:

: **R4136**

1. Python.

```
import numpy as np
import matplotlib.pyplot as plt
import os
import random
import scipy
import torch

torch.cuda.synchronize()
torch.cuda.empty_cache()

cuda = torch.device('cuda')
print(torch.cuda.get_device_properties(cuda))
```

```
_CudaDeviceProperties(name='NVIDIA GeForce RTX 3080 Laptop GPU', major=8, minor=6, total_mem
```

2. .

```
name = random.choice(os.listdir("dataset"))

# name = 'testLab1Var7.csv'

print(f"Dataset: {name}")

dataset = np.genfromtxt(f"dataset/{name}", delimiter=',')

dataset = [dataset[:, i] for i in range(dataset.shape[1])]
title = ["time", "current", "voltage"]

dataset_dict = dict(zip(title, dataset))
```

```
Dataset: testLab1Var11.csv
```

3. .

, ,
.

```
"""

"""
time_period = 0.1
```

```
time_interval = random.random() * (dataset_dict["time"][-1] - time_period)
time_interval = (time_interval, time_interval + time_period)

print(f"           {time_interval}")
```

           (28.65413982391623, 28.75413982391623)

```
plt.plot(dataset_dict["time"], dataset_dict["current"])
plt.xlim(time_interval)
plt.xlabel('    ,  ')
plt.ylabel('      ,  ')
plt.legend(["             "])
plt.grid()
```

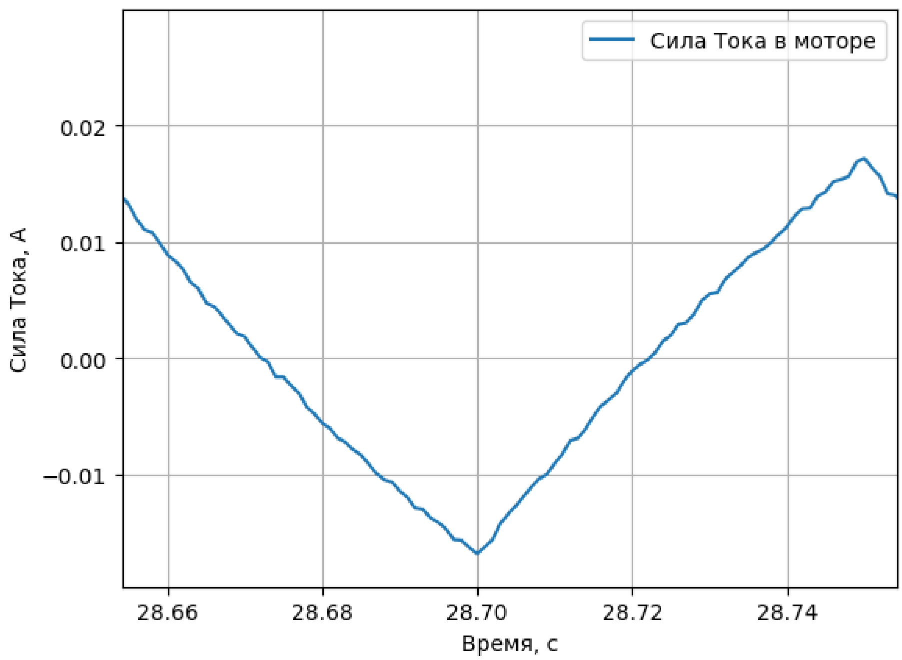
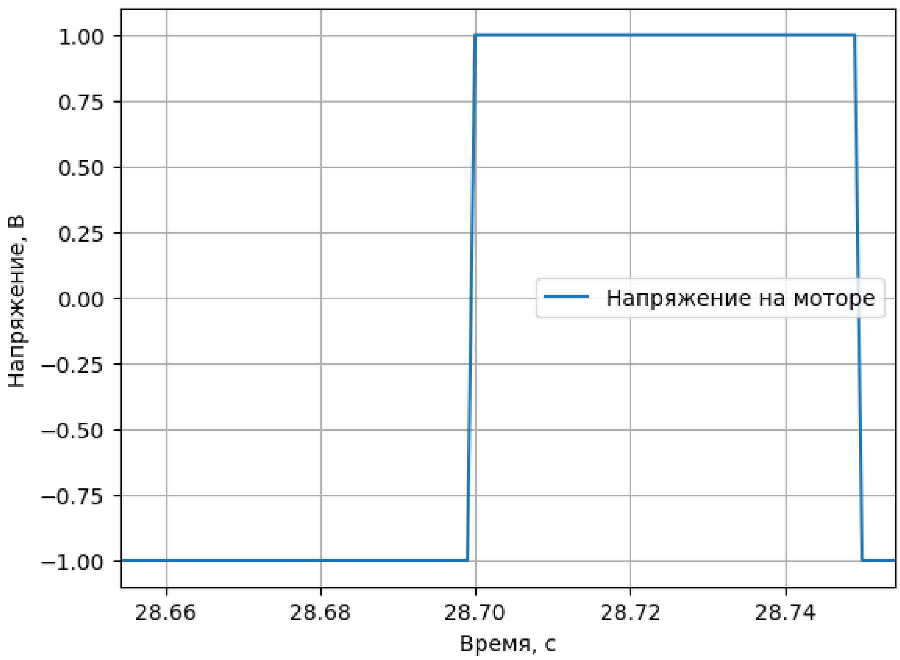


