Predicting Electromyography (EMG) Signal for Gesture Recognition

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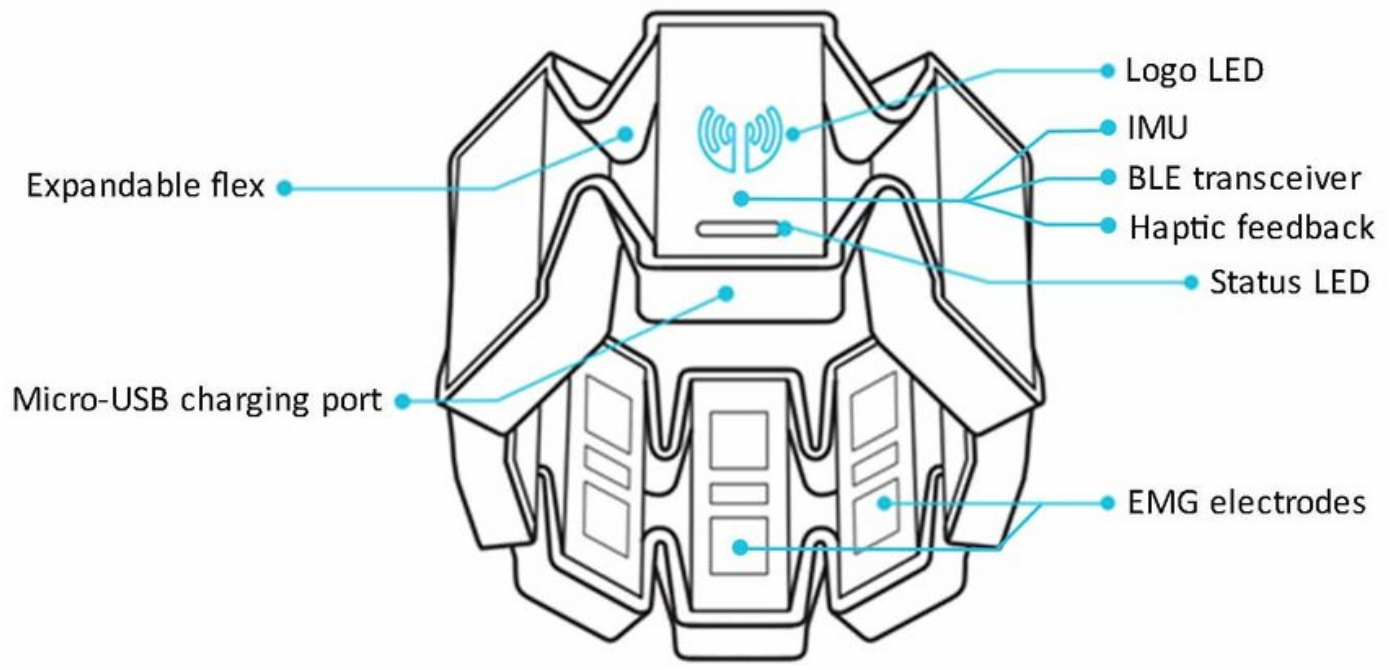
1.Intoduction/Precise problem statement

For recording patterns, we used a MYO Thalmic bracelet worn on a user’s forearm, and a PC with a Bluetooth receiver. The bracelet is equipped with eight sensors equally spaced around the forearm that simultaneously acquire myographic signals. The signals are sent through a Bluetooth interface to a PC.



2.Experiment

The files of raw EMG data recorded by MYO Thalmic bracelet from Center for Machine Learning and Intelligent Systems -University of California, Irvine (UCI) (https://archive.ics.uci.edu/ml/datasets/EMG+data+for+gestures), but the data of this project are imported by Kaggle,EMG Signal for gesture recognition (https://www.kaggle.com/datasets/sojanprajapati/emg-signal-for-gesture-recognition), which are ready for analysis.

Data Set Characteristics:	Time-Series	**Number of Instances:**	30000	**Area:**	Life
Attribute Characteristics:	Real	**Number of Attributes:**	6	**Date Donated**	2019-01-07
Associated Tasks:	Classification	**Missing Values?**	N/A	**Number of Web Hits:**	76800

We present EMG data for 36 subjects while they performed series of static hand gestures.The subject performs two series, each of which consists of six (seven) basic gestures. Each gesture was performed for 3 seconds with a pause of 3 seconds between gestures. The file of data consist of 11 columns:

Column 1: Time - time in ms

Column 2-9: Channel - eight EMG channels of MYO Thalmic bracelet

Column 10: Class – the label of gestures:

0 - unmarked data, 1 - hand at rest, 2 - hand clenched in a fist, 3 - wrist flexion, 4 – wrist extension, 5 – radial deviations, 6 - ulnar deviations, 7 - extended palm (the gesture was not performed by all subjects).

> Column 11: Label - refers to the subject who performed the experiment. There were 36 subjects, each performed 7 gestures twice.

In [1]:

```
#Importing Libraries
import pandas as pd
import seaborn as sns
import numpy as np
import matplotlib.pyplot as plt
from matplotlib import rc
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import train_test_split
from sklearn.neighbors import KNeighborsClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import classification_report,confusion_matrix,roc_curve
from sklearn.metrics import accuracy_score
```

In [2]:

```
#Importing the data
df=pd.read_csv('EMG-data.csv')
df
```

Out[2]:

	time	channel1	channel2	channel3	channel4	channel5	channel6	channel7	chan
0	1	0.00001	-0.00002	-0.00001	-0.00003	0.00000	-0.00001	0.00000	-0.00
1	5	0.00001	-0.00002	-0.00001	-0.00003	0.00000	-0.00001	0.00000	-0.00
2	6	-0.00001	0.00001	0.00002	0.00000	0.00001	-0.00002	-0.00001	0.00
3	7	-0.00001	0.00001	0.00002	0.00000	0.00001	-0.00002	-0.00001	0.00
4	8	-0.00001	0.00001	0.00002	0.00000	0.00001	-0.00002	-0.00001	0.00
...	...	...	...	...	...	...	...	...	
4237902	50962	0.00001	-0.00001	-0.00002	-0.00004	-0.00012	0.00000	0.00002	0.00
4237903	50963	0.00001	-0.00001	-0.00002	-0.00004	-0.00012	0.00000	0.00002	0.00
4237904	50964	0.00001	-0.00001	-0.00002	-0.00004	-0.00012	0.00000	0.00002	0.00
4237905	50965	0.00001	-0.00001	-0.00002	-0.00004	-0.00012	0.00000	0.00002	0.00
4237906	50966	0.00001	-0.00001	-0.00002	-0.00004	-0.00012	0.00000	0.00002	0.00

4237907 rows × 11 columns

At the "filtered_df" is created the new data set without the unmarked data (class = 0)

In [3]:

```
filtered_df=df[df['class']!=0]
filtered_df
```

Out[3]:

