In [5]:
```
import torch
import torch.nn as nn
import torch.nn.functional as F
from torch.utils.data import DataLoader
from torchvision import datasets, transforms
from torchvision.utils import make_grid
import numpy as np
import pandas as pd
from sklearn.metrics import confusion_matrix
import matplotlib.pyplot as plt
```

In [6]:
```
tf = transforms.ToTensor()
```

In [7]:
```
train_ds = datasets.MNIST(root='./mnist',train=True,download=True,transform=tf)
```

```
Downloading http://yann.lecun.com/exdb/mnist/train-images-idx3-ubyte.gz
Failed to download (trying next):
<urlopen error [SSL: CERTIFICATE_VERIFY_FAILED] certificate verify failed: certificate has expired (_ssl.c:1000)
>

Downloading https://ossci-datasets.s3.amazonaws.com/mnist/train-images-idx3-ubyte.gz
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Downloading https://ossci-datasets.s3.amazonaws.com/mnist/t10k-labels-idx1-ubyte.gz
Downloading https://ossci-datasets.s3.amazonaws.com/mnist/t10k-labels-idx1-ubyte.gz to ./mnist\MNIST\raw\t10k-labels-idx1-ubyte.gz
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Extracting ./mnist\MNIST\raw\t10k-labels-idx1-ubyte.gz to ./mnist\MNIST\raw
```

In [13]:
```
test_ds = datasets.MNIST(root='./mnist',train=False,download=True,transform=tf)
```

In [14]:
```
train_ds
test_ds
```

Out[14]:
```
Dataset MNIST
    Number of datapoints: 10000
    Root location: ./mnist
    Split: Test
    StandardTransform
Transform: ToTensor()
```

In [15]:
```
train_loader = torch.utils.data.DataLoader(train_ds,batch_size=10,shuffle=True)
test_loader = torch.utils.data.DataLoader(test_ds,batch_size=10,shuffle=False)
```

In [16]:
```
class ConvolutionalNetwork(nn.Module):
  def __init__(self):
    super().__init__()
    self.conv1 = nn.Conv2d(1,6,3,1)
    self.conv2 = nn.Conv2d(6,16,3,1)
```

```
    self.fc1 = nn.Linear(5*5*16, 120)
    self.fc2 = nn.Linear(120, 84)
    self.fc3 = nn.Linear(84, 10)

  def forward(self, X):
    X = F.leaky_relu(self.conv1(X))
    X = F.max_pool2d(X,2,2)

    X = F.leaky_relu(self.conv2(X))
    X = F.max_pool2d(X,2,2)


    X = X.view(-1, 16*5*5)
    X = F.leaky_relu(self.fc1(X))
    X = F.leaky_relu(self.fc2(X))
    X = self.fc3(X)
    return F.log_softmax(X, dim=1)
```

In [17]:
```
model = ConvolutionalNetwork()
model
```

Out[17]:
```
ConvolutionalNetwork(
  (conv1): Conv2d(1, 6, kernel_size=(3, 3), stride=(1, 1))
  (conv2): Conv2d(6, 16, kernel_size=(3, 3), stride=(1, 1))
  (fc1): Linear(in_features=400, out_features=120, bias=True)
  (fc2): Linear(in_features=120, out_features=84, bias=True)
  (fc3): Linear(in_features=84, out_features=10, bias=True)
)
```

In [18]:
```
criterion = nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.parameters(), lr=0.003)
```

