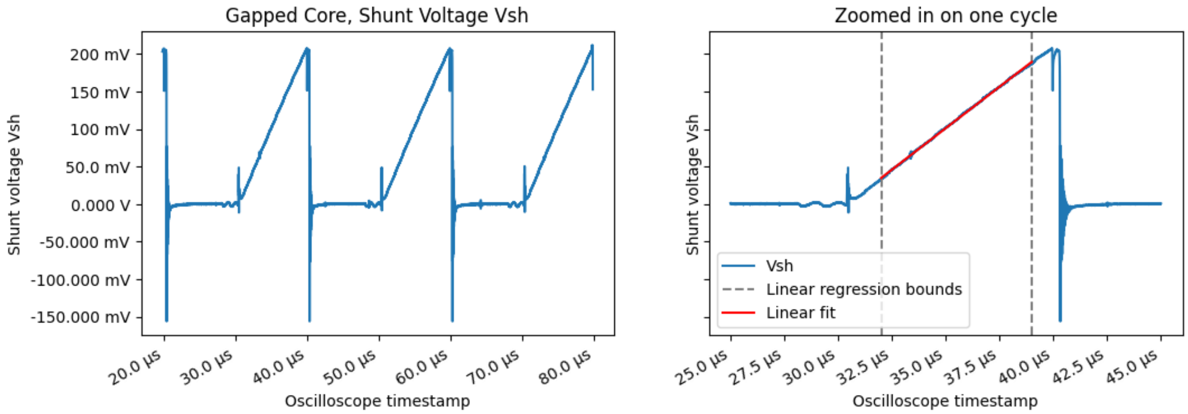
Ian Eykamp

Lab group: Ian Eykamp, Lauren Xiong, Melissa Kazazic

For the gapped core inductor

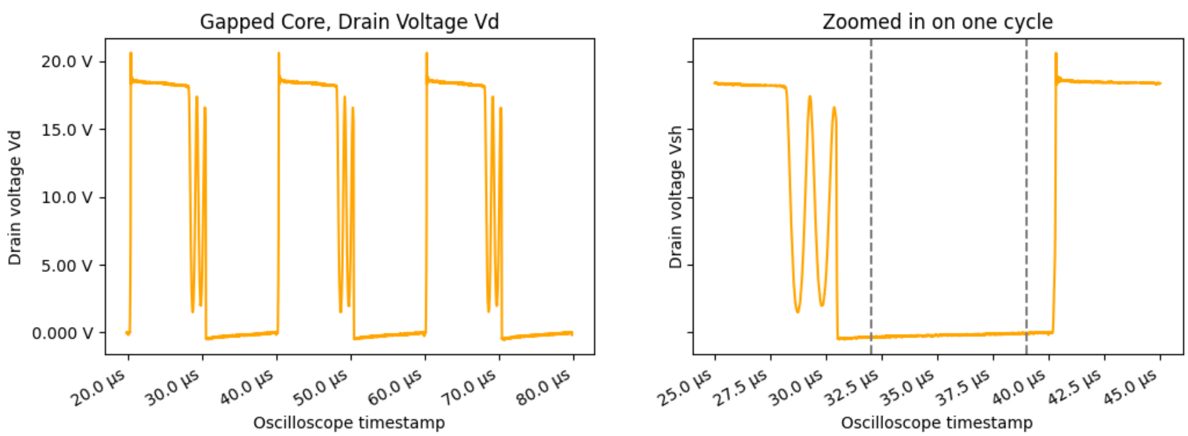
In [ ]:
```python
(df, tspan, tstep) = helper.read_rigol_csv("IronCore_Vsh_Vd.csv", ch1 = "Vsh", ch2
df_envelope = df
df_zoom = df[(df["t"] > 25e-6) & (df["t"] < 45e-6)]
linear_ts = (32e-6, 39e-6)
df_linreg = df[(df["t"] > linear_ts[0]) & (df["t"] < linear_ts[1])]

fig, (ax1, ax2) = plt.subplots(nrows = 1, ncols = 2, sharex = False, sharey = True,
fig.autofmt_xdate()
helper.axes_labels("Oscilloscope timestamp", "s", "Shunt voltage Vsh", "V", title =
ax1.plot(df_envelope["t"], df_envelope["Vsh"], label = "Vsh")

helper.axes_labels("Oscilloscope timestamp", "s", "Shunt voltage Vsh", "V", title =
ax2.plot(df_zoom["t"], df_zoom["Vsh"], label = "Vsh")
ax2.axvline(x = linear_ts[0], linestyle = "dashed", color = "grey", label = "Linear
ax2.axvline(x = linear_ts[1], linestyle = "dashed", color = "grey")

x = df_linreg["t"]
y = df_linreg["Vsh"]
A = np.vstack([x, np.ones(len(x))]).T
a, b = np.linalg.lstsq(A, y, rcond=None)[0]
ax2.plot(df_linreg["t"], df_linreg["t"] * a + b, linestyle = "solid", color = "red"
ax2.legend(loc = "lower left")

Vin = 17.8 # V
Vout = 9.08 # V
dIdt = a / 0.05 # ohms
Vinductor = Vin - Vout
L = Vinductor / dIdt
print(f"L: {si_format(L, precision = 2)}H")
```

```
L: 19.75 µH
```