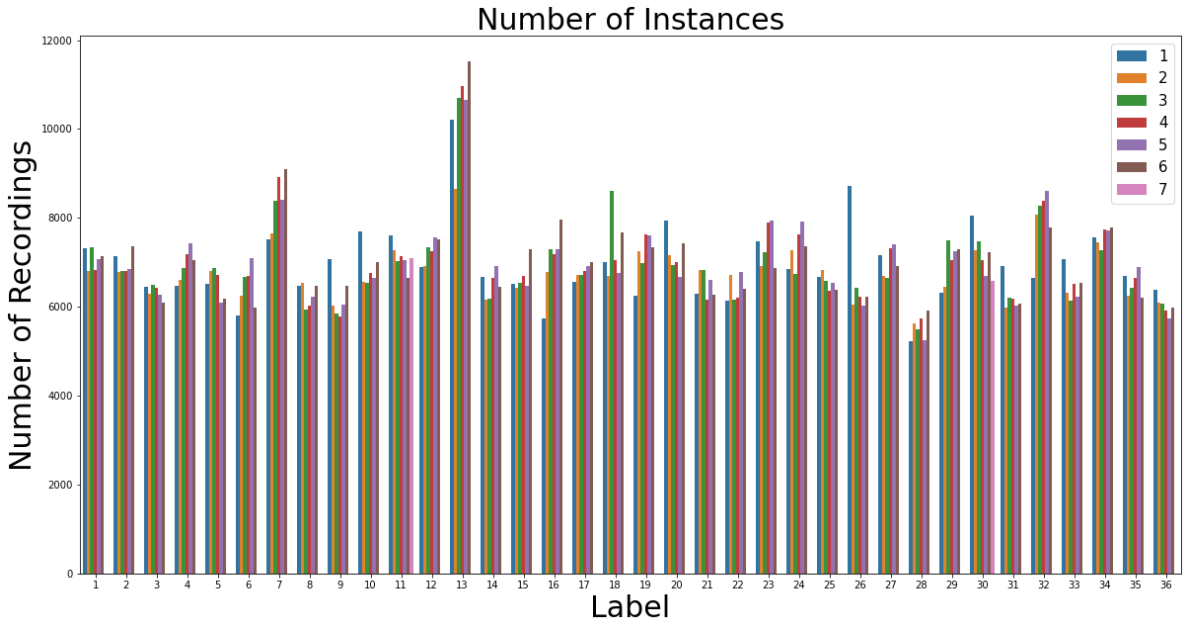
	time	channel1	channel2	channel3	channel4	channel5	channel6	channel7	chan
2287	2400	-0.00001	0.00000	-0.00001	0.00000	0.00000	-0.00001	-0.00001	0.00
2288	2401	-0.00001	-0.00002	0.00000	-0.00001	-0.00001	-0.00001	-0.00003	-0.00
2289	2402	-0.00001	-0.00002	0.00000	-0.00001	-0.00001	-0.00001	-0.00003	-0.00
2290	2403	-0.00001	-0.00002	0.00000	-0.00001	-0.00001	-0.00001	-0.00003	-0.00
2291	2404	-0.00001	-0.00002	0.00000	-0.00001	-0.00001	-0.00001	-0.00003	-0.00
...	...	...	...	...	...	...	...	...	
4237207	50226	0.00009	0.00001	0.00003	0.00001	-0.00003	-0.00008	0.00004	0.00
4237208	50227	0.00009	0.00001	0.00003	0.00001	-0.00003	-0.00008	0.00004	0.00
4237209	50228	0.00009	0.00001	0.00003	0.00001	-0.00003	-0.00008	0.00004	0.00
4237210	50229	0.00014	0.00003	-0.00001	0.00001	-0.00012	0.00006	-0.00007	-0.00
4237211	50230	0.00014	0.00003	-0.00001	0.00001	-0.00012	0.00006	-0.00007	-0.00

1512750 rows × 11 columns

The new number of instances

In [4]:

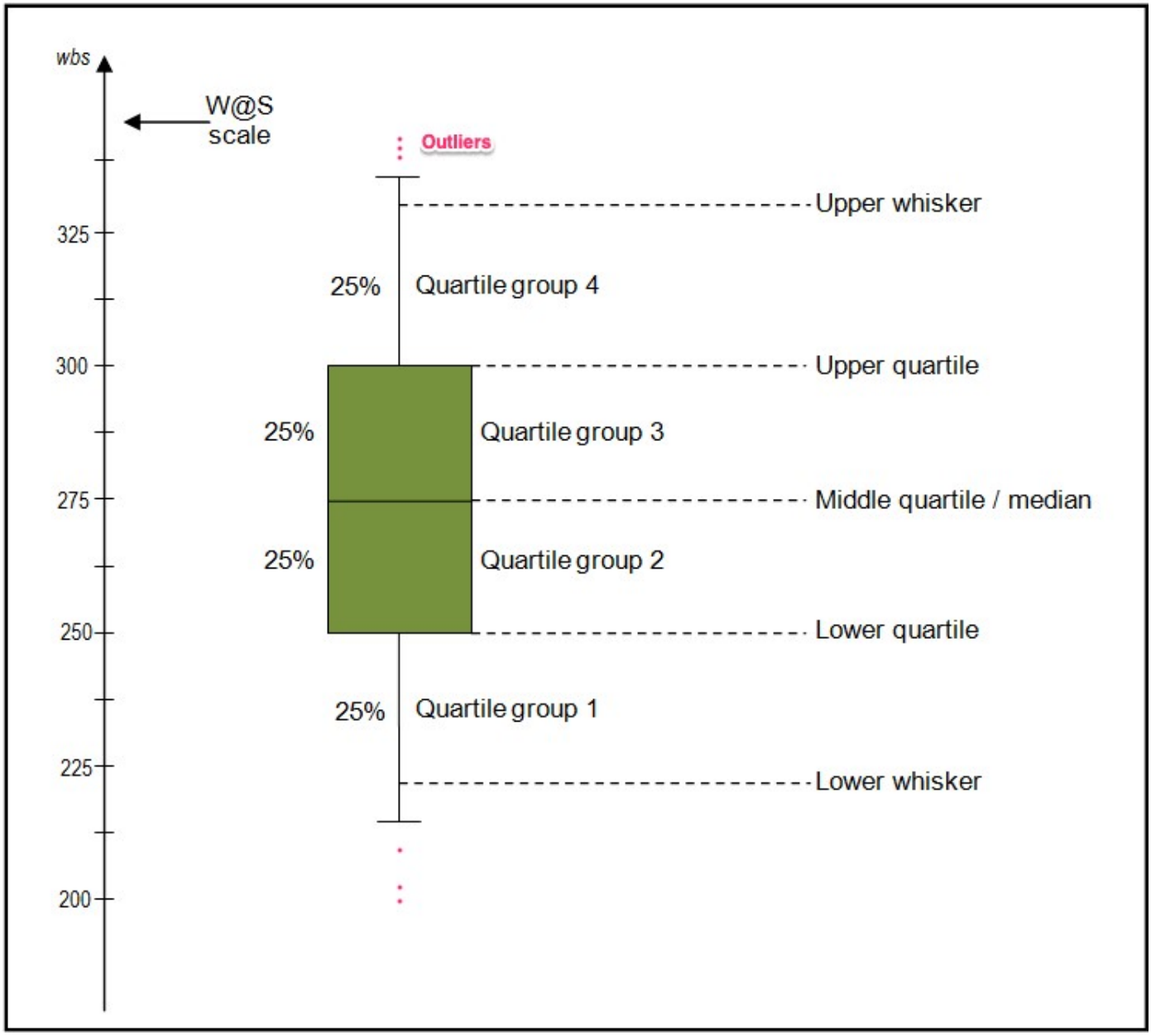
```
plt.figure(figsize=(20,10))
sns.countplot(x='label', hue='class', data=filtered_df)

# Add legend
plt.legend(fontsize=15)

# Add title
plt.title("Number of Instances",fontsize=30)

# # Add labels
plt.xlabel("Label",fontsize=30)
plt.ylabel("Number of Recordings",fontsize=30)

plt.show()
```