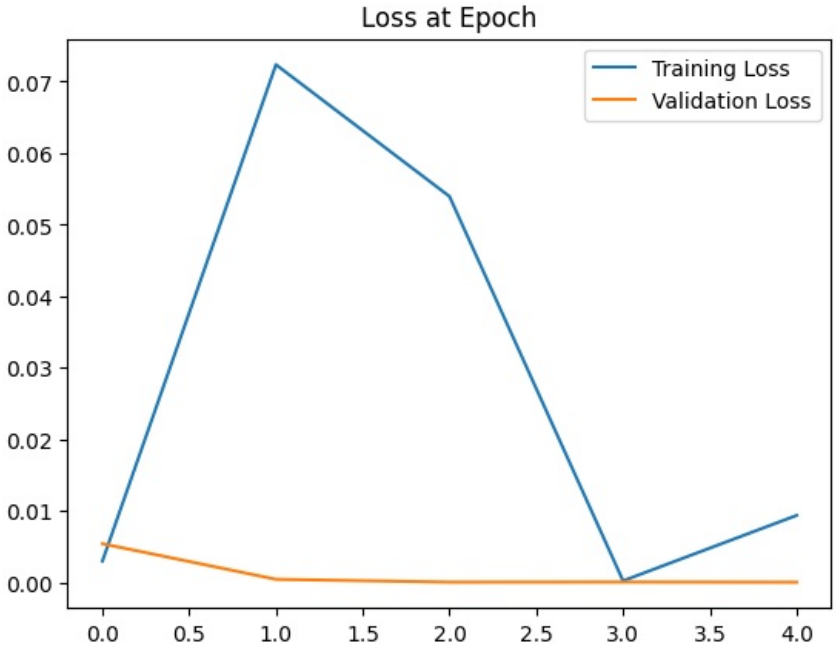
In [19]:
```
import time
start_time = time.time()

# Create Variables To Tracks Things
epochs = 5
train_losses = []
test_losses = []
train_correct = []
test_correct = []

# For Loop of Epochs
for i in range(epochs):
  trn_corr = 0
  tst_corr = 0


  # Train
  for b,(X_train, y_train) in enumerate(train_loader):
    b+=1 # start our batches at 1
    y_pred = model(X_train) # get predicted values from the training set. Not flattened 2D
    loss = criterion(y_pred, y_train) # how off are we? Compare the predictions to correct answers in y_train

    predicted = torch.max(y_pred.data, 1)[1] # add up the number of correct predictions. Indexed off the first
    batch_corr = (predicted == y_train).sum() # how many we got correct from this batch. True = 1, False=0, sum
    trn_corr += batch_corr # keep track as we go along in training.

    # Update our parameters
    optimizer.zero_grad()
    loss.backward()
    optimizer.step()


    # Print out some results
    if b%600 == 0:
      print(f'Epoch: {i}  Batch: {b}  Loss: {loss.item()}')

  train_losses.append(loss)
  train_correct.append(trn_corr)


  # Test
  with torch.no_grad(): #No gradient so we don't update our weights and biases with test data
    for b,(X_test, y_test) in enumerate(test_loader):
      y_val = model(X_test)
      predicted = torch.max(y_val.data, 1)[1]
      tst_corr += (predicted == y_test).sum()


  loss = criterion(y_val, y_test)
  test_losses.append(loss)
```

```
  test_correct.append(tst_corr)



current_time = time.time()
total = current_time - start_time
print(f'Training Took: {total/60} minutes!')
```

```
Epoch: 0  Batch: 600  Loss: 0.17075492441654205
Epoch: 0  Batch: 1200  Loss: 0.01225349958986044
Epoch: 0  Batch: 1800  Loss: 0.01613873988389969
Epoch: 0  Batch: 2400  Loss: 0.0418255552649498
Epoch: 0  Batch: 3000  Loss: 0.081080861389637
Epoch: 0  Batch: 3600  Loss: 0.6141346096992493
Epoch: 0  Batch: 4200  Loss: 0.02168860472738743
Epoch: 0  Batch: 4800  Loss: 0.00635731965303421
Epoch: 0  Batch: 5400  Loss: 0.0028516072779893875
Epoch: 0  Batch: 6000  Loss: 0.002972275484353304
Epoch: 1  Batch: 600  Loss: 0.000315128912916407
Epoch: 1  Batch: 1200  Loss: 0.01602208986878395
Epoch: 1  Batch: 1800  Loss: 0.0005551063222810626
Epoch: 1  Batch: 2400  Loss: 0.006829893682152033
Epoch: 1  Batch: 3000  Loss: 0.017594045028090477
Epoch: 1  Batch: 3600  Loss: 0.0002464220451656729
Epoch: 1  Batch: 4200  Loss: 0.037505630403757095
Epoch: 1  Batch: 4800  Loss: 0.003114315215498209
Epoch: 1  Batch: 5400  Loss: 0.003481730818748474
Epoch: 1  Batch: 6000  Loss: 0.0723716989159584
Epoch: 2  Batch: 600  Loss: 0.007853088900446892
Epoch: 2  Batch: 1200  Loss: 0.00031140385544858873
Epoch: 2  Batch: 1800  Loss: 0.0015322810504585505
Epoch: 2  Batch: 2400  Loss: 0.0054453774355351925
Epoch: 2  Batch: 3000  Loss: 2.053882235486526e-05
Epoch: 2  Batch: 3600  Loss: 0.016054591163992882
Epoch: 2  Batch: 4200  Loss: 3.3611460821703076e-05
Epoch: 2  Batch: 4800  Loss: 0.035297442227602005
Epoch: 2  Batch: 5400  Loss: 3.473460674285889e-05
Epoch: 2  Batch: 6000  Loss: 0.05395128205418587
Epoch: 3  Batch: 600  Loss: 0.0002421886456431821
Epoch: 3  Batch: 1200  Loss: 0.00033609423553571105
Epoch: 3  Batch: 1800  Loss: 0.8312262296676636
Epoch: 3  Batch: 2400  Loss: 0.11930812895298004
Epoch: 3  Batch: 3000  Loss: 0.007025485392659903
Epoch: 3  Batch: 3600  Loss: 0.17995990812778473
Epoch: 3  Batch: 4200  Loss: 0.002310117706656456
Epoch: 3  Batch: 4800  Loss: 3.807288157986477e-05
Epoch: 3  Batch: 5400  Loss: 0.011191745288670063
Epoch: 3  Batch: 6000  Loss: 0.00021347722213249654
Epoch: 4  Batch: 600  Loss: 2.047871021204628e-05
Epoch: 4  Batch: 1200  Loss: 0.0002615692210383713
Epoch: 4  Batch: 1800  Loss: 0.0009082118049263954
Epoch: 4  Batch: 2400  Loss: 0.011802678927779198
Epoch: 4  Batch: 3000  Loss: 0.0012283597607165575
Epoch: 4  Batch: 3600  Loss: 0.020469076931476593
Epoch: 4  Batch: 4200  Loss: 0.3913133144378662
Epoch: 4  Batch: 4800  Loss: 0.0005069398903287947
Epoch: 4  Batch: 5400  Loss: 0.0008200071752071381
Epoch: 4  Batch: 6000  Loss: 0.009360486641526222
Training Took: 4.408597914377848 minutes!
```