In [ ]:
```
fig, (ax1, ax2) = plt.subplots(nrows = 1, ncols = 2, sharex = False, sharey = True,
fig.autofmt_xdate()
helper.axes_labels("Oscilloscope timestamp", "s", "Drain voltage Vd", "V", title =
ax1.plot(df_envelope["t"], df_envelope["Vd"], color = "orange", label = "Vd")

helper.axes_labels("Oscilloscope timestamp", "s", "Drain voltage Vsh", "V", title =
ax2.plot(df_zoom["t"], df_zoom["Vd"], color = "orange", label = "Vd")
ax2.axvline(x = linear_ts[0], linestyle = "dashed", color = "grey", label = "Linear
ax2.axvline(x = linear_ts[1], linestyle = "dashed", color = "grey")
```

Out[ ]: <matplotlib.lines.Line2D at 0x1f7885a2d60>

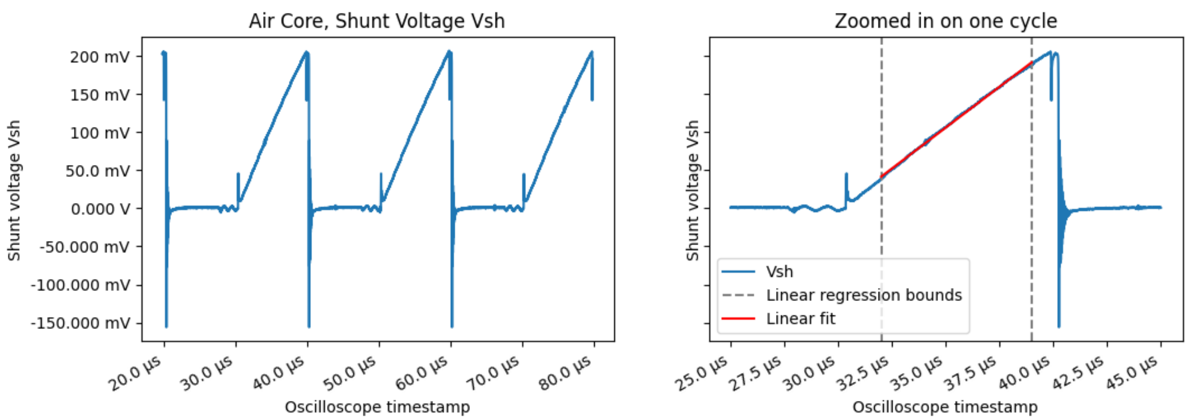


For the triangular air core inductor

In [ ]:
```
(df, tspan, tstep) = helper.read_rigol_csv("triangular_airCore.csv", ch1 = "Vsh", c
df_envelope = df
df_zoom = df[(df["t"] > 25e-6) & (df["t"] < 45e-6)]
linear_ts = (32e-6, 39e-6)
df_linreg = df[(df["t"] > linear_ts[0]) & (df["t"] < linear_ts[1])]

fig, (ax1, ax2) = plt.subplots(nrows = 1, ncols = 2, sharex = False, sharey = True,
fig.autofmt_xdate()
helper.axes_labels("Oscilloscope timestamp", "s", "Shunt voltage Vsh", "V", title =
ax1.plot(df_envelope["t"], df_envelope["Vsh"], label = "Vsh")

helper.axes_labels("Oscilloscope timestamp", "s", "Shunt voltage Vsh", "V", title =
ax2.plot(df_zoom["t"], df_zoom["Vsh"], label = "Vsh")
ax2.axvline(x = linear_ts[0], linestyle = "dashed", color = "grey", label = "Linear
```

