In [40]:
```python
import warnings
warnings.filterwarnings('ignore')
from tensorflow.examples.tutorials.mnist import input_data
import tensorflow as tf
import numpy as np
import seaborn as sns
```

In [2]:
```python
from prettytable import PrettyTable
table = PrettyTable()
table.field_names= ["Model","No of Hidden Layers","No of Units","Accuracy"]
print(table)
```

```
+-------+---------------------+-------------+----------+
| Model | No of Hidden Layers | No of Units | Accuracy |
+-------+---------------------+-------------+----------+
+-------+---------------------+-------------+----------+
```

In [41]:
```python
mnist_data = input_data.read_data_sets("MNIST_data/", one_hot=True)
```

```
Extracting MNIST_data/train-images-idx3-ubyte.gz
Extracting MNIST_data/train-labels-idx1-ubyte.gz
Extracting MNIST_data/t10k-images-idx3-ubyte.gz
Extracting MNIST_data/t10k-labels-idx1-ubyte.gz
```

In [42]:
```python
print("number of data points : ", mnist_data.train.images.shape[0],
      "number of pixels in each image :",mnist_data.train.images.shape[1])
```

```
number of data points :  55000 number of pixels in each image : 784
```

In [43]:
```python
# Get a list of devices like GPUs and CPUs available to TF

from tensorflow.python.client import device_lib
print(device_lib.list_local_devices())
```

```
[name: "/device:CPU:0"
device_type: "CPU"
memory_limit: 268435456
locality {
}
incarnation: 12397839269985006041
, name: "/device:XLA_CPU:0"
device_type: "XLA_CPU"
memory_limit: 17179869184
locality {
}
incarnation: 17473238461952891567
physical_device_desc: "device: XLA_CPU device"
]
```

In [44]:
```python
# %matplotlib notebook
import matplotlib.pyplot as plt
import time
# https://gist.github.com/greydanus/f6eee59eaf1d90fcb3b534a25362cea4
# https://stackoverflow.com/a/14434334
def plt_dynamic(x, y, y_1, ax, ticks, fig, colors=['b']):
    ax.plot(x, y, 'b', label="Train Loss")
    ax.plot(x, y_1, 'r', label="Test Loss")
    if len(x)==1:
        plt.legend()
    fig.canvas.draw()
```

In [45]:
```
# Parameters
training_epochs = 15
learning_rate = 0.001
batch_size = 100
display_step = 1
```

In [46]:
```
# 2 Layer MLP
```

In [79]:
```
# Network Parameters
n_hidden_1 = 256 # 1st layer number of neurons
n_hidden_2 = 256 # 2nd layer number of neurons
n_input = 784 # MNIST data input (img shape: 28*28)
n_classes = 10 # MNIST total classes (0-9 digits)
```

In [89]:
```
x = tf.placeholder(tf.float32, [None, n_input])
y_ = tf.placeholder(tf.float32, [None, n_classes])

# keep_prob: we will be using these placeholders when we use dropouts,
# while testing model
keep_prob = tf.placeholder(tf.float32)
# keep_prob_input: we will be using these placeholders when we use dropouts,
# while training model
keep_prob_input = tf.placeholder(tf.float32)
```

In [81]:
```
# Weight initialization
# He Normal initialization.
weights_relu = {
    'h1': tf.Variable(tf.random_normal([n_input, n_hidden_1],
                            stddev=(2/(n_hidden_1+1))**0.5, mean=0)),

    'h2': tf.Variable(tf.random_normal([n_hidden_1, n_hidden_2],
                            stddev=(2/(n_hidden_2+1))**0.5, mean=0)),

    'out': tf.Variable(tf.random_normal([n_hidden_2, n_classes],
                            stddev=(2/(n_classes+1))**0.5, mean=0))
}

biases = {
    'b1': tf.Variable(tf.random_normal([n_hidden_1])),
    'b2': tf.Variable(tf.random_normal([n_hidden_2])),
    'out': tf.Variable(tf.random_normal([n_classes]))
}
```

In [82]:
```python
# Model 1
use_batchNorm, use_dropOut = True, True   # WE have to keep changing these switches
epsilon = 1e-3

print( 'x:', x.get_shape(), 'W[h1]:', weights_relu['h1'].get_shape(),
                              'b[h1]:', biases['b1'].get_shape())

# Hidden layer with Relu activation
layer_1 = tf.add(tf.matmul(x, weights_relu['h1']), biases['b1'])

if use_batchNorm:
    # Calculate the mean and variance of x.
    batch_mean_1, batch_var_1 = tf.nn.moments(layer_1,[0])
    scale_1 = tf.Variable(tf.ones([n_hidden_1]))
    beta_1 = tf.Variable(tf.zeros([n_hidden_1]))
    # https://www.tensorflow.org/api_docs/python/tf/nn/batch_normalization
    layer_1 = tf.nn.batch_normalization(layer_1, batch_mean_1, batch_var_1,
                                        beta_1, scale_1, epsilon)
layer_1 = tf.nn.relu(layer_1)
if use_dropOut:
    layer_1 = tf.nn.dropout(layer_1, keep_prob)

print( 'layer_1:', layer_1.get_shape(), 'W[h2]:', weights_relu['h2'].get_shape(),
                              'b[h2]:', biases['b2'].get_shape())

# Hidden layer with Relu activation
layer_2 = tf.add(tf.matmul(layer_1, weights_relu['h2']), biases['b2'])
if use_batchNorm:
    batch_mean_2, batch_var_2 = tf.nn.moments(layer_2, [0])
    scale_2 = tf.Variable(tf.ones([n_hidden_2]))
    beta_2 = tf.Variable(tf.zeros([n_hidden_2]))
    layer_2 = tf.nn.batch_normalization(layer_2, batch_mean_2, batch_var_2,
                                        beta_2, scale_2, epsilon)

layer_2 = tf.nn.relu(layer_2)
if use_dropOut:
    layer_2 = tf.nn.dropout(layer_2, keep_prob)

print( 'layer_2:', layer_2.get_shape(), 'W[out]:', weights_relu['out'].get_shape(),
                              'b3:', biases['out'].get_shape())

# Output layer with Sigmoid activation
out_layer = tf.matmul(layer_2, weights_relu['out']) + biases['out']
out_layer = tf.nn.sigmoid(out_layer)
print('out_layer:',out_layer.get_shape())
```

```
x: (?, 784) W[h1]: (784, 256) b[h1]: (256,)
layer_1: (?, 256) W[h2]: (256, 256) b[h2]: (256,)
layer_2: (?, 256) W[out]: (256, 10) b3: (10,)
out_layer: (?, 10)
```

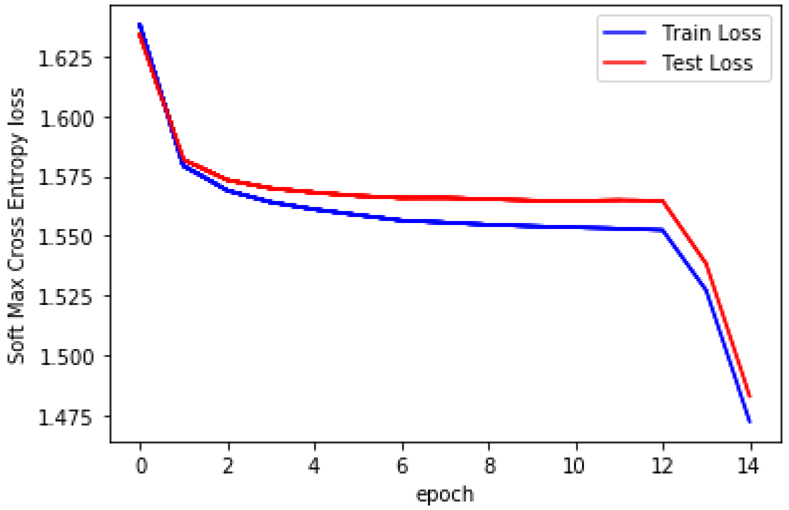
In [47]:
```python
# set up cost and optimizer

cost_sgd = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(logits = out_layer, labels = y_))
optimizer_adam = tf.train.AdamOptimizer(learning_rate=learning_rate).minimize(cost_sgd)
```

In [48]:

```
def run_model():
    with tf.Session() as sess:
        tf.global_variables_initializer().run()
        fig,ax = plt.subplots(1,1)
        ax.set_xlabel('epoch') ; ax.set_ylabel('Soft Max Cross Entropy loss')
        xs, ytrs, ytes = [], [], []
        for epoch in range(training_epochs):
            train_avg_cost = 0.
            test_avg_cost = 0.
            total_batch = int(mnist_data.train.num_examples/batch_size)

            # Loop over all batches
            for i in range(total_batch):
                batch_xs, batch_ys = mnist_data.train.next_batch(batch_size)

                # here we use AdamOptimizer
                _, c, w = sess.run([optimizer_adam, cost_sgd,weights_relu],
                                   feed_dict={x: batch_xs, y_: batch_ys, keep_prob: 0.5})
                train_avg_cost += c / total_batch
                c = sess.run(cost_sgd, feed_dict={x: mnist_data.test.images,
                                            y_: mnist_data.test.labels,  keep_prob: 1.0})
                test_avg_cost += c / total_batch

            xs.append(epoch)
            ytrs.append(train_avg_cost)
            ytes.append(test_avg_cost)
            plt_dynamic(xs, ytrs, ytes, ax, np.arange(1.3, 1.8, step=0.04),fig,
                        "input-relu(256)-relu(256)-sigmoid(output)-AdamOptimizer")

            if epoch%display_step == 0:
                print("Epoch:", '%04d' % (epoch+1), "train cost={:.9f}".format(train_avg_cost),
                                                    "test cost={:.9f}".format(test_avg_cost))
        plt_dynamic(xs, ytrs, ytes, ax, np.arange(1.3, 1.8, step=0.04),fig,
                    "input-relu(256)-relu(256)-sigmoid(output)-AdamOptimizer")

        # we are calculating the final accuracy on the test data
        correct_prediction = tf.equal(tf.argmax(out_layer,1), tf.argmax(y_,1))
        accuracy = tf.reduce_mean(tf.cast(correct_prediction, tf.float32))
        print("Accuracy:", accuracy.eval({x: mnist_data.test.images,
                                          y_: mnist_data.test.labels, keep_prob: 1.0}))
        return w, c
```