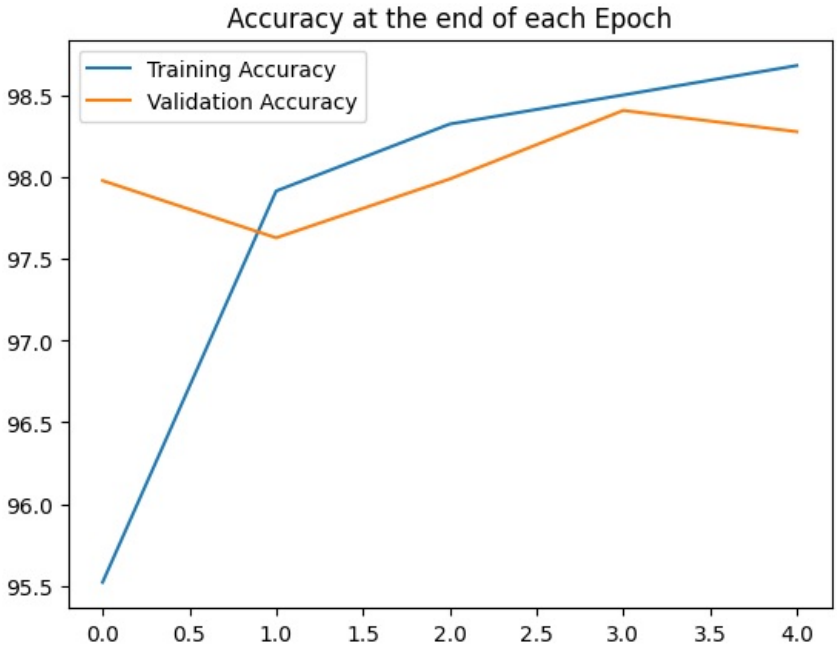
In [20]:
```
train_losses = [tl.item() for tl in train_losses]
plt.plot(train_losses, label="Training Loss")
plt.plot(test_losses, label="Validation Loss")
plt.title("Loss at Epoch")
plt.legend()
```