3.Data Analysis

3.1 Boxplots

Boxplots are used to show the distribution of categorical data. A box plot (or box-and-whisker plot) shows the distribution of quantitative data in a way that facilitates comparisons between variables or across levels of a categorical variable. The box shows the quartiles of the dataset while the whiskers extend to show the rest of the distribution, except for points that are determined to be “outliers” using a method that is a function of the inter-quartile range. To be more specific Box plot is a method which graphically show the spread of a numerical variable through quartiles.



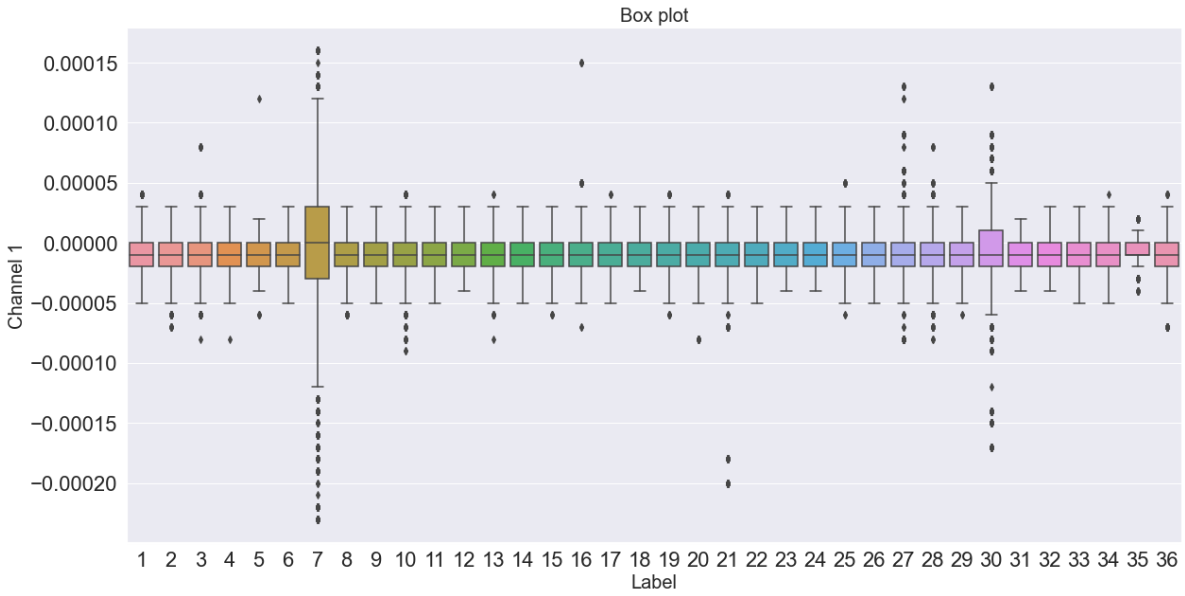
The first step of present analysis is about the box plots between channels and labels. Indicatively, is presented the box plot of channel 1, while the box plots of other channels are demonstrated to the Appendix chapter.

Even if the data have been cleaned, the box plot shows that there are plenty of outliers, especially for the the 7th label. The 7th label demonstrate a lot more outliers and more extended compared to other labels. The modeling could be optimized by removing the outliers of all labels or the 7th label.

A hypothesis is made that the outliers of our data will not impact the performance of the machine learning models that will be used in this project

In [5]:

```
class1=df[df['class']==1] # matrix with the class=1
plt.figure(figsize=(20,10))
sns.set(font_scale=2)
sns.boxplot(x='label',y='channel1',data=class1)
plt.xlabel('Label',fontsize=20)
plt.ylabel('Channel 1',fontsize=20)
plt.title('Box plot',fontsize=20)
plt.show()
```



Below, it is demonstrated more information about the data of class 1.

In [6]:

```
class1.describe()
```

Out[6]:

	time	channel1	channel2	channel3	channel4	chann
count	250055.000000	250055.000000	250055.000000	250055.000000	250055.000000	250055.000(
mean	17544.549507	-0.000008	-0.000010	-0.000010	-0.000009	-0.000(
std	15818.264801	0.000017	0.000024	0.000044	0.000044	0.000(
min	1.000000	-0.000230	-0.000840	-0.000670	-0.000600	-0.001
25%	2320.000000	-0.000020	-0.000020	-0.000030	-0.000030	-0.000(
50%	4338.000000	-0.000010	-0.000010	-0.000010	-0.000010	-0.000(
75%	33267.000000	0.000000	0.000000	0.000010	0.000010	0.000(
max	45596.000000	0.000160	0.000320	0.000550	0.000770	0.001

In case that the model need to be optimized, the code below will be used to remove the outliers. Especially, the outliers of 7th label (std=0.000017) have the most significant impact on the models' accuracy.

In [7]:

```
outliers_of_class1_ch1=class1[(class1['channel1']>0.000017)|(class1['channel1']<-0.000017)]
outliers_of_class1_ch1[outliers_of_class1_ch1['label']==7]
```

Out[7]:

	time	channel1	channel2	channel3	channel4	channel5	channel6	channel7	chann
686394	2064	0.00006	0.00002	-0.00002	-0.00006	-0.00010	-0.00001	0.00002	0.000
686395	2065	0.00006	0.00002	-0.00002	-0.00006	-0.00010	-0.00001	0.00002	0.000
686396	2066	0.00006	0.00002	-0.00002	-0.00006	-0.00010	-0.00001	0.00002	0.000
686397	2067	0.00006	0.00002	-0.00002	-0.00006	-0.00010	-0.00001	0.00002	0.000
686398	2068	0.00006	0.00002	-0.00002	-0.00006	-0.00010	-0.00001	0.00002	0.000
...	...	...	...	...	...	...	...	...	
787975	35854	-0.00008	-0.00003	0.00003	0.00019	0.00037	0.00001	0.00000	-0.000
787976	35855	-0.00008	-0.00003	0.00003	0.00019	0.00037	0.00001	0.00000	-0.000
787977	35856	-0.00008	-0.00003	0.00003	0.00019	0.00037	0.00001	0.00000	-0.000
787978	35857	-0.00008	-0.00003	0.00003	0.00019	0.00037	0.00001	0.00000	-0.000
787979	35858	-0.00008	-0.00003	0.00003	0.00019	0.00037	0.00001	0.00000	-0.000