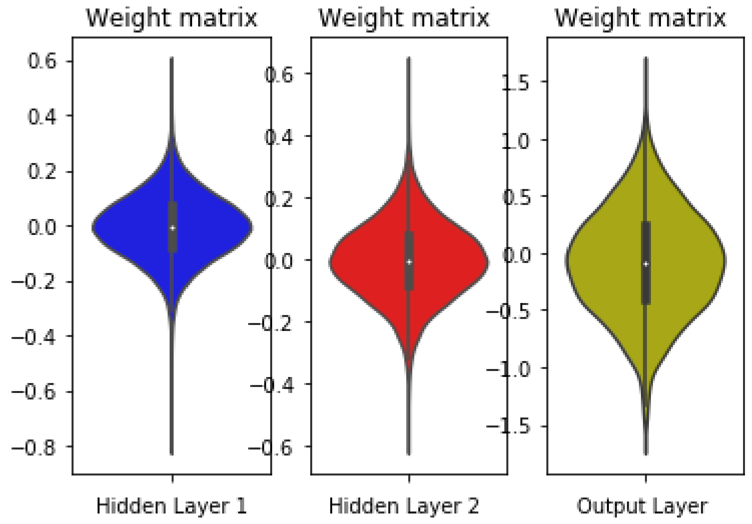
In [15]:
```
# Without BN and Dropout
w,c = run_model()
```

```
Epoch: 0001 train cost=1.638137851 test cost=1.634130663
Epoch: 0002 train cost=1.579409492 test cost=1.581957993
Epoch: 0003 train cost=1.569017958 test cost=1.573428834
Epoch: 0004 train cost=1.564145212 test cost=1.569962316
Epoch: 0005 train cost=1.561130864 test cost=1.568191827
Epoch: 0006 train cost=1.558779271 test cost=1.566803451
Epoch: 0007 train cost=1.556484338 test cost=1.565923119
Epoch: 0008 train cost=1.555649045 test cost=1.565952892
Epoch: 0009 train cost=1.554709715 test cost=1.565424182
Epoch: 0010 train cost=1.554094869 test cost=1.564856987
Epoch: 0011 train cost=1.553592909 test cost=1.564700108
Epoch: 0012 train cost=1.553080339 test cost=1.564989796
Epoch: 0013 train cost=1.552461133 test cost=1.564709585
Epoch: 0014 train cost=1.527282557 test cost=1.538429071
Epoch: 0015 train cost=1.472550573 test cost=1.483117800
Accuracy: 0.9757
```



In [16]:

```
# Plot weight distriubtion at the end of training.
h1_w = w['h1'].flatten().reshape(-1,1)
h2_w = w['h2'].flatten().reshape(-1,1)
out_w = w['out'].flatten().reshape(-1,1)

fig = plt.figure()
plt.subplot(1, 3, 1)
plt.title("Weight matrix")
ax = sns.violinplot(y=h1_w,color='b')
plt.xlabel('Hidden Layer 1')

plt.subplot(1, 3, 2)
plt.title("Weight matrix ")
ax = sns.violinplot(y=h2_w, color='r')
plt.xlabel('Hidden Layer 2 ')

plt.subplot(1, 3, 3)
plt.title("Weight matrix ")
ax = sns.violinplot(y=out_w,color='y')
plt.xlabel('Output Layer ')
plt.show()
```



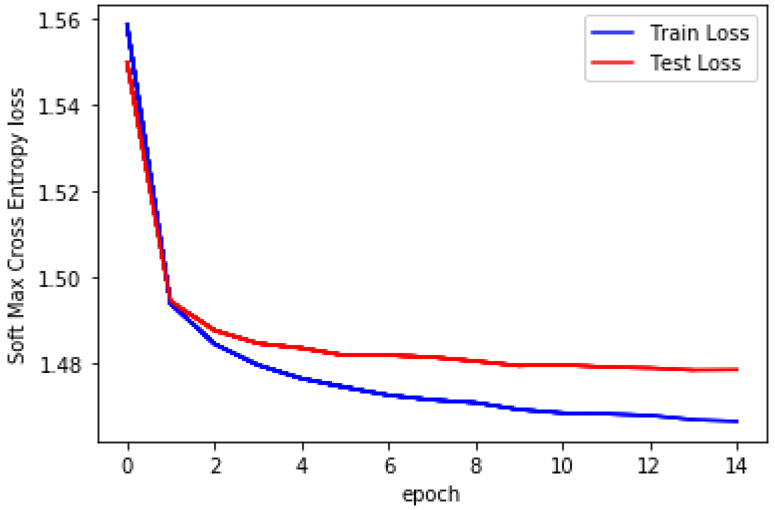
In [18]:

```
# "Model","No of Layers","No of Units","Activation","Accuracy"
table.add_row(["No BN & No Dropout",2,"[784,256,256,10]",0.97])
print(table)
```

```
+--------------------+--------------------+------------------+----------+
|       Model        | No of Hidden Layers |   No of Units    | Accuracy |
+--------------------+--------------------+------------------+----------+
| No BN & No Dropout |         2          | [784,256,256,10] |   0.97   |
+--------------------+--------------------+------------------+----------+
```

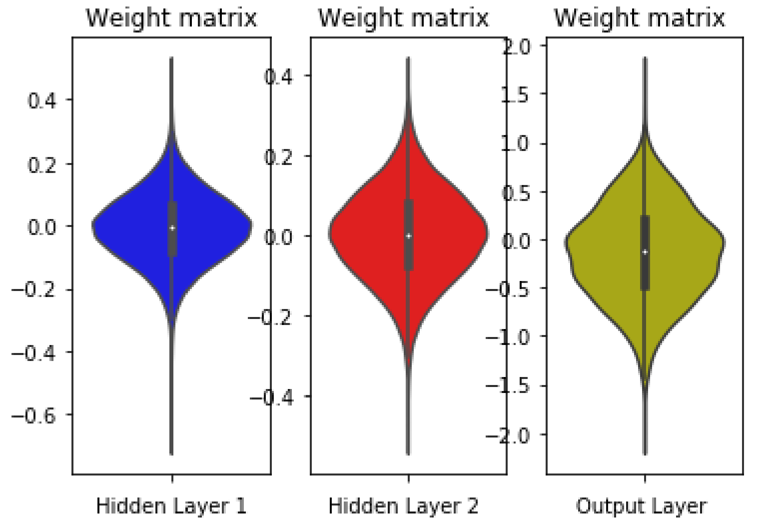
In [25]:
```
# With BN and Without Dropout
w,c = run_model()
```

```
Epoch: 0001 train cost=1.558521085 test cost=1.549814029
Epoch: 0002 train cost=1.494003643 test cost=1.494502273
Epoch: 0003 train cost=1.484580707 test cost=1.487758414
Epoch: 0004 train cost=1.479685761 test cost=1.484713249
Epoch: 0005 train cost=1.476566528 test cost=1.483627151
Epoch: 0006 train cost=1.474599217 test cost=1.481932188
Epoch: 0007 train cost=1.472807444 test cost=1.481972849
Epoch: 0008 train cost=1.471720335 test cost=1.481531454
Epoch: 0009 train cost=1.471059687 test cost=1.480596901
Epoch: 0010 train cost=1.469470541 test cost=1.479541919
Epoch: 0011 train cost=1.468687457 test cost=1.479752764
Epoch: 0012 train cost=1.468454835 test cost=1.479216068
Epoch: 0013 train cost=1.468112926 test cost=1.479006874
Epoch: 0014 train cost=1.467127276 test cost=1.478531238
Epoch: 0015 train cost=1.466731349 test cost=1.478610994
Accuracy: 0.9814
```



In [26]:

```
# Plot weight distriubtion at the end of training.
h1_w = w['h1'].flatten().reshape(-1,1)
h2_w = w['h2'].flatten().reshape(-1,1)
out_w = w['out'].flatten().reshape(-1,1)

fig = plt.figure()
plt.subplot(1, 3, 1)
plt.title("Weight matrix")
ax = sns.violinplot(y=h1_w,color='b')
plt.xlabel('Hidden Layer 1')

plt.subplot(1, 3, 2)
plt.title("Weight matrix ")
ax = sns.violinplot(y=h2_w, color='r')
plt.xlabel('Hidden Layer 2 ')

plt.subplot(1, 3, 3)
plt.title("Weight matrix ")
ax = sns.violinplot(y=out_w,color='y')
plt.xlabel('Output Layer ')
plt.show()
```



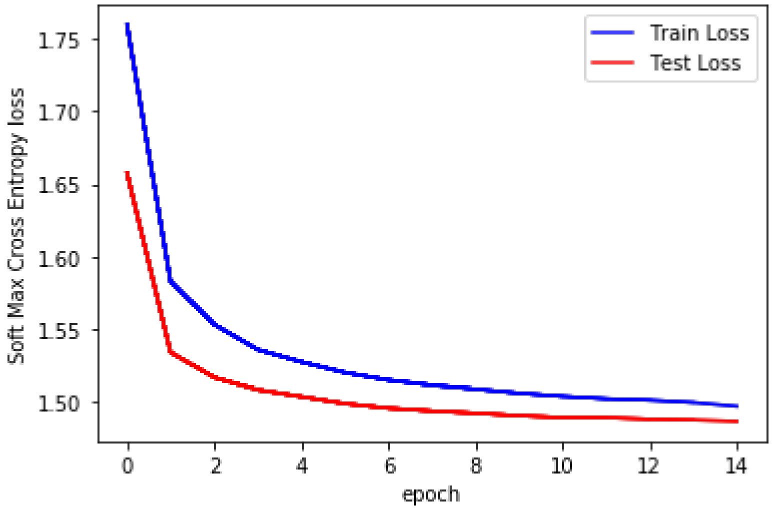
In [46]:

```
# "Model","No of Layers","No of Units","Activation","Accuracy"
table.add_row(["BN & No Dropout",2,"[784,256,256,10]",0.98])
print(table)
```

```
+-------------------+--------------------+------------------+----------+
|       Model       | No of Hidden Layers |   No of Units    | Accuracy |
+-------------------+--------------------+------------------+----------+
| No BN & No Dropout |         2          | [784,256,256,10] |   0.97   |
|  BN & No Dropout   |         2          | [784,256,256,10] |   0.98   |
+-------------------+--------------------+------------------+----------+
```

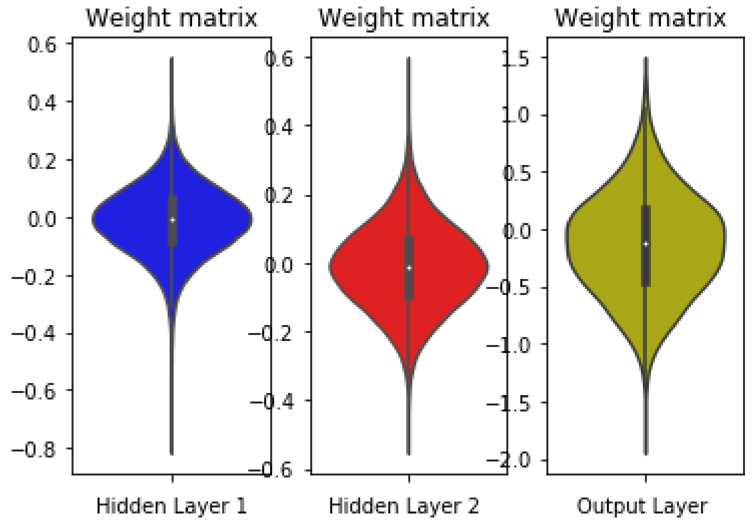
In [71]:
```
# Without BN and With Dropout
w,c = run_model()
```

```
Epoch: 0001 train cost=1.759903436 test cost=1.657631977
Epoch: 0002 train cost=1.582765761 test cost=1.533581437
Epoch: 0003 train cost=1.552725868 test cost=1.516168935
Epoch: 0004 train cost=1.535371889 test cost=1.507832254
Epoch: 0005 train cost=1.526957184 test cost=1.503152479
Epoch: 0006 train cost=1.519619572 test cost=1.498384231
Epoch: 0007 train cost=1.514480329 test cost=1.495229675
Epoch: 0008 train cost=1.511001006 test cost=1.493295799
Epoch: 0009 train cost=1.508342153 test cost=1.491744414
Epoch: 0010 train cost=1.505548809 test cost=1.490057549
Epoch: 0011 train cost=1.503413466 test cost=1.488765062
Epoch: 0012 train cost=1.501725340 test cost=1.488661042
Epoch: 0013 train cost=1.500776122 test cost=1.487625888
Epoch: 0014 train cost=1.499179063 test cost=1.487094166
Epoch: 0015 train cost=1.496562637 test cost=1.486118458
Accuracy: 0.9667
```