Figure 1: png

```
plt.plot(dataset_dict["time"], dataset_dict["voltage"])
plt.xlim(time_interval)
plt.xlabel('    ,  ')
plt.ylabel('      ,  ')
plt.legend(["              "])
plt.grid()
```



1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
Напряжение, В
Напряжение на моторе
28.66
28.68
28.70
28.72
28.74
Время, с

Figure 2: png

4. L R.

.

:

$$\begin{cases} u = e + R \times i + L \times \dfrac{di}{t} \\ M - M_C = J\dfrac{d\omega}{t} \\ M = C_M \times \Phi \times i \\ e = C_\omega \times \Phi \times \omega \end{cases}$$

u - ,

e - ( ) ,

i - ,

Φ - , ,

M - ,

M - ,

ω - ,

R - ,

L - ,

J - ,

$_\omega$ - ,

\- .

, :

$$\omega = 0 \rightarrow e = C_\omega \times \Phi \times \omega = 0 \rightarrow u = R \times i + L \times \frac{di}{t}$$

:

$$L \times \frac{di}{t} = u - R \times i$$

$$\frac{di}{t} = \frac{u}{L} - \frac{R}{L} \times i$$

$s = \dfrac{d}{t}$:

$$s \times i = \frac{u}{L} - \frac{R}{L} \times i$$

, $G_c = \frac{i}{u}$:

$$G_c(s) = \frac{1}{L \times (s + \frac{R}{L})}$$

Forward Euler (difference) discretization, :

$$s = \frac{z-1}{T_d}$$

$$G_d(z) = G_c(s = \frac{z-1}{T_s}) = \frac{1}{L \times (\frac{z-1}{T_s} + \frac{R}{L})}$$

$$G_d(z_i = z^{-1}) = \frac{T_d}{R \times T_d - L + L \times z_i^{-1}}$$

$$G_d(z_i) = \frac{T_d \times z_i}{L - L \times z_i + R \times T_d \times z_i}$$

z^{-1}:

$$G_d(z = z_i^{-1}) = \frac{T_d \times z^{-1}}{L - L \times z^{-1} + R \times T_d \times z^{-1}} = \frac{i(z)}{u(z)}$$

$$T_d \times u(z) * z^{-1} = i(z) * (L - L \times z^{-1} + R \times T_d \times z^{-1})$$

$$T_d \times u(z) * z^{-1} = i(z) * L - i(z) * L \times z^{-1} + i(z) * R \times T_d \times z^{-1}$$