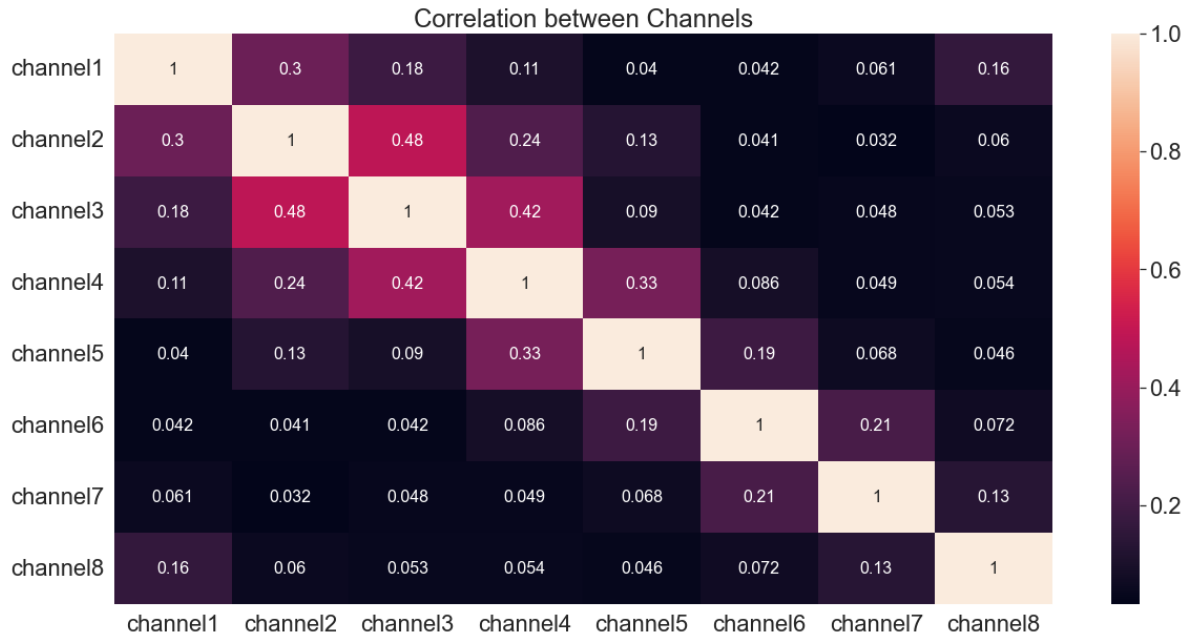
5333 rows × 11 columns

3.2 Heatmaps

A heatmap is a two-dimensional graphical representation of data where the individual values that are contained in a matrix are represented as colours. The heatmap below represent the correlation between channels. It is observed below that there is no significant correlation between the channels of class 1. The heatmaps of other classes are demonstrated to the Appendix chapter.

In [8]:

```
plt.figure(figsize=(20,10))
sns.heatmap(df[df['class']==1].drop(columns=['time','label','class']).corr(),annot=True,
            annot_kws={"size": 16})
sns.set(font_scale=2)
plt.title('Correlation between Channels')
plt.show()
```



4.Normalizing the Data

In order to apply the machine learning algorithms of 5th chapter, the data should be normalized.

In [9]:

```
df1=df.drop(columns=['time','label'])
df1=df[df['class']!=0]
```

In [10]:

```
scaler = StandardScaler()
scaler.fit(df1.drop('class',axis=1))
scaled_features = scaler.transform(df1.drop('class',axis=1))
```

5.Experimental Results/Machine Learning Algorithms

SPLITTING DATA TO 70% TRAIN & 30% TEST

In [11]:

```
X = df1.drop(columns='class',axis=1)
y = df1['class']
X_train, X_test, y_train, y_test = train_test_split(scaled_features,df1['class'],
                                                    test_size=0.30)
```

5.1 Logistic Regression Model

Logistic Regression is a machine learning method used for Binary Classification. Consequently, a low value of accuracy is expected.

In [12]:

```
LR = LogisticRegression()
LR_fit = LR.fit(X_train, y_train)
LR_pred = LR_fit.predict(X_test)
print("Logistic Regression is %f percent accurate" % (accuracy_score(LR_pred, y_test)*100))
```

```
Logistic Regression is 17.663196 percent accurate
```

5.2 K Nearest Neighbors (KNN) CLASSIFIER

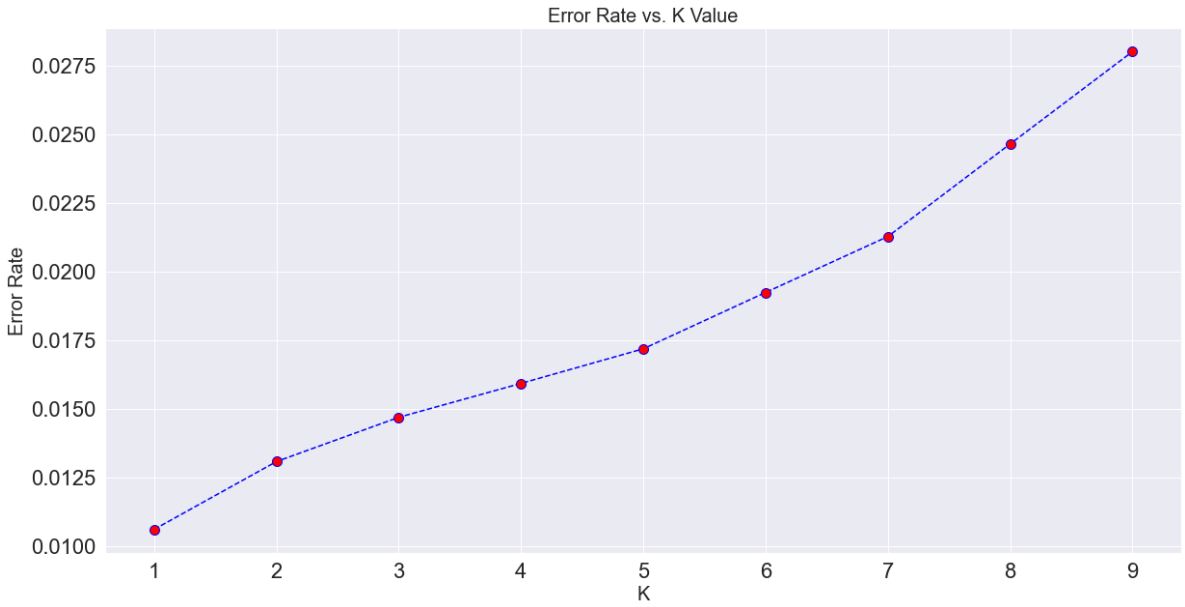
Due to the fact that the dataset is high dimensional, it is easily concluded that by increasing the number of neighbors, the performance is decreasing.