In [72]:

```
# Plot weight distriubtion at the end of training.
h1_w = w['h1'].flatten().reshape(-1,1)
h2_w = w['h2'].flatten().reshape(-1,1)
out_w = w['out'].flatten().reshape(-1,1)

fig = plt.figure()
plt.subplot(1, 3, 1)
plt.title("Weight matrix")
ax = sns.violinplot(y=h1_w,color='b')
plt.xlabel('Hidden Layer 1')

plt.subplot(1, 3, 2)
plt.title("Weight matrix ")
ax = sns.violinplot(y=h2_w, color='r')
plt.xlabel('Hidden Layer 2 ')

plt.subplot(1, 3, 3)
plt.title("Weight matrix ")
ax = sns.violinplot(y=out_w,color='y')
plt.xlabel('Output Layer ')
plt.show()
```



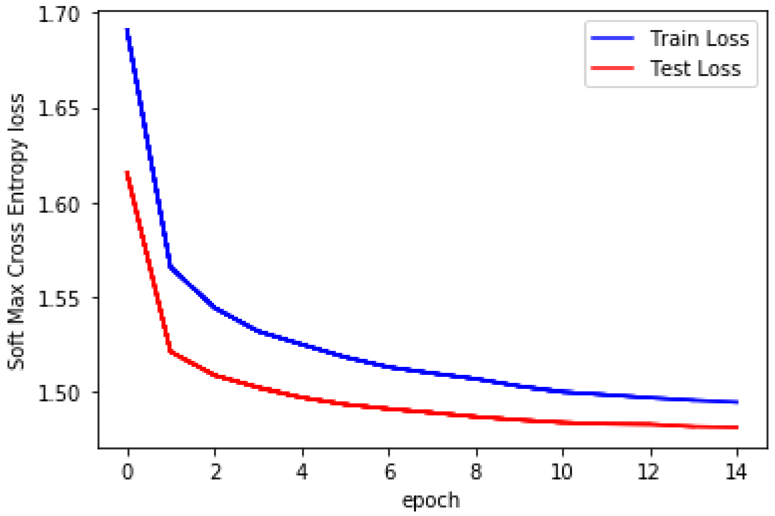
In [74]:

```
# "Model","No of Layers","No of Units","Activation","Accuracy"
table.add_row(["No BN & Dropout",2,"[784,256,256,10]",0.96])
print(table)
```

```
+-------------------+--------------------+------------------+----------+
|       Model       | No of Hidden Layers |   No of Units    | Accuracy |
+-------------------+--------------------+------------------+----------+
| No BN & No Dropout |         2          | [784,256,256,10] |   0.97   |
|  BN & No Dropout  |         2          | [784,256,256,10] |   0.98   |
|  No BN & Dropout  |         2          | [784,256,256,10] |   0.96   |
+-------------------+--------------------+------------------+----------+
```

In [85]:
```
# With BN and With Dropout
w,c = run_model()
```

```
Epoch: 0001 train cost=1.690725416 test cost=1.615356161
Epoch: 0002 train cost=1.565698045 test cost=1.520944096
Epoch: 0003 train cost=1.544162516 test cost=1.508412771
Epoch: 0004 train cost=1.531726814 test cost=1.502059145
Epoch: 0005 train cost=1.524816981 test cost=1.496960920
Epoch: 0006 train cost=1.518074628 test cost=1.493297059
Epoch: 0007 train cost=1.512760148 test cost=1.490948573
Epoch: 0008 train cost=1.509534764 test cost=1.488903993
Epoch: 0009 train cost=1.506565269 test cost=1.486767072
Epoch: 0010 train cost=1.502722313 test cost=1.485075052
Epoch: 0011 train cost=1.499809036 test cost=1.483703831
Epoch: 0012 train cost=1.498365546 test cost=1.482924277
Epoch: 0013 train cost=1.496802299 test cost=1.482756910
Epoch: 0014 train cost=1.495493095 test cost=1.481520048
Epoch: 0015 train cost=1.494422861 test cost=1.481174957
Accuracy: 0.9757
```



In [87]:
```
# "Model","No of Layers","No of Units","Activation","Accuracy"
table.add_row(["BN & Dropout",2,"[784,256,256,10]",0.97])
print(table)
```

```
+-------------------+--------------------+------------------+----------+
|       Model       | No of Hidden Layers |   No of Units    | Accuracy |
+-------------------+--------------------+------------------+----------+
| No BN & No Dropout |         2          | [784,256,256,10] |   0.97   |
|  BN & No Dropout  |         2          | [784,256,256,10] |   0.98   |
|  No BN & Dropout  |         2          | [784,256,256,10] |   0.96   |
|    BN & Dropout   |         2          | [784,256,256,10] |   0.97   |
+-------------------+--------------------+------------------+----------+
```

In [86]:
```
# 3 Layer MLP
```

In [131]:
```
# Network Parameters
n_hidden_1 = 512 # 1st layer number of neurons
n_hidden_2 = 256 # 2nd layer number of neurons
n_hidden_3 = 128 # 3rd layer number of neurons
n_input = 784 # MNIST data input (img shape: 28*28)
n_classes = 10 # MNIST total classes (0-9 digits)
```

In [132]:

```
x = tf.placeholder(tf.float32, [None, n_input])
y_ = tf.placeholder(tf.float32, [None, n_classes])

keep_prob = tf.placeholder(tf.float32)
keep_prob_input = tf.placeholder(tf.float32)
```

In [133]:

```
# Weight initialization
# He Normal initialization.
weights_relu = {
    'h1': tf.Variable(tf.random_normal([n_input, n_hidden_1],
                            stddev=(2/(n_hidden_1+1))**0.5, mean=0)),

    'h2': tf.Variable(tf.random_normal([n_hidden_1, n_hidden_2],
                            stddev=(2/(n_hidden_2+1))**0.5, mean=0)),

    'h3': tf.Variable(tf.random_normal([n_hidden_2, n_hidden_3],
                            stddev=(2/(n_hidden_3+1))**0.5, mean=0)),

    'out': tf.Variable(tf.random_normal([n_hidden_3, n_classes],
                            stddev=(2/(n_classes+1))**0.5, mean=0))
}

biases = {
    'b1': tf.Variable(tf.random_normal([n_hidden_1])),
    'b2': tf.Variable(tf.random_normal([n_hidden_2])),
    'b3': tf.Variable(tf.random_normal([n_hidden_3])),
    'out': tf.Variable(tf.random_normal([n_classes]))
}
```

In [134]:

```
# Model 2
use_batchNorm, use_dropOut = True, True   # WE have to keep changing these switches
epsilon = 1e-3

print( 'x:', x.get_shape(), 'W[h1]:', weights_relu['h1'].get_shape(),
                              'b[h1]:', biases['b1'].get_shape())

# Hidden layer with Relu activation
layer_1 = tf.add(tf.matmul(x, weights_relu['h1']), biases['b1'])

if use_batchNorm:
    # Calculate the mean and variance of x.
    batch_mean_1, batch_var_1 = tf.nn.moments(layer_1,[0])
    scale_1 = tf.Variable(tf.ones([n_hidden_1]))
    beta_1 = tf.Variable(tf.zeros([n_hidden_1]))
    # https://www.tensorflow.org/api_docs/python/tf/nn/batch_normalization
    layer_1 = tf.nn.batch_normalization(layer_1, batch_mean_1, batch_var_1,
                                        beta_1, scale_1, epsilon)
layer_1 = tf.nn.relu(layer_1)
if use_dropOut:
    layer_1 = tf.nn.dropout(layer_1, keep_prob)

print( 'layer_1:', layer_1.get_shape(), 'W[h2]:', weights_relu['h2'].get_shape(),
                              'b[h2]:', biases['b2'].get_shape())

# Hidden layer with Relu activation
layer_2 = tf.add(tf.matmul(layer_1, weights_relu['h2']), biases['b2'])
if use_batchNorm:
    batch_mean_2, batch_var_2 = tf.nn.moments(layer_2, [0])
    scale_2 = tf.Variable(tf.ones([n_hidden_2]))
    beta_2 = tf.Variable(tf.zeros([n_hidden_2]))
    layer_2 = tf.nn.batch_normalization(layer_2, batch_mean_2, batch_var_2,
                                        beta_2, scale_2, epsilon)

layer_2 = tf.nn.relu(layer_2)
if use_dropOut:
    layer_2 = tf.nn.dropout(layer_2, keep_prob)

print( 'layer_2:', layer_2.get_shape(), 'W[h3]:', weights_relu['h3'].get_shape(),
                              'b3:', biases['b3'].get_shape())

layer_3 = tf.add(tf.matmul(layer_2, weights_relu['h3']), biases['b3'])
if use_batchNorm:
    batch_mean_3, batch_var_3 = tf.nn.moments(layer_3, [0])
    scale_3 = tf.Variable(tf.ones([n_hidden_3]))
    beta_3 = tf.Variable(tf.zeros([n_hidden_3]))
    layer_3 = tf.nn.batch_normalization(layer_3, batch_mean_3, batch_var_3,
                                        beta_3, scale_3, epsilon)

layer_3 = tf.nn.relu(layer_3)
if use_dropOut:
    layer_3 = tf.nn.dropout(layer_3, keep_prob)

print( 'layer_3:', layer_3.get_shape(), 'W[out]:', weights_relu['out'].get_shape(),
                              'b3:', biases['out'].get_shape())

# Output layer with Sigmoid activation
out_layer = tf.matmul(layer_3, weights_relu['out']) + biases['out']
out_layer = tf.nn.sigmoid(out_layer)
print('out_layer:',out_layer.get_shape())
```

```
x: (?, 784) W[h1]: (784, 512) b[h1]: (512,)
layer_1: (?, 512) W[h2]: (512, 256) b[h2]: (256,)
layer_2: (?, 256) W[h3]: (256, 128) b3: (128,)
layer_3: (?, 128) W[out]: (128, 10) b3: (10,)
out_layer: (?, 10)
```