Out[20]:
```
<matplotlib.legend.Legend at 0x1cd694b5f10>
```



In [22]:
```
plt.plot([t/600 for t in train_correct], label="Training Accuracy")
plt.plot([t/100 for t in test_correct], label="Validation Accuracy")
plt.title("Accuracy at the end of each Epoch")
plt.legend()
```

Out[22]: <matplotlib.legend.Legend at 0x1cd01c83d40>



In [23]:
```
test_load_everything = DataLoader(test_ds, batch_size=10000, shuffle=False)

with torch.no_grad():
  correct = 0
  for X_test, y_test in test_load_everything:
    y_val = model(X_test)
    predicted = torch.max(y_val, 1)[1]
```

```
    correct += (predicted == y_test).sum()

correct.item()/len(test_ds)*100
```

Out[23]: 98.28

In [24]:
```
test_ds[6969][0]
test_ds[6969][0].reshape(28,28)
```

Out[24]:
```
tensor([[0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000,
         0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000,
         0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000,
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        [0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000,
         0.0000, 0.5020, 1.0000, 1.0000, 0.7490, 0.0000, 0.0000, 0.0000, 0.0000,
```

```
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          0.0000],
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          0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000,
          0.0000]])
```
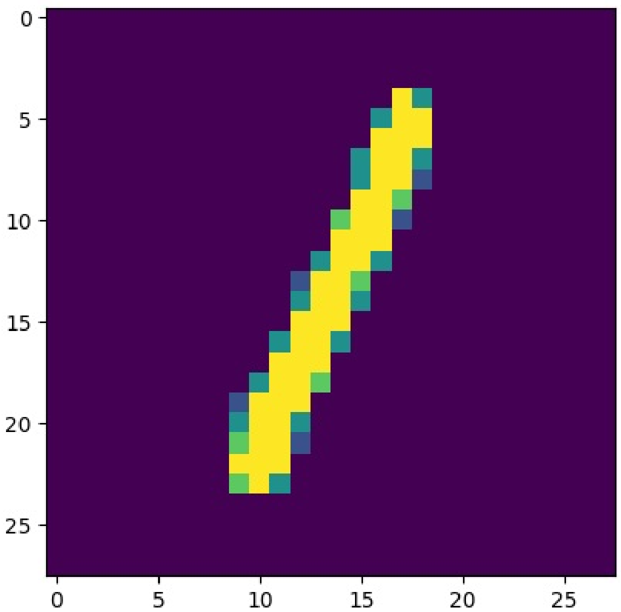

In [25]:
```
plt.imshow(test_ds[6969][0].reshape(28,28))
```

Out[25]:
```
<matplotlib.image.AxesImage at 0x1cd01c32240>
```



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