In [13]:

```
error_rate = []

# Will take some time
for i in range(1,10):

    knn = KNeighborsClassifier(n_neighbors=i)
    knn.fit(X_train,y_train)
    pred_i = knn.predict(X_test)
    error_rate.append(np.mean(pred_i != y_test))
```

In [14]:

```
plt.figure(figsize=(20,10))
plt.plot(range(1,10),error_rate,color='blue', linestyle='dashed', marker='o',
         markerfacecolor='red', markersize=10)
sns.set(font_scale=2)
plt.title('Error Rate vs. K Value',fontsize=20)
plt.xlabel('K',fontsize=20)
plt.ylabel('Error Rate',fontsize=20)
plt.show()
```



In [15]:

```
knn = KNeighborsClassifier(n_neighbors=1)
knn.fit(X_train,y_train)
pred_knn = knn.predict(X_test)
print(classification_report(y_test,pred_knn))
```

```
              precision    recall  f1-score   support

           1       1.00      1.00      1.00     74977
           2       0.99      0.99      0.99     72896
           3       0.99      0.99      0.99     74870
           4       0.98      0.99      0.99     75455
           5       0.99      0.99      0.99     75592
           6       0.99      0.99      0.99     75862
           7       0.98      0.98      0.98      4173

    accuracy                           0.99    453825
   macro avg       0.99      0.99      0.99    453825
weighted avg       0.99      0.99      0.99    453825
```

In [17]:

```
knn = KNeighborsClassifier(n_neighbors=7)
knn.fit(X_train,y_train)
pred_knn = knn.predict(X_test)
print(classification_report(y_test,pred_knn))
```

```
              precision    recall  f1-score   support

           1       0.99      1.00      1.00     74977
           2       0.98      0.97      0.98     72896
           3       0.98      0.98      0.98     74870
           4       0.97      0.98      0.97     75455
           5       0.97      0.97      0.97     75592
           6       0.98      0.98      0.98     75862
           7       0.97      0.95      0.96      4173

    accuracy                           0.98    453825
   macro avg       0.98      0.98      0.98    453825
weighted avg       0.98      0.98      0.98    453825
```

5.3 Random Forest

Random forest method is expected to be the most fitting classification method to this problem than the previous machine learning algorithms, due to the complexity of compination of decision trees.

In [18]:

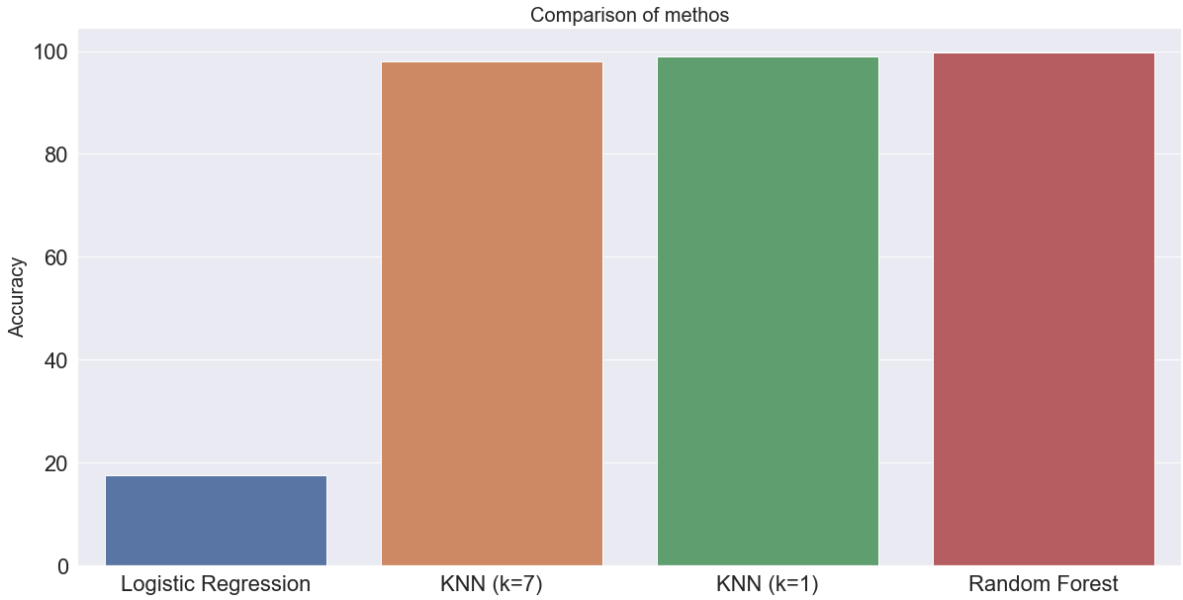
```
RF = RandomForestClassifier()
RF_fit = RF.fit(X_train, y_train)
RF_pred = RF_fit.predict(X_test)
print("Random Forests is %f percent accurate" % (accuracy_score(RF_pred, y_test)*100))
```

```
Random Forests is 99.621440 percent accurate
```

5.4 Comparison of the methods

In [19]:

```
plt.figure(figsize=(20,10))
sns.set(font_scale=2)
plt.ylabel('Accuracy',fontsize=20)
plt.title('Comparison of methos',fontsize=20)
sns.barplot(x=['Logistic Regression', 'KNN (k=7)', 'KNN (k=1)', 'Random Forest'], y=[17.63,
plt.show()
```



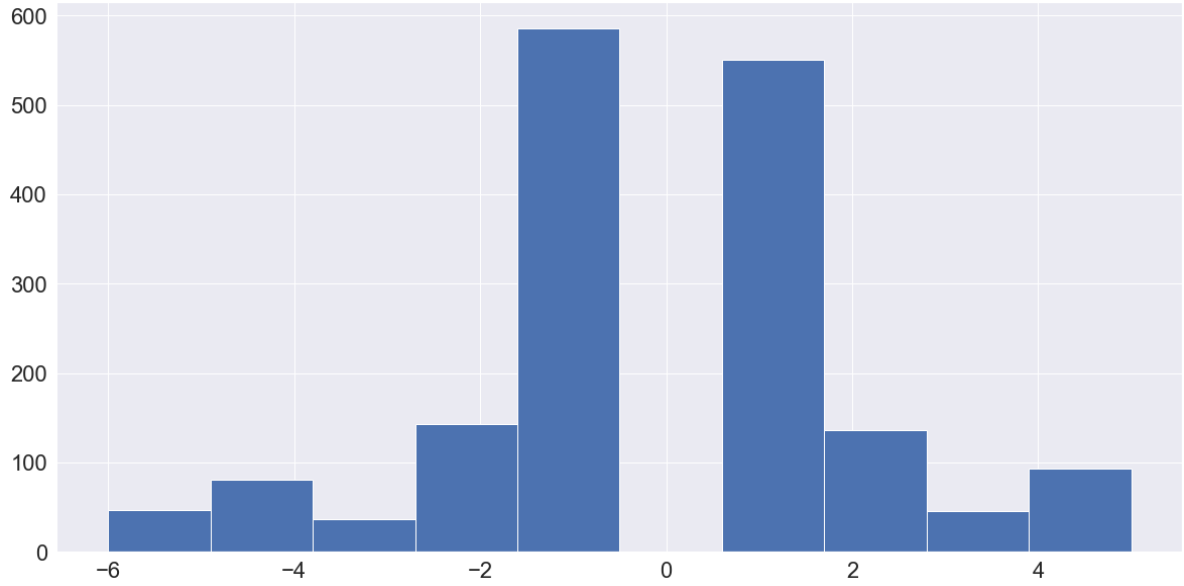
6.Residuals Analysis

In [20]:

```
#RESIDUALS ANALYSIS
error=RF_pred-y_test #calculating the error of random forest method
error=pd.DataFrame(error)
```