In [135]:

```
# set up cost and optimizer

cost_sgd = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(logits = out_layer, labels = y_))
optimizer_adam = tf.train.AdamOptimizer(learning_rate=learning_rate).minimize(cost_sgd)
```

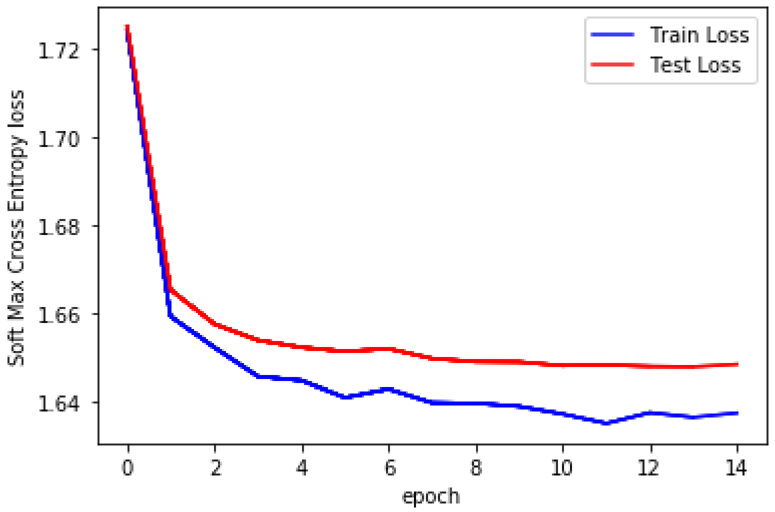
In [136]:

```
def run_model():
    with tf.Session() as sess:
        tf.global_variables_initializer().run()
        fig,ax = plt.subplots(1,1)
        ax.set_xlabel('epoch') ; ax.set_ylabel('Soft Max Cross Entropy loss')
        xs, ytrs, ytes = [], [], []
        for epoch in range(training_epochs):
            train_avg_cost = 0.
            test_avg_cost = 0.
            total_batch = int(mnist_data.train.num_examples/batch_size)

            # Loop over all batches
            for i in range(total_batch):
                batch_xs, batch_ys = mnist_data.train.next_batch(batch_size)

                # here we use AdamOptimizer
                _, c, w = sess.run([optimizer_adam, cost_sgd,weights_relu],
                                   feed_dict={x: batch_xs, y_: batch_ys, keep_prob: 0.5})
                train_avg_cost += c / total_batch
                c = sess.run(cost_sgd, feed_dict={x: mnist_data.test.images,
                                              y_: mnist_data.test.labels,  keep_prob: 1.0})
                test_avg_cost += c / total_batch

            xs.append(epoch)
            ytrs.append(train_avg_cost)
            ytes.append(test_avg_cost)
            plt_dynamic(xs, ytrs, ytes, ax, np.arange(1.3, 1.8, step=0.04),fig,
                        "input-relu(512)-relu(256)-relu(128)-sigmoid(output)-AdamOptimizer")

            if epoch%display_step == 0:
                print("Epoch:", '%04d' % (epoch+1), "train cost={:.9f}".format(train_avg_cost),
                                                "test cost={:.9f}".format(test_avg_cost))
        plt_dynamic(xs, ytrs, ytes, ax, np.arange(1.3, 1.8, step=0.04),fig,
                    "input-relu(512)-relu(256)-relu(128)-sigmoid(output)-AdamOptimizer")

        # we are calculating the final accuracy on the test data
        correct_prediction = tf.equal(tf.argmax(out_layer,1), tf.argmax(y_,1))
        accuracy = tf.reduce_mean(tf.cast(correct_prediction, tf.float32))
        print("Accuracy:", accuracy.eval({x: mnist_data.test.images,
                                          y_: mnist_data.test.labels, keep_prob: 1.0}))
        return w, c
```

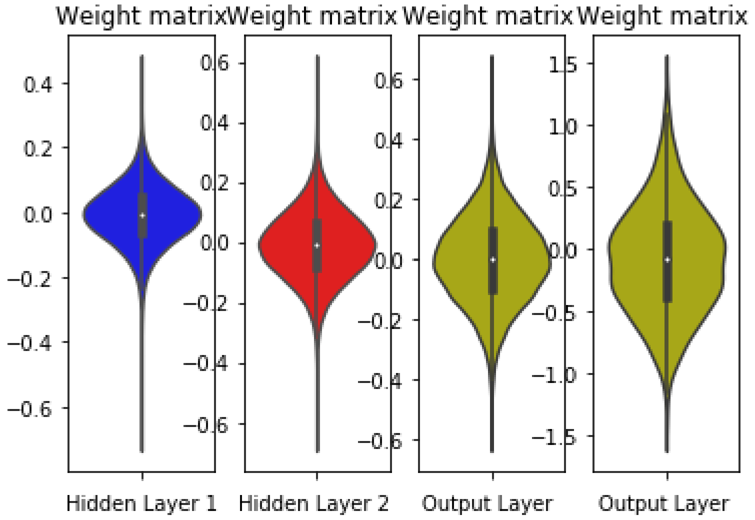
In [137]:
```
def plot_weight(w):
    # Plot weight distriubtion at the end of training.
    h1_w = w['h1'].flatten().reshape(-1,1)
    h2_w = w['h2'].flatten().reshape(-1,1)
    h3_w = w['h3'].flatten().reshape(-1,1)
    out_w = w['out'].flatten().reshape(-1,1)

    fig = plt.figure()
    plt.subplot(1, 4, 1)
    plt.title("Weight matrix")
    ax = sns.violinplot(y=h1_w,color='b')
    plt.xlabel('Hidden Layer 1')

    plt.subplot(1, 4, 2)
    plt.title("Weight matrix ")
    ax = sns.violinplot(y=h2_w, color='r')
    plt.xlabel('Hidden Layer 2 ')

    plt.subplot(1, 4, 3)
    plt.title("Weight matrix ")
    ax = sns.violinplot(y=h3_w,color='y')
    plt.xlabel('Output Layer ')

    plt.subplot(1, 4, 4)
    plt.title("Weight matrix ")
    ax = sns.violinplot(y=out_w,color='y')
    plt.xlabel('Output Layer ')
    plt.show()
```

In [105]:
```
# Without BN and Without Dropout
w,c = run_model()
```

```
Epoch: 0001 train cost=1.724415028 test cost=1.725089503
Epoch: 0002 train cost=1.659226547 test cost=1.665297671
Epoch: 0003 train cost=1.652102614 test cost=1.657444872
Epoch: 0004 train cost=1.645525534 test cost=1.653770006
Epoch: 0005 train cost=1.644605266 test cost=1.652141756
Epoch: 0006 train cost=1.640791462 test cost=1.651228265
Epoch: 0007 train cost=1.642705981 test cost=1.651835701
Epoch: 0008 train cost=1.639625619 test cost=1.649619522
Epoch: 0009 train cost=1.639511052 test cost=1.648886293
Epoch: 0010 train cost=1.638805584 test cost=1.648827449
Epoch: 0011 train cost=1.637063793 test cost=1.647981633
Epoch: 0012 train cost=1.634926372 test cost=1.648139446
Epoch: 0013 train cost=1.637360113 test cost=1.647825703
Epoch: 0014 train cost=1.636315347 test cost=1.647731843
Epoch: 0015 train cost=1.637297489 test cost=1.648290913
Accuracy: 0.7807
```



In [106]:
```
plot_weight(w)
```

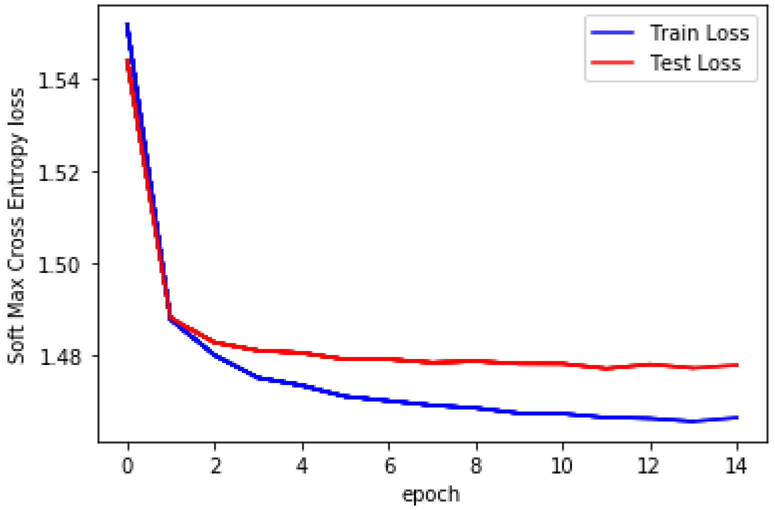


In [107]:
```
# "Model","No of Layers","No of Units","Accuracy"
table.add_row(["No BN & No Dropout",3,"[784,512,256,128,10]",0.78])
print(table)
```

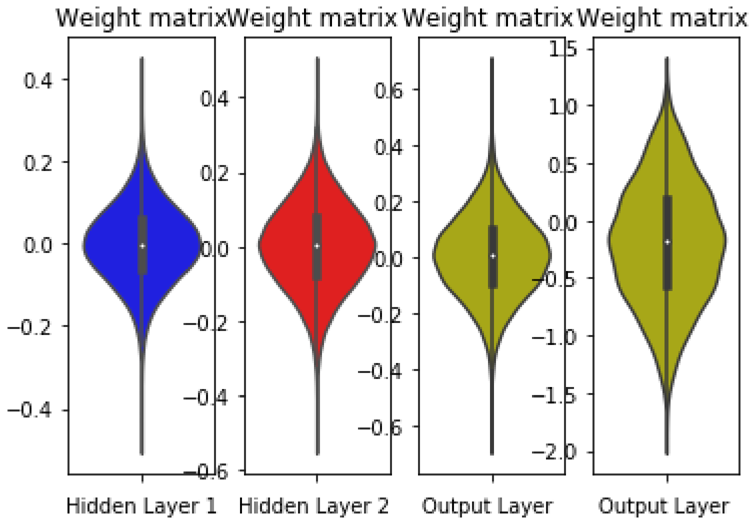
```
+--------------------+---------------------+----------------------+----------+
|       Model        | No of Hidden Layers |     No of Units      | Accuracy |
+--------------------+---------------------+----------------------+----------+
| No BN & No Dropout |          2          |   [784,256,256,10]   |   0.97   |
|  BN & No Dropout   |          2          |   [784,256,256,10]   |   0.98   |
|  No BN & Dropout   |          2          |   [784,256,256,10]   |   0.96   |
|    BN & Dropout    |          2          |   [784,256,256,10]   |   0.97   |
| No BN & No Dropout |          3          | [784,512,256,128,10] |   0.78   |
+--------------------+---------------------+----------------------+----------+
```