$$i(z) * L = T_d \times u(z) * z^{-1} + i(z) * L \times z^{-1} - i(z) * R \times T_d \times z^{-1}$$

$$i(z) = u(z) * z^{-1} \times (\frac{T_d}{L}) + i(z) * z^{-1} \times (1 - \frac{R \times T_d}{L})$$

$$i(z) = u(z) * z^{-1} \times (\frac{T_d}{L}) - i(z) * z^{-1} \times (\frac{R \times T_d - L}{L})$$

z^{-1} - , ,
:

$$i_k = u_{k-1} \times (\frac{T_d}{L}) - i_{k-1} \times (\frac{R \times T_d - L}{L})$$

:

$$Y_{n\times1} = i_{1:end}$$

$$X_{n\times2} = [i_{0:end-1} | u_{0:end-1}]$$

$$K_{2\times1} = [\frac{T_d}{L} | \frac{R \times T_d - L}{L}]^T$$

$$Y = X * K$$

:

```
X = np.transpose(np.concatenate([np.array([dataset_dict["voltage"], ]), np.array([dataset_di
Y = np.transpose(np.array([dataset_dict["current"], ]))

# X : n*k
# K : k*1
# X * K = Y
# [U(k-1);I(k-1)] * K = [I(k)]

X = X[:-1, :]  # U(k-1);I(k-1)
Y = Y[1:, :]  # I(k)

print(X.shape)
print(Y.shape)

X_tensor = torch.tensor(X, device=cuda, dtype=torch.float64)
Y_tensor = torch.tensor(Y, device=cuda, dtype=torch.float64)
```

```
(100000, 2)
(100000, 1)
```

Moore–Penrose .

$Y = X \times K + e$:

```
def get_pseudoinverse(matrix):
    matrix_svd = torch.svd(matrix)
```

```
    matrix_psi = matrix_svd.V
    matrix_psi = torch.mm(matrix_psi, torch.diag(1 / matrix_svd.S))
    matrix_psi = torch.mm(matrix_psi, matrix_svd.U.T)

    return matrix_psi

X_psi = get_pseudoinverse(X_tensor)

print(X_psi.shape)
print(X_tensor.shape)
```

```
torch.Size([2, 100000])
torch.Size([100000, 2])
```

X X , :

```
print(torch.mm(X_psi, X_tensor))
```

```
tensor([[ 1.0000e+00,  3.7524e-19],
        [-2.7756e-16,  1.0000e+00]], device='cuda:0', dtype=torch.float64)
```

$X \times K = Y \rightarrow K = X^{+} \times Y$, X^{+} - , X

```
K_approx = torch.mm(X_psi, Y_tensor)
print(K_approx)
```

```
tensor([[6.9068e-04],
        [9.9025e-01]], device='cuda:0', dtype=torch.float64)
```

```
K = K_approx.cpu()

Td = 0.001
L = Td / K[0]
R = (L - K[1] * L) / Td

print('            R = ', R.numpy()[0], '   ')
print('            L = ', L.numpy()[0], '   ')
```

```
            R =  14.12081504070506
            L =  1.4478479999320457
```

,

```
R = 1 / K[0] * (1 - K[1])
T = -Td / np.log(K[1])
L = T * R

print('R = ', R.numpy()[0], ' Ohm')
print('L = ', L.numpy()[0], ' Hn')
```

```
R =  14.120815040705097  Ohm
L =  1.4407760594432346  Hn
```

5 .