In [21]:

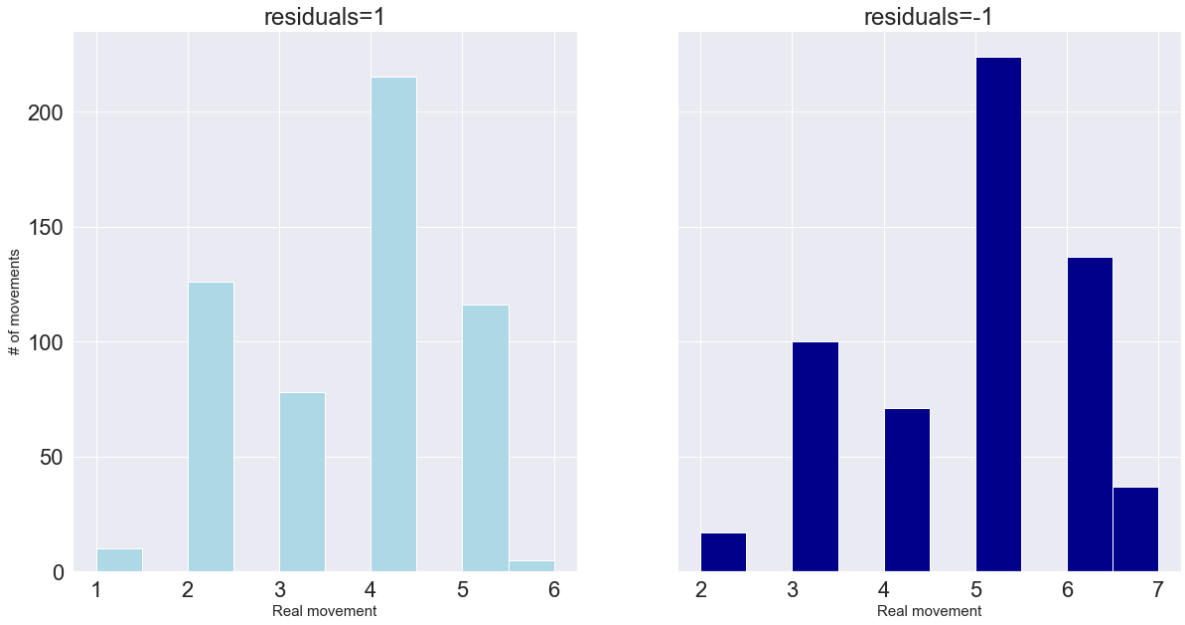
```
plt.figure(figsize=(20,10))
df_with_res=df1.merge(error,left_index=True, right_index=True).rename(columns={'class_y':'r
df_with_res=df_with_res[df_with_res['residuals']!=0]
df_with_res['residuals'].hist()
plt.show()
```



From a quick residuals analysis, it can be easily stated that our model may incorrectly predict movement 5 for movement 6 and vice versa.

In [22]:

```
fig, axes = plt.subplots(1,2, sharey=True, figsize=(20,10))
df_with_res[(df_with_res['residuals']==1)]['class_x'].plot(kind='hist',title='residuals=1',

df_with_res[(df_with_res['residuals']==-1)]['class_x'].plot(kind='hist',title='residuals=-1

axes[0].set_xlabel('Real movement',fontsize=15)
axes[1].set_xlabel('Real movement',fontsize=15)
axes[0].set_ylabel('# of movements',fontsize=15)
plt.show()
```



6.Concluding Remarks

The conclusion of this project is:

1) The hypothesis of not removing the outliers has no significant impact to the performance of machine learning methods.

2) The random forest method scores the best value of accuracy than Logistic Regression and KNN methods.

3) Accuracies of our model is expected to be high, due to the large amount of training data