In [115]:
```
# With BN and Without Dropout
w,c = run_model()
```

```
Epoch: 0001 train cost=1.551555210 test cost=1.543841784
Epoch: 0002 train cost=1.487830318 test cost=1.488076750
Epoch: 0003 train cost=1.480044753 test cost=1.482815591
Epoch: 0004 train cost=1.475148520 test cost=1.481060569
Epoch: 0005 train cost=1.473546803 test cost=1.480563408
Epoch: 0006 train cost=1.471222049 test cost=1.479159074
Epoch: 0007 train cost=1.470258818 test cost=1.479168120
Epoch: 0008 train cost=1.469298829 test cost=1.478460877
Epoch: 0009 train cost=1.468701959 test cost=1.478745731
Epoch: 0010 train cost=1.467593025 test cost=1.478216683
Epoch: 0011 train cost=1.467463743 test cost=1.478199854
Epoch: 0012 train cost=1.466641587 test cost=1.477163676
Epoch: 0013 train cost=1.466444323 test cost=1.478065499
Epoch: 0014 train cost=1.465809254 test cost=1.477271322
Epoch: 0015 train cost=1.466594505 test cost=1.477898204
Accuracy: 0.9807
```



In [116]:
```
plot_weight(w)
```



In [120]:

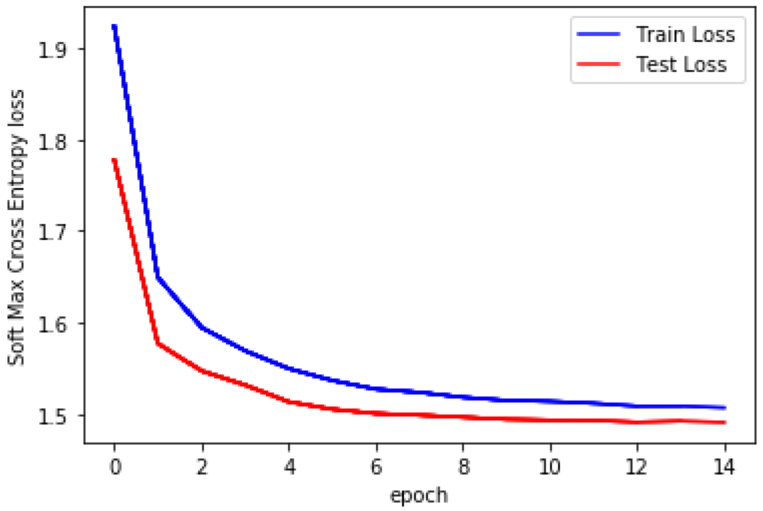
```
# "Model","No of Layers","No of Units","Accuracy"
table.add_row(["BN & No Dropout",3,"[784,512,256,128,10]",0.98])
print(table)
```

```
+-------------------+--------------------+----------------------+----------+
|       Model       | No of Hidden Layers |      No of Units      | Accuracy |
+-------------------+--------------------+----------------------+----------+
| No BN & No Dropout |         2          |   [784,256,256,10]   |   0.97   |
|  BN & No Dropout   |         2          |   [784,256,256,10]   |   0.98   |
|  No BN & Dropout   |         2          |   [784,256,256,10]   |   0.96   |
|    BN & Dropout    |         2          |   [784,256,256,10]   |   0.97   |
| No BN & No Dropout |         3          | [784,512,256,128,10] |   0.78   |
|  BN & No Dropout   |         3          | [784,512,256,128,10] |   0.98   |
+-------------------+--------------------+----------------------+----------+
```

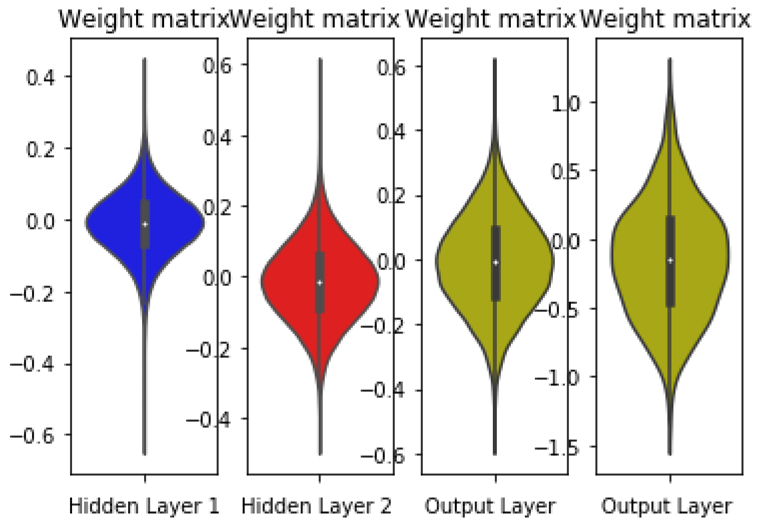
In [128]:

```
w, c = run_model()
```

```
Epoch: 0001 train cost=1.923547436 test cost=1.777374396
Epoch: 0002 train cost=1.649888306 test cost=1.577592450
Epoch: 0003 train cost=1.594784350 test cost=1.547438501
Epoch: 0004 train cost=1.569458596 test cost=1.531973240
Epoch: 0005 train cost=1.550009896 test cost=1.513707142
Epoch: 0006 train cost=1.537074297 test cost=1.505633482
Epoch: 0007 train cost=1.527585533 test cost=1.500962739
Epoch: 0008 train cost=1.524057899 test cost=1.499139460
Epoch: 0009 train cost=1.518706366 test cost=1.496905099
Epoch: 0010 train cost=1.515258675 test cost=1.494631038
Epoch: 0011 train cost=1.514191138 test cost=1.493741981
Epoch: 0012 train cost=1.512068743 test cost=1.493467327
Epoch: 0013 train cost=1.508987658 test cost=1.491482919
Epoch: 0014 train cost=1.509052733 test cost=1.492746291
Epoch: 0015 train cost=1.507254042 test cost=1.491235861
Accuracy: 0.9598
```



In [129]:
```
plot_weight(w)
```

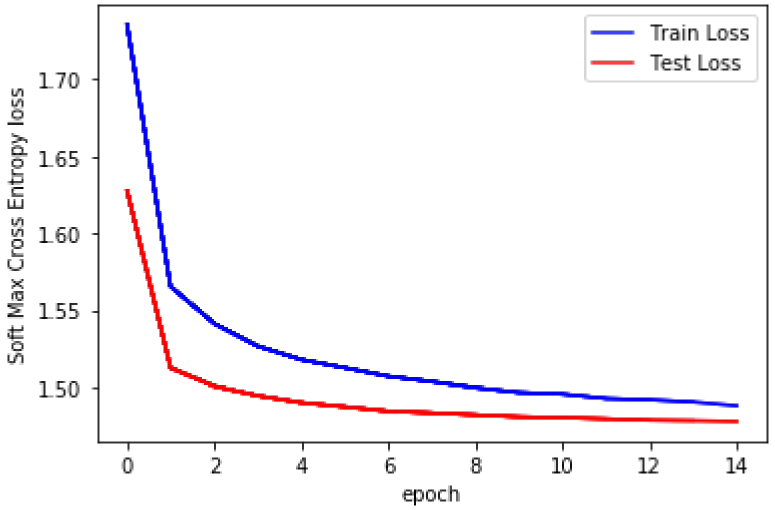


In [130]:
```
# "Model","No of Layers","No of Units","Accuracy"
table.add_row(["No BN & Dropout",3,"[784,512,256,128,10]",0.95])
print(table)
```

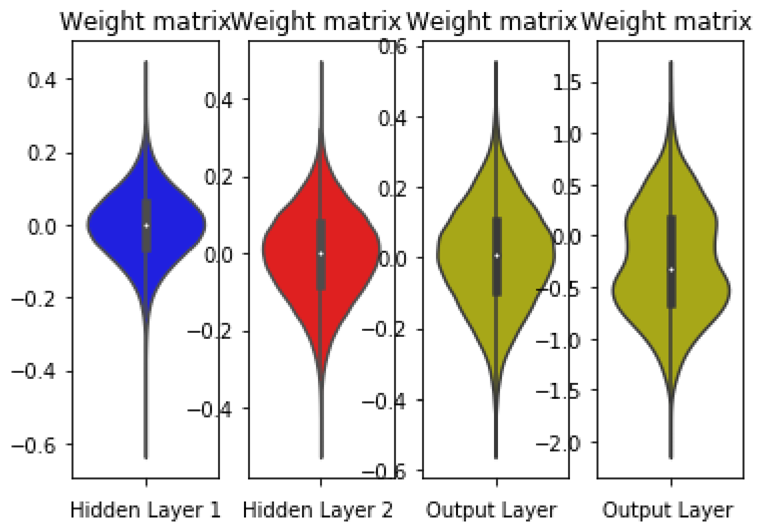
Model	No of Hidden Layers	No of Units	Accuracy
No BN & No Dropout	2	[784,256,256,10]	0.97
BN & No Dropout	2	[784,256,256,10]	0.98
No BN & Dropout	2	[784,256,256,10]	0.96
BN & Dropout	2	[784,256,256,10]	0.97
No BN & No Dropout	3	[784,512,256,128,10]	0.78
BN & No Dropout	3	[784,512,256,128,10]	0.98
No BN & Dropout	3	[784,512,256,128,10]	0.95

In [138]:
```
w,c = run_model()
```

```
Epoch: 0001 train cost=1.735147609 test cost=1.627619583
Epoch: 0002 train cost=1.565496151 test cost=1.512552367
Epoch: 0003 train cost=1.541189906 test cost=1.500751421
Epoch: 0004 train cost=1.526590909 test cost=1.494708527
Epoch: 0005 train cost=1.517893760 test cost=1.490246117
Epoch: 0006 train cost=1.512601304 test cost=1.487560744
Epoch: 0007 train cost=1.507109816 test cost=1.484684251
Epoch: 0008 train cost=1.503703494 test cost=1.483565541
Epoch: 0009 train cost=1.499799664 test cost=1.482330774
Epoch: 0010 train cost=1.496795461 test cost=1.481065884
Epoch: 0011 train cost=1.495785201 test cost=1.480551332
Epoch: 0012 train cost=1.492922471 test cost=1.479732544
Epoch: 0013 train cost=1.492114149 test cost=1.478903759
Epoch: 0014 train cost=1.490680125 test cost=1.478579580
Epoch: 0015 train cost=1.488233277 test cost=1.478082604
Accuracy: 0.9785
```



In [139]:
```
plot_weight(w)
```



In [140]:
```python
# "Model","No of Layers","No of Units","Accuracy"
table.add_row(["BN & Dropout",3,"[784,512,256,128,10]",0.97])
print(table)
```

```
+--------------------+----------------------+----------------------+----------+
|       Model        | No of Hidden Layers |      No of Units      | Accuracy |
+--------------------+----------------------+----------------------+----------+
| No BN & No Dropout |          2          |   [784,256,256,10]    |   0.97   |
|  BN & No Dropout   |          2          |   [784,256,256,10]    |   0.98   |
|  No BN & Dropout   |          2          |   [784,256,256,10]    |   0.96   |
|    BN & Dropout    |          2          |   [784,256,256,10]    |   0.97   |
| No BN & No Dropout |          3          | [784,512,256,128,10] |   0.78   |
|  BN & No Dropout   |          3          | [784,512,256,128,10] |   0.98   |
|  No BN & Dropout   |          3          | [784,512,256,128,10] |   0.95   |
|    BN & Dropout    |          3          | [784,512,256,128,10] |   0.97   |
+--------------------+----------------------+----------------------+----------+
```