Y $X \times K$,

$e = Y - X \times K$

:

$$S(K) = \sum e_i^2 = e^T \times e = (Y - X \times K)^T \times (Y - X \times K)$$

:

$$\sigma_Y = \sqrt{\frac{S(K)}{n}}$$

```
e2_Y = torch.mm(Y_tensor.T - torch.mm(X_tensor, K_approx).T, Y_tensor - torch.mm(X_tensor, K
sigma2_Y = torch.divide(e2_Y, Y_tensor.shape[0])

sigma_Y = torch.sqrt(sigma2_Y)
sigma_Y = sigma_Y.cpu().numpy()[0][0]

print(sigma_Y)
```

```
0.00030117986995266334
```

```
Y_predict = torch.mm(X_tensor, K_approx)
Y_predict = Y_predict.cpu().numpy()

# print(Y_predict.T[0].shape)
# print(dataset_dict["current"][1:].shape)

plt.plot(dataset_dict["time"][1:], dataset_dict["current"][1:], 'b')
plt.plot(dataset_dict["time"][1:], Y_predict.T[0], 'r--')
plt.xlim(time_interval)
plt.xlabel('   ,  ')
plt.ylabel('     ,  ')
plt.legend(["              ", "            "])
plt.grid()
```

,

, , , Y

:

```
# print(Y_predict.T[0].shape)
# print(dataset_dict["current"][1:].shape)

max_offset = np.max(np.abs(dataset_dict["current"][1:] - Y_predict.T[0]))

plt.plot(dataset_dict["time"][1:], dataset_dict["current"][1:] - Y_predict.T[0], 'g')
```

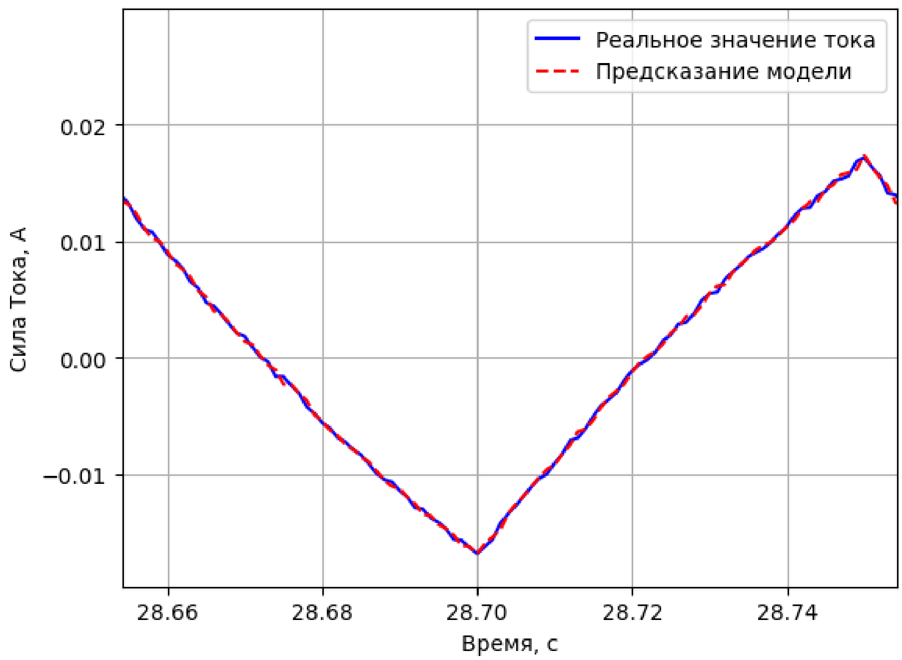

Реальное значение тока
Предсказание модели
0.02
0.01
0.00
−0.01
Сила Тока, А
28.66
28.68
28.70
28.72
28.74
Время, с

Figure 3: png

```
plt.hlines([-sigma_Y, sigma_Y], dataset_dict["time"][0], dataset_dict["time"][-1], 'r')
plt.hlines([-max_offset, max_offset], dataset_dict["time"][0], dataset_dict["time"][-1], 'b'
plt.xlim(time_interval)
plt.xlabel('    ,  ')
plt.ylabel('      ,  ')
plt.legend(["                    ", f"                 = {sigma_Y:.6f}", f"              = {ma
plt.grid()
```

Figure 4: png

, ,

σ_Y, ,

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