Appendix

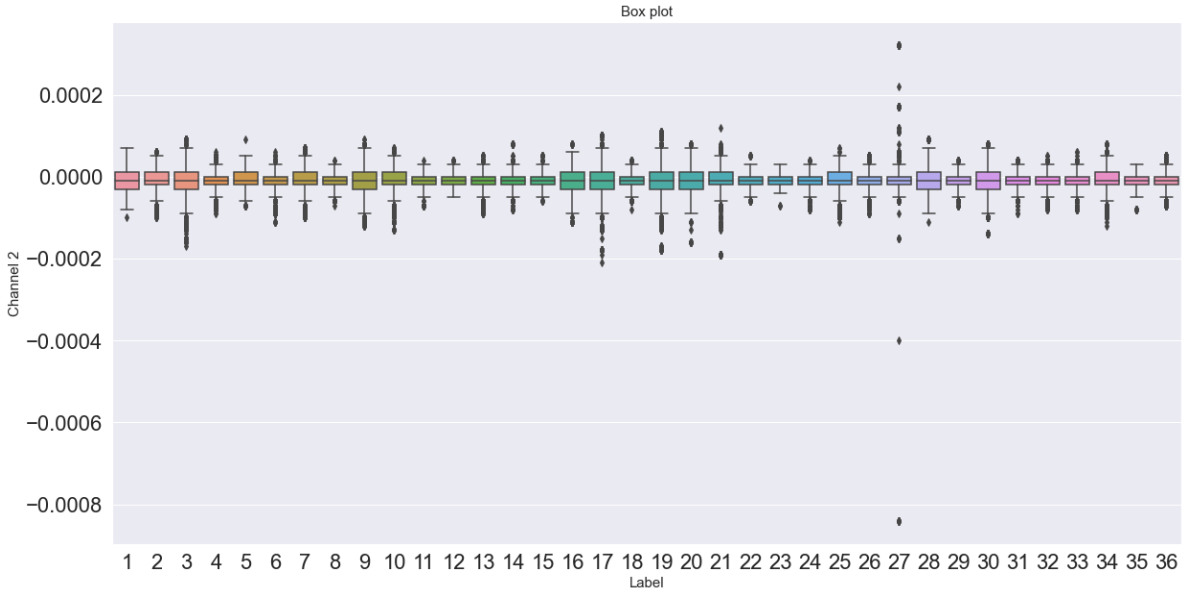
Data Analysis

Boxplots

Boxplots of Class 1

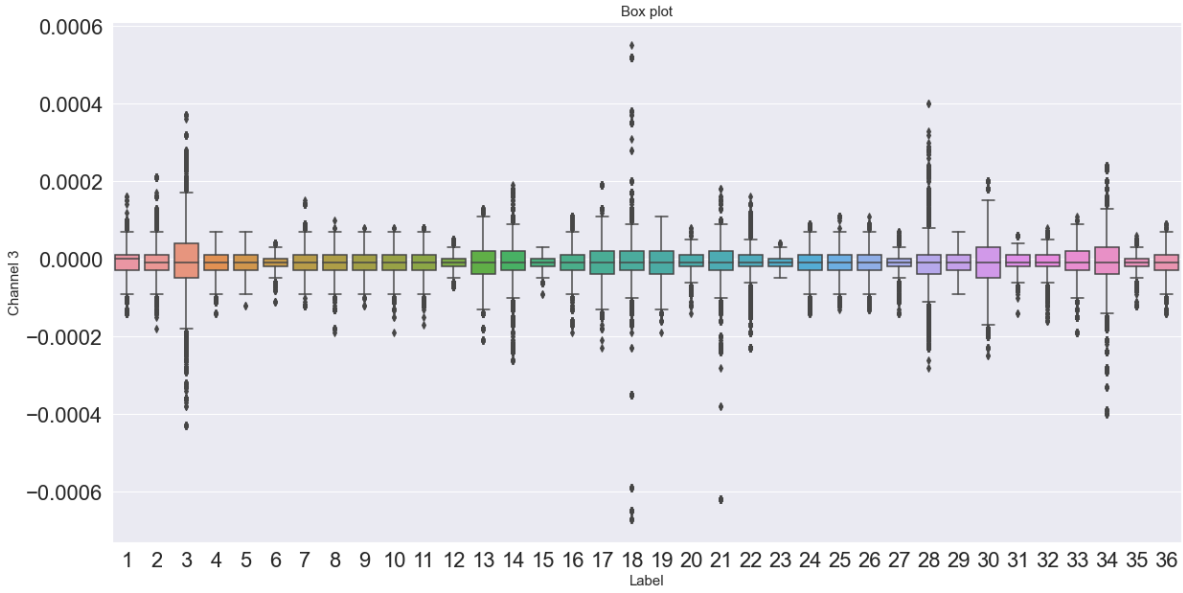
In [23]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel2',data=class1)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 2',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



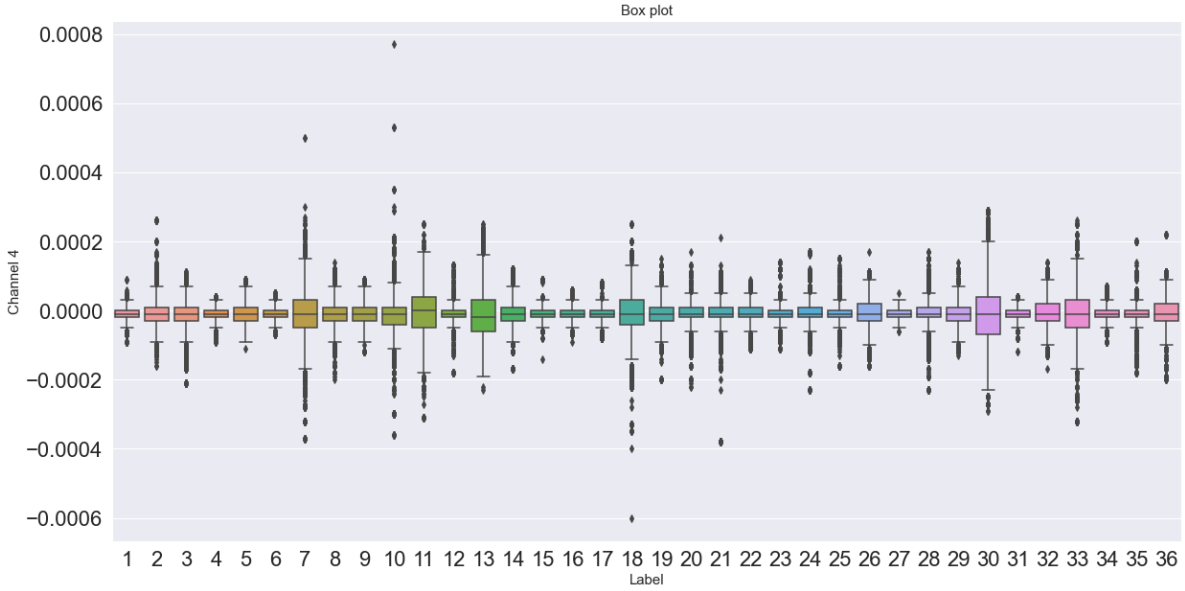
In [24]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel3',data=class1)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 3',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



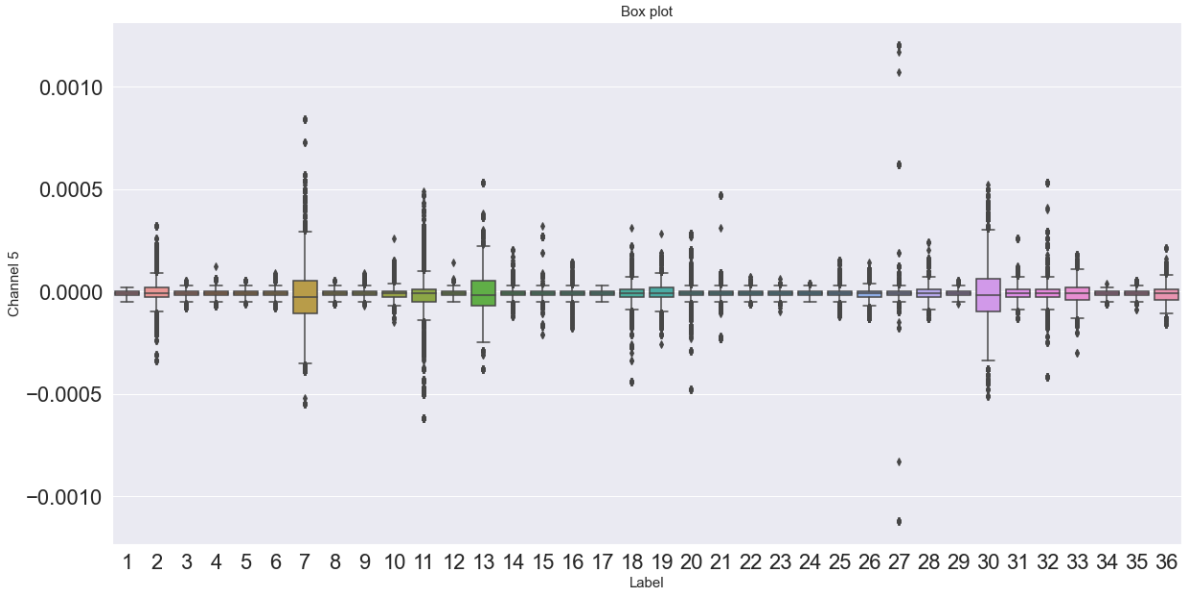
In [25]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel4',data=class1)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 4',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