In [141]:
```python
# 5 Layer MLP
```

In [49]:
```python
# Network Parameters
n_hidden_1 = 512 # 1st layer number of neurons
n_hidden_2 = 384 # 2nd layer number of neurons
n_hidden_3 = 256 # 3rd layer number of neurons
n_hidden_4 = 128 # 4th layer number of neurons
n_hidden_5 = 64  # 5th layer number of neurons
n_input = 784 # MNIST data input (img shape: 28*28)
n_classes = 10 # MNIST total classes (0-9 digits)
```

In [50]:
```python
x = tf.placeholder(tf.float32, [None, n_input])
y_ = tf.placeholder(tf.float32, [None, n_classes])

keep_prob = tf.placeholder(tf.float32)
keep_prob_input = tf.placeholder(tf.float32)
```

In [51]:
```
# Weight initialization
# He Normal initialization.
weights_relu = {
    'h1': tf.Variable(tf.random_normal([n_input, n_hidden_1],
                            stddev=(2/(n_hidden_1+1))**0.5, mean=0)),

    'h2': tf.Variable(tf.random_normal([n_hidden_1, n_hidden_2],
                            stddev=(2/(n_hidden_2+1))**0.5, mean=0)),

    'h3': tf.Variable(tf.random_normal([n_hidden_2, n_hidden_3],
                            stddev=(2/(n_hidden_3+1))**0.5, mean=0)),

    'h4': tf.Variable(tf.random_normal([n_hidden_3, n_hidden_4],
                            stddev=(2/(n_hidden_4+1))**0.5, mean=0)),

    'h5': tf.Variable(tf.random_normal([n_hidden_4, n_hidden_5],
                            stddev=(2/(n_hidden_5+1))**0.5, mean=0)),

    'out': tf.Variable(tf.random_normal([n_hidden_5, n_classes],
                            stddev=(2/(n_classes+1))**0.5, mean=0))
}

biases = {
    'b1': tf.Variable(tf.random_normal([n_hidden_1])),
    'b2': tf.Variable(tf.random_normal([n_hidden_2])),
    'b3': tf.Variable(tf.random_normal([n_hidden_3])),
    'b4': tf.Variable(tf.random_normal([n_hidden_4])),
    'b5': tf.Variable(tf.random_normal([n_hidden_5])),
    'out': tf.Variable(tf.random_normal([n_classes]))
}
```

In [52]:

```
# Model 3
use_batchNorm, use_dropOut = False, True   # WE have to keep changing these switches
epsilon = 1e-3

print( 'x:', x.get_shape(), 'W[h1]:', weights_relu['h1'].get_shape(),
                              'b[h1]:', biases['b1'].get_shape())

# Hidden layer with Relu activation
layer_1 = tf.add(tf.matmul(x, weights_relu['h1']), biases['b1'])

if use_batchNorm:
    # Calculate the mean and variance of x.
    batch_mean_1, batch_var_1 = tf.nn.moments(layer_1,[0])
    scale_1 = tf.Variable(tf.ones([n_hidden_1]))
    beta_1 = tf.Variable(tf.zeros([n_hidden_1]))
    # https://www.tensorflow.org/api_docs/python/tf/nn/batch_normalization
    layer_1 = tf.nn.batch_normalization(layer_1, batch_mean_1, batch_var_1,
                                        beta_1, scale_1, epsilon)
layer_1 = tf.nn.relu(layer_1)
if use_dropOut:
    layer_1 = tf.nn.dropout(layer_1, keep_prob)

print( 'layer_1:', layer_1.get_shape(), 'W[h2]:', weights_relu['h2'].get_shape(),
                              'b[h2]:', biases['b2'].get_shape())

# Hidden layer with Relu activation
layer_2 = tf.add(tf.matmul(layer_1, weights_relu['h2']), biases['b2'])
if use_batchNorm:
    batch_mean_2, batch_var_2 = tf.nn.moments(layer_2, [0])
    scale_2 = tf.Variable(tf.ones([n_hidden_2]))
    beta_2 = tf.Variable(tf.zeros([n_hidden_2]))
    layer_2 = tf.nn.batch_normalization(layer_2, batch_mean_2, batch_var_2,
                                        beta_2, scale_2, epsilon)

layer_2 = tf.nn.relu(layer_2)
if use_dropOut:
    layer_2 = tf.nn.dropout(layer_2, keep_prob)

print( 'layer_2:', layer_2.get_shape(), 'W[h3]:', weights_relu['h3'].get_shape(),
                              'b[h3]:', biases['b3'].get_shape())

layer_3 = tf.add(tf.matmul(layer_2, weights_relu['h3']), biases['b3'])
if use_batchNorm:
    batch_mean_3, batch_var_3 = tf.nn.moments(layer_3, [0])
    scale_3 = tf.Variable(tf.ones([n_hidden_3]))
    beta_3 = tf.Variable(tf.zeros([n_hidden_3]))
    layer_3 = tf.nn.batch_normalization(layer_3, batch_mean_3, batch_var_3,
                                        beta_3, scale_3, epsilon)

layer_3 = tf.nn.relu(layer_3)
if use_dropOut:
    layer_3 = tf.nn.dropout(layer_3, keep_prob)

print( 'layer_3:', layer_3.get_shape(), 'W[h4]:', weights_relu['h4'].get_shape(),
                              'b[h4]:', biases['b4'].get_shape())

layer_4 = tf.add(tf.matmul(layer_3, weights_relu['h4']), biases['b4'])
if use_batchNorm:
    batch_mean_4, batch_var_4 = tf.nn.moments(layer_4, [0])
    scale_4 = tf.Variable(tf.ones([n_hidden_4]))
    beta_4 = tf.Variable(tf.zeros([n_hidden_4]))
    layer_4 = tf.nn.batch_normalization(layer_4, batch_mean_4, batch_var_4,
                                        beta_4, scale_4, epsilon)

layer_4 = tf.nn.relu(layer_4)
```

```python
if use_dropOut:
    layer_4 = tf.nn.dropout(layer_4, keep_prob)

print( 'layer_4:', layer_4.get_shape(), 'W[h5]:', weights_relu['h5'].get_shape(),
                              'b[h5]:', biases['b5'].get_shape())

layer_5 = tf.add(tf.matmul(layer_4, weights_relu['h5']), biases['b5'])
if use_batchNorm:
    batch_mean_5, batch_var_5 = tf.nn.moments(layer_5, [0])
    scale_5 = tf.Variable(tf.ones([n_hidden_5]))
    beta_5 = tf.Variable(tf.zeros([n_hidden_5]))
    layer_5 = tf.nn.batch_normalization(layer_5, batch_mean_5, batch_var_5,
                                        beta_5, scale_5, epsilon)

layer_5 = tf.nn.relu(layer_5)
if use_dropOut:
    layer_5 = tf.nn.dropout(layer_5, keep_prob)

print( 'layer_5:', layer_5.get_shape(), 'W[out]:', weights_relu['out'].get_shape(),
                              'b[h5]:', biases['out'].get_shape())

# Output layer with Sigmoid activation
out_layer = tf.matmul(layer_5, weights_relu['out']) + biases['out']
out_layer = tf.nn.sigmoid(out_layer)
print('out_layer:',out_layer.get_shape())
```

```
x: (?, 784) W[h1]: (784, 512) b[h1]: (512,)
layer_1: (?, 512) W[h2]: (512, 384) b[h2]: (384,)
layer_2: (?, 384) W[h3]: (384, 256) b[h3]: (256,)
layer_3: (?, 256) W[h4]: (256, 128) b[h4]: (128,)
layer_4: (?, 128) W[h5]: (128, 64) b[h5]: (64,)
layer_5: (?, 64) W[out]: (64, 10) b[h5]: (10,)
out_layer: (?, 10)
```

In [53]:

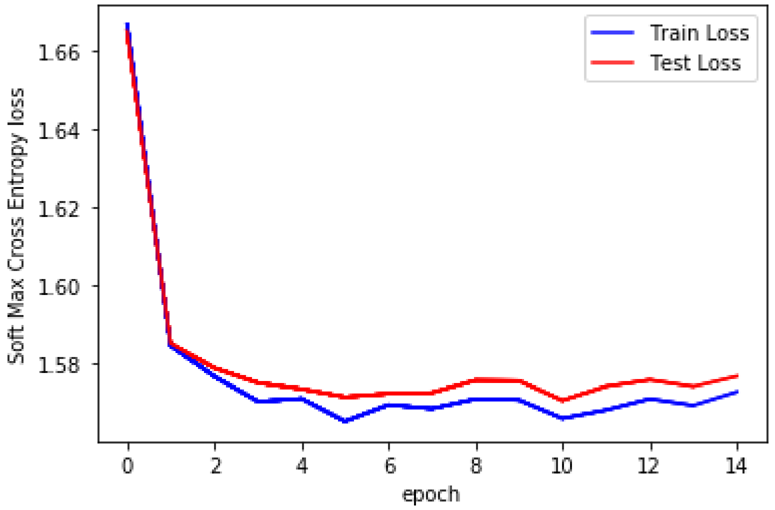
```python
# set up cost and optimizer

cost_sgd = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(logits = out_layer, labels = y_))
optimizer_adam = tf.train.AdamOptimizer(learning_rate=learning_rate).minimize(cost_sgd)
```

In [54]:
```python
def run_model():
    with tf.Session() as sess:
        tf.global_variables_initializer().run()
        fig,ax = plt.subplots(1,1)
        ax.set_xlabel('epoch') ; ax.set_ylabel('Soft Max Cross Entropy loss')
        xs, ytrs, ytes = [], [], []
        for epoch in range(training_epochs):
            train_avg_cost = 0.
            test_avg_cost = 0.
            total_batch = int(mnist_data.train.num_examples/batch_size)

            # Loop over all batches
            for i in range(total_batch):
                batch_xs, batch_ys = mnist_data.train.next_batch(batch_size)

                # here we use AdamOptimizer
                _, c, w = sess.run([optimizer_adam, cost_sgd,weights_relu],
                                   feed_dict={x: batch_xs, y_: batch_ys, keep_prob: 0.5})
                train_avg_cost += c / total_batch
                c = sess.run(cost_sgd, feed_dict={x: mnist_data.test.images,
                                              y_: mnist_data.test.labels,  keep_prob: 1.0})
                test_avg_cost += c / total_batch

            xs.append(epoch)
            ytrs.append(train_avg_cost)
            ytes.append(test_avg_cost)
            plt_dynamic(xs, ytrs, ytes, ax, np.arange(1.3, 1.8, step=0.04),fig,
                "input-relu(512)-relu(384)-relu(256)-relu(128)-relu(64)-sigmoid(output)-AdamOptimizer")

            if epoch%display_step == 0:
                print("Epoch:", '%04d' % (epoch+1), "train cost={:.9f}".format(train_avg_cost),
                                                  "test cost={:.9f}".format(test_avg_cost))
        plt_dynamic(xs, ytrs, ytes, ax, np.arange(1.3, 1.8, step=0.04),fig,
                "input-relu(512)-relu(384)-relu(256)-relu(128)-relu(64)-sigmoid(output)-AdamOptimizer")

        # we are calculating the final accuracy on the test data
        correct_prediction = tf.equal(tf.argmax(out_layer,1), tf.argmax(y_,1))
        accuracy = tf.reduce_mean(tf.cast(correct_prediction, tf.float32))
        print("Accuracy:", accuracy.eval({x: mnist_data.test.images,
                                          y_: mnist_data.test.labels, keep_prob: 1.0}))
        return w, c
```