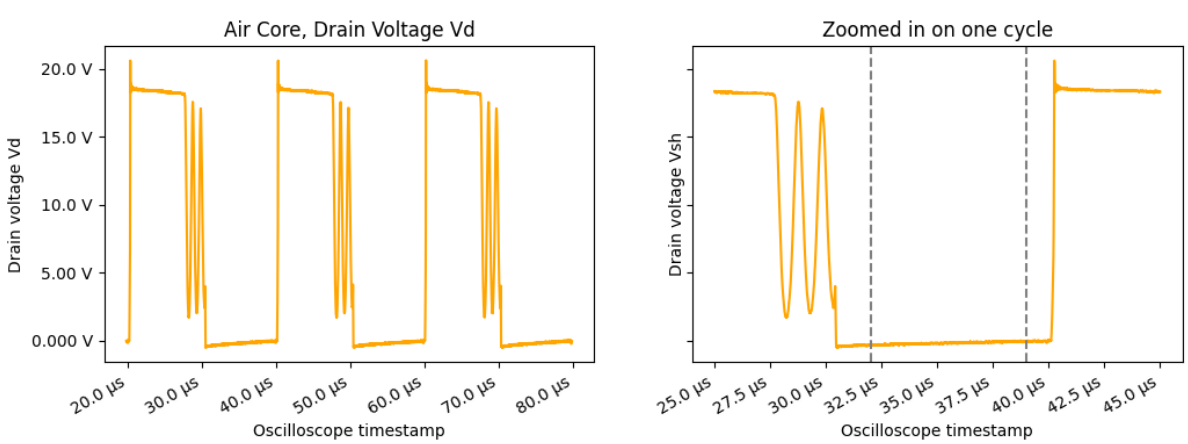
```
ax2.axvline(x = linear_ts[1], linestyle = "dashed", color = "grey")

x = df_linreg["t"]
y = df_linreg["Vsh"]
A = np.vstack([x, np.ones(len(x))]).T
a, b = np.linalg.lstsq(A, y, rcond=None)[0]
ax2.plot(df_linreg["t"], df_linreg["t"] * a + b, linestyle = "solid", color = "red"
ax2.legend(loc = "lower left")

Vin = 17.8 # V
Vout = 9.08 # V
dIdt = a / 0.05 # ohms
Vinductor = Vin - Vout
L = Vinductor / dIdt
print(f"L: {si_format(L, precision = 2)}H")
```

```
L: 20.32 µH
```



In [ ]:
```
fig, (ax1, ax2) = plt.subplots(nrows = 1, ncols = 2, sharex = False, sharey = True,
fig.autofmt_xdate()
helper.axes_labels("Oscilloscope timestamp", "s", "Drain voltage Vd", "V", title =
ax1.plot(df_envelope["t"], df_envelope["Vd"], color = "orange", label = "Vd")

helper.axes_labels("Oscilloscope timestamp", "s", "Drain voltage Vsh", "V", title =
ax2.plot(df_zoom["t"], df_zoom["Vd"], color = "orange", label = "Vd")
ax2.axvline(x = linear_ts[0], linestyle = "dashed", color = "grey", label = "Linear
ax2.axvline(x = linear_ts[1], linestyle = "dashed", color = "grey")
```

Out[ ]:
```
<matplotlib.lines.Line2D at 0x1f7887821c0>
```



Results:

The gapped core inductor had an experimental inductance value of 19.75uH at 4A of current. My air core inductor from lesson 5 had an inductance of 20.32uH at a similar current. In both cases, this is a larger inductance than was obtained on the LCR meter (18.96uH and 18.69uH for the gapped core and air core, respectively).

This is reminiscent of Lab 3, in which the calculated inductance value also depended on current, albeit in Lab 3, the inductance decreased with higher current.

Estimating efficiency

This is the entirety of my independent steps (I should have probably done more but I didn't have the time). I researched the Steinmetz equation by reading this app note:

https://www.we-online.com/components/media/o109035v410%20AppNotes_ANP029_AccurateInductorLossDete

I found Pcv from the inductor from the PC95 ferrite material datasheet and showed that at 50kHz, the power loss due to magnetic hysteresis is negligible.

In [ ]:
```
# Imports and setup
from pint import UnitRegistry
import math
import numpy

# use pint
units = UnitRegistry()
units.default_format = "~P"
```

In [ ]:
```
def power_efficiency(Vin, Iin, Vout, Rload = 5 * units.ohm):
    Iout = Vout / Rload
    return (Vout * Iout) / (Vin * Iin)

Iin_gap_core = 1.08 * units.amp
Vin_gap_core = 17.8 * units.volt
Vout_gap_core = 9.33 * units.volt
efficiency_gap_core = power_efficiency(Vin_gap_core, Iin_gap_core, Vout_gap_core)
print(f"Gap core inductor efficiency: {round(efficiency_gap_core.to_base_units() *

Iin_air_core = 1.10 * units.amp
Vin_air_core = 17.8 * units.volt
Vout_air_core = 9.08 * units.volt
efficiency_air_core = power_efficiency(Vin_air_core, Iin_air_core, Vout_air_core)
print(f"Air core inductor efficiency: {round(efficiency_air_core.to_base_units() *
```

```
Gap core inductor efficiency: 90.56%
Air core inductor efficiency: 84.21%
```

In [ ]:
```
core_volume = 2850 * units.millimeter ** 3
Pcv = 30 * units.kilowatt / units.meter ** 3
power_loss = Pcv * core_volume
print(f"Power loss due to magnetic hysteresis: {round(power_loss.to('watt'), 2)}")
print(f"Total power through inductor: {round((Iin_gap_core * Vin_gap_core).to('watt
```

```
Power loss due to magnetic hysteresis: 0.09 W
Total power through inductor: 19.22 W
```