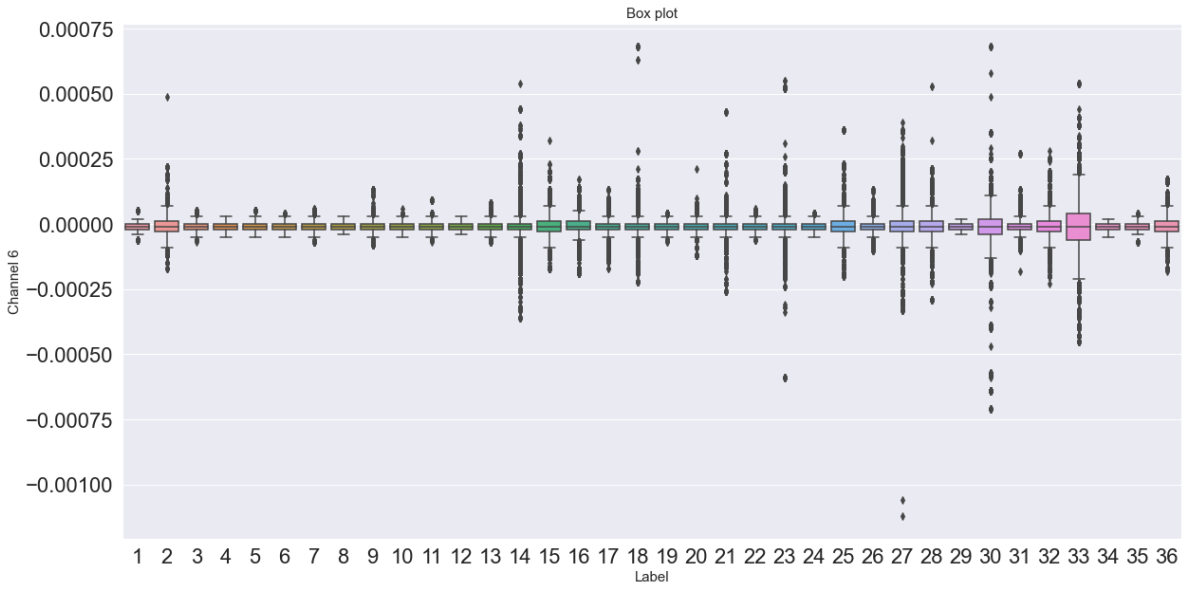
In [26]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel5',data=class1)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 5',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



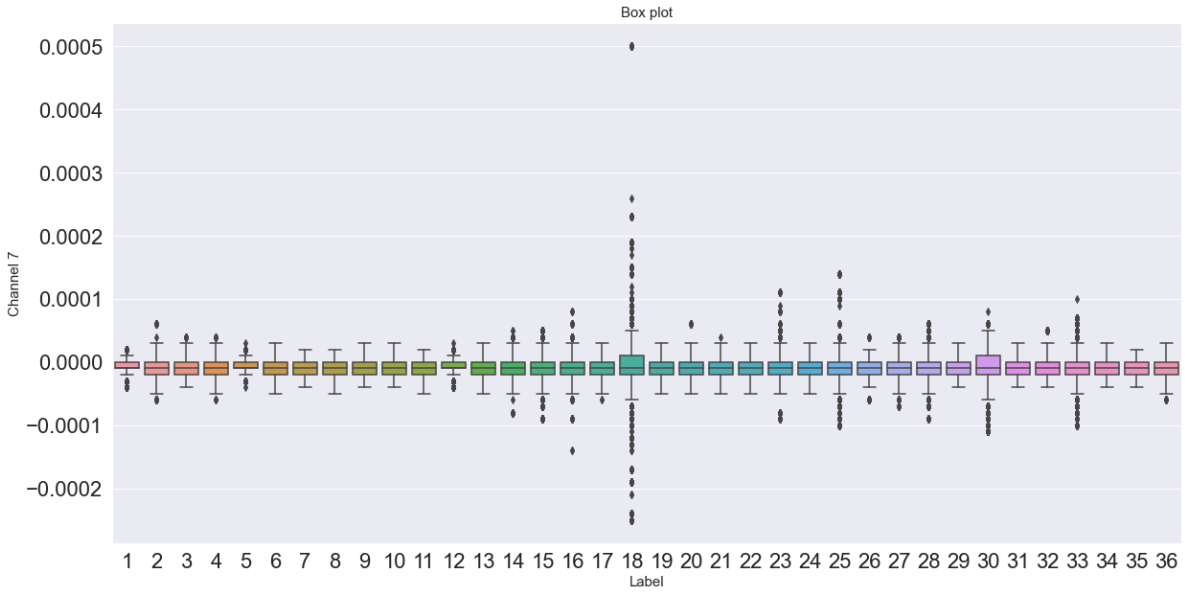
In [27]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel6',data=class1)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 6',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



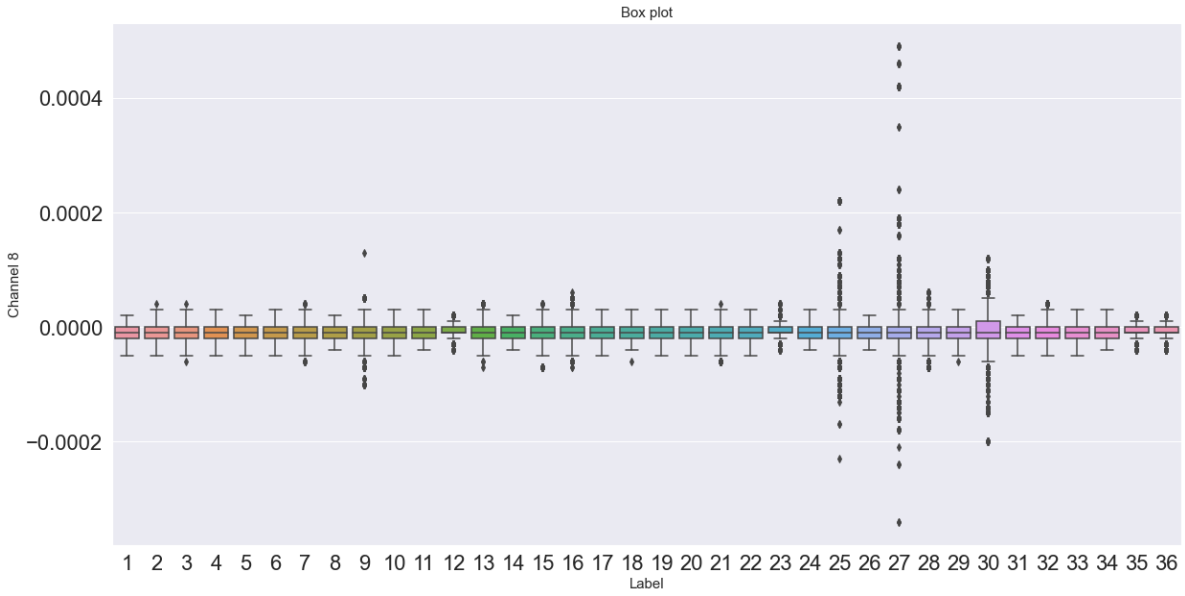
In [28]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel7',data