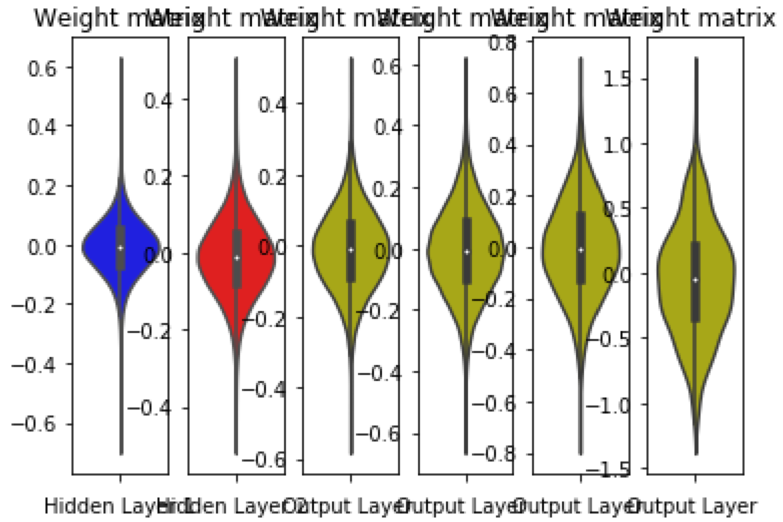
In [55]:
```
def plot_weight(w):
    # Plot weight distriubtion at the end of training.
    h1_w = w['h1'].flatten().reshape(-1,1)
    h2_w = w['h2'].flatten().reshape(-1,1)
    h3_w = w['h3'].flatten().reshape(-1,1)
    h4_w = w['h4'].flatten().reshape(-1,1)
    h5_w = w['h5'].flatten().reshape(-1,1)
    out_w = w['out'].flatten().reshape(-1,1)

    fig = plt.figure()
    plt.subplot(1, 6, 1)
    plt.title("Weight matrix")
    ax = sns.violinplot(y=h1_w,color='b')
    plt.xlabel('Hidden Layer 1')

    plt.subplot(1, 6, 2)
    plt.title("Weight matrix ")
    ax = sns.violinplot(y=h2_w, color='r')
    plt.xlabel('Hidden Layer 2 ')

    plt.subplot(1, 6, 3)
    plt.title("Weight matrix ")
    ax = sns.violinplot(y=h3_w,color='y')
    plt.xlabel('Output Layer ')

    plt.subplot(1, 6, 4)
    plt.title("Weight matrix ")
    ax = sns.violinplot(y=h4_w,color='y')
    plt.xlabel('Output Layer ')

    plt.subplot(1, 6, 5)
    plt.title("Weight matrix ")
    ax = sns.violinplot(y=h5_w,color='y')
    plt.xlabel('Output Layer ')

    plt.subplot(1, 6, 6)
    plt.title("Weight matrix ")
    ax = sns.violinplot(y=out_w,color='y')
    plt.xlabel('Output Layer ')
    plt.show()
```

In [153]:
```
# Without BN and Without Dropout
w,c = run_model()
```

```
Epoch: 0001 train cost=1.666388924 test cost=1.664768569
Epoch: 0002 train cost=1.584407962 test cost=1.584915396
Epoch: 0003 train cost=1.576518192 test cost=1.578678144
Epoch: 0004 train cost=1.570174091 test cost=1.574943084
Epoch: 0005 train cost=1.570907821 test cost=1.573335734
Epoch: 0006 train cost=1.565126382 test cost=1.571309181
Epoch: 0007 train cost=1.569327874 test cost=1.572164182
Epoch: 0008 train cost=1.568363352 test cost=1.572397860
Epoch: 0009 train cost=1.570808167 test cost=1.575564265
Epoch: 0010 train cost=1.570558932 test cost=1.575461745
Epoch: 0011 train cost=1.565854115 test cost=1.570420797
Epoch: 0012 train cost=1.568019303 test cost=1.574033220
Epoch: 0013 train cost=1.570836614 test cost=1.575691985
Epoch: 0014 train cost=1.569169731 test cost=1.573997481
Epoch: 0015 train cost=1.572603820 test cost=1.576607630
Accuracy: 0.8584
```



In [154]:
```
plot_weight(w)
```

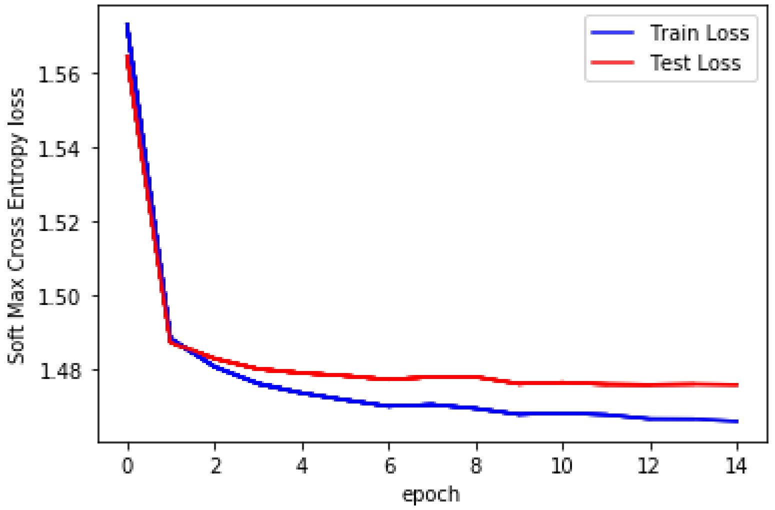


In [155]:
```
# "Model","No of Layers","No of Units","Accuracy"
table.add_row(["No BN & No Dropout",5,"[784,384,512,256,128,64,10]",0.85])
print(table)
```

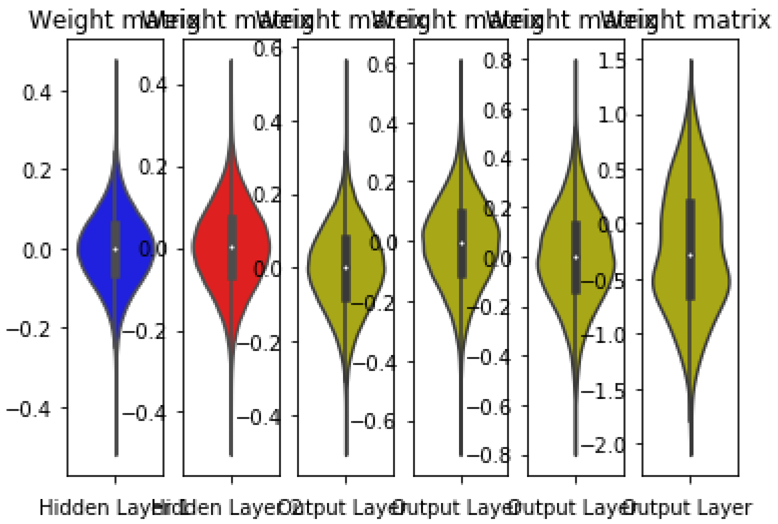
```
+--------------------+---------------------+-----------------------------+----------+
|       Model        | No of Hidden Layers |         No of Units         | Accuracy |
+--------------------+---------------------+-----------------------------+----------+
| No BN & No Dropout |          2          |       [784,256,256,10]      |   0.97   |
|  BN & No Dropout   |          2          |       [784,256,256,10]      |   0.98   |
|  No BN & Dropout   |          2          |       [784,256,256,10]      |   0.96   |
|    BN & Dropout    |          2          |       [784,256,256,10]      |   0.97   |
| No BN & No Dropout |          3          |     [784,512,256,128,10]    |   0.78   |
|  BN & No Dropout   |          3          |     [784,512,256,128,10]    |   0.98   |
|  No BN & Dropout   |          3          |     [784,512,256,128,10]    |   0.95   |
|    BN & Dropout    |          3          |     [784,512,256,128,10]    |   0.97   |
| No BN & No Dropout |          5          | [784,384,512,256,128,64,10] |   0.85   |
+--------------------+---------------------+-----------------------------+----------+
```

In [163]:
```
# With BN and Without Dropout
w,c = run_model()
```

```
Epoch: 0001 train cost=1.572831467 test cost=1.564109642
Epoch: 0002 train cost=1.488379573 test cost=1.487347141
Epoch: 0003 train cost=1.480788367 test cost=1.482998726
Epoch: 0004 train cost=1.476273555 test cost=1.480205759
Epoch: 0005 train cost=1.473853672 test cost=1.479110637
Epoch: 0006 train cost=1.471989698 test cost=1.478369296
Epoch: 0007 train cost=1.470287845 test cost=1.477342008
Epoch: 0008 train cost=1.470725852 test cost=1.478051731
Epoch: 0009 train cost=1.469680078 test cost=1.478038399
Epoch: 0010 train cost=1.468082133 test cost=1.476221145
Epoch: 0011 train cost=1.468418921 test cost=1.476566579
Epoch: 0012 train cost=1.467979412 test cost=1.476099741
Epoch: 0013 train cost=1.466876512 test cost=1.475988147
Epoch: 0014 train cost=1.466847590 test cost=1.476136869
Epoch: 0015 train cost=1.466201833 test cost=1.475974899
Accuracy: 0.9822
```



In [164]:
```
plot_weight(w)
```

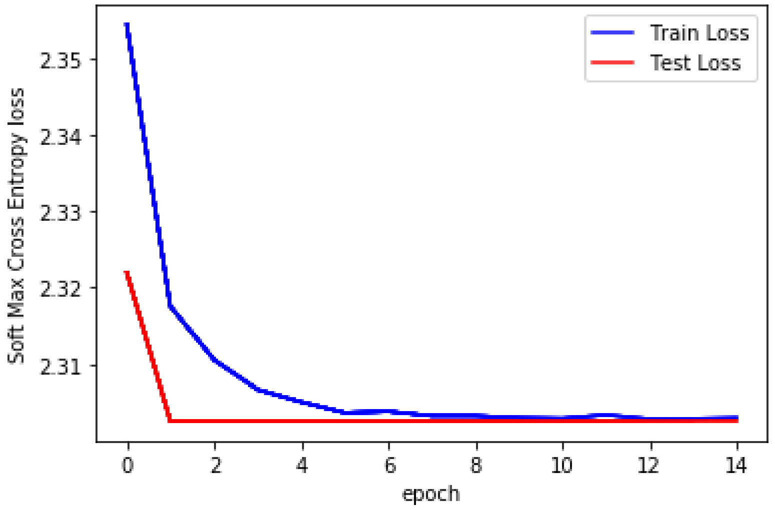


In [165]:
```
# "Model","No of Layers","No of Units","Accuracy"
table.add_row(["BN & No Dropout",5,"[784,384,512,256,128,64,10]",0.98])
print(table)
```

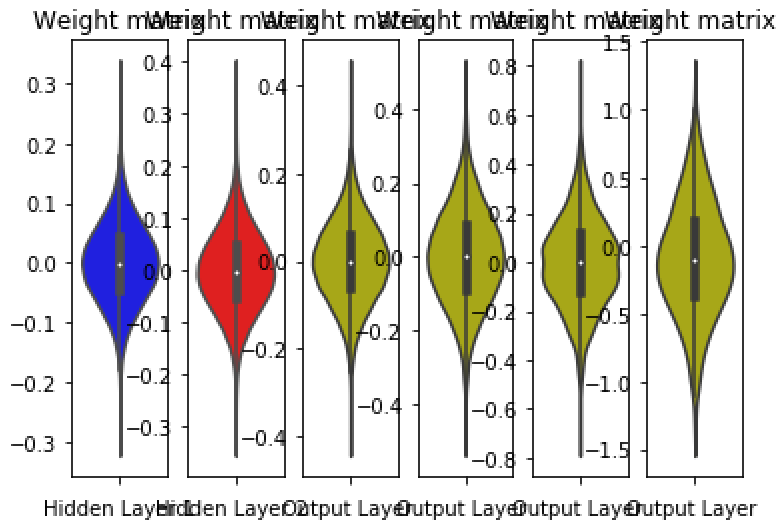
```
+--------------------+--------------------+-----------------------------+----------+
|       Model        | No of Hidden Layers |         No of Units         | Accuracy |
+--------------------+--------------------+-----------------------------+----------+
| No BN & No Dropout |          2          |       [784,256,256,10]      |   0.97   |
|  BN & No Dropout   |          2          |       [784,256,256,10]      |   0.98   |
|  No BN & Dropout   |          2          |       [784,256,256,10]      |   0.96   |
|    BN & Dropout    |          2          |       [784,256,256,10]      |   0.97   |
| No BN & No Dropout |          3          |     [784,512,256,128,10]    |   0.78   |
|  BN & No Dropout   |          3          |     [784,512,256,128,10]    |   0.98   |
|  No BN & Dropout   |          3          |     [784,512,256,128,10]    |   0.95   |
|    BN & Dropout    |          3          |     [784,512,256,128,10]    |   0.97   |
| No BN & No Dropout |          5          | [784,384,512,256,128,64,10] |   0.85   |
|  BN & No Dropout   |          5          | [784,384,512,256,128,64,10] |   0.98   |
+--------------------+--------------------+-----------------------------+----------+
```

In [56]:
```
# No BN and With Dropout
w,c = run_model()
```

```
Epoch: 0001 train cost=2.354361770 test cost=2.321973105
Epoch: 0002 train cost=2.317582014 test cost=2.302601576
Epoch: 0003 train cost=2.310513624 test cost=2.302601576
Epoch: 0004 train cost=2.306676997 test cost=2.302601576
Epoch: 0005 train cost=2.305071158 test cost=2.302601576
Epoch: 0006 train cost=2.303673732 test cost=2.302601576
Epoch: 0007 train cost=2.303841054 test cost=2.302601576
Epoch: 0008 train cost=2.303264282 test cost=2.302601576
Epoch: 0009 train cost=2.303260448 test cost=2.302601576
Epoch: 0010 train cost=2.302998356 test cost=2.302601576
Epoch: 0011 train cost=2.302923910 test cost=2.302601576
Epoch: 0012 train cost=2.303382092 test cost=2.302601576
Epoch: 0013 train cost=2.302851424 test cost=2.302601576
Epoch: 0014 train cost=2.302882841 test cost=2.302601576
Epoch: 0015 train cost=2.303055505 test cost=2.302601576
Accuracy: 0.098
```



In [17]:
```
plot_weight(w)
```

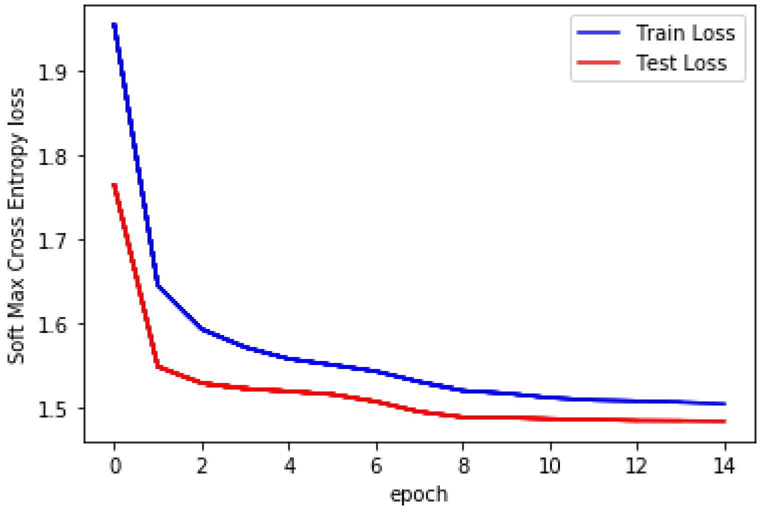


In [29]:
```
# "Model","No of Layers","No of Units","Accuracy"
table.add_row(["No BN & Dropout",5,"[784,384,512,256,128,64,10]",0.098])
print(table)
```

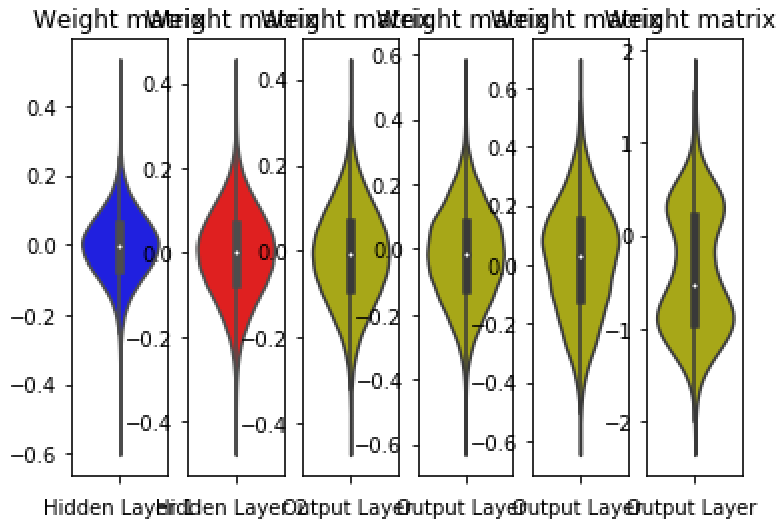
Model	No of Hidden Layers	No of Units	Accuracy
No BN & No Dropout	2	[784,256,256,10]	0.97
BN & No Dropout	2	[784,256,256,10]	0.98
No BN & Dropout	2	[784,256,256,10]	0.96
BN & Dropout	2	[784,256,256,10]	0.97
No BN & No Dropout	3	[784,512,256,128,10]	0.78
BN & No Dropout	3	[784,512,256,128,10]	0.98
No BN & Dropout	3	[784,512,256,128,10]	0.95
BN & Dropout	3	[784,512,256,128,10]	0.97
No BN & No Dropout	5	[784,384,512,256,128,64,10]	0.85
BN & No Dropout	5	[784,384,512,256,128,64,10]	0.98
No BN & Dropout	5	[784,384,512,256,128,64,10]	0.098

In [37]:
```
# With BN and With Dropout
w,c = run_model()
```

```
Epoch: 0001 train cost=1.954594129 test cost=1.764196298
Epoch: 0002 train cost=1.644420621 test cost=1.547594223
Epoch: 0003 train cost=1.592272512 test cost=1.527866930
Epoch: 0004 train cost=1.570611747 test cost=1.521848925
Epoch: 0005 train cost=1.556867586 test cost=1.518750438
Epoch: 0006 train cost=1.549666221 test cost=1.515069666
Epoch: 0007 train cost=1.542048534 test cost=1.506556306
Epoch: 0008 train cost=1.529550910 test cost=1.494383340
Epoch: 0009 train cost=1.519507929 test cost=1.487945196
Epoch: 0010 train cost=1.516298204 test cost=1.487287529
Epoch: 0011 train cost=1.511072840 test cost=1.485856568
Epoch: 0012 train cost=1.508224884 test cost=1.485102043
Epoch: 0013 train cost=1.507137326 test cost=1.483881110
Epoch: 0014 train cost=1.505805542 test cost=1.483576352
Epoch: 0015 train cost=1.503525722 test cost=1.482891660
Accuracy: 0.975
```



In [38]:
```
plot_weight(w)
```



In [39]:
```
# "Model","No of Layers","No of Units","Accuracy"
table.add_row(["BN & Dropout",5,"[784,384,512,256,128,64,10]",0.97])
print(table)
```

```
+--------------------+--------------------+----------------------------+----------+
|       Model        | No of Hidden Layers |         No of Units        | Accuracy |
+--------------------+--------------------+----------------------------+----------+
| No BN & No Dropout |          2          |       [784,256,256,10]      |   0.97   |
|  BN & No Dropout   |          2          |       [784,256,256,10]      |   0.98   |
|  No BN & Dropout   |          2          |       [784,256,256,10]      |   0.96   |
|    BN & Dropout    |          2          |       [784,256,256,10]      |   0.97   |
| No BN & No Dropout |          3          |     [784,512,256,128,10]    |   0.78   |
|  BN & No Dropout   |          3          |     [784,512,256,128,10]    |   0.98   |
|  No BN & Dropout   |          3          |     [784,512,256,128,10]    |   0.95   |
|    BN & Dropout    |          3          |     [784,512,256,128,10]    |   0.97   |
| No BN & No Dropout |          5          | [784,384,512,256,128,64,10] |   0.85   |
|  BN & No Dropout   |          5          | [784,384,512,256,128,64,10] |   0.98   |
|  No BN & Dropout   |          5          | [784,384,512,256,128,64,10] |  0.098   |
|    BN & Dropout    |          5          | [784,384,512,256,128,64,10] |   0.97   |
+--------------------+--------------------+----------------------------+----------+
```

In [57]:
```
# Conclusions
```

1. We tried many various types of model architectures 2. Overall we find that using batch normalisation and dropouts generally improve the model performance 3. we also find that increasing the number of hidden layers may not be as important in improving the model performance

In [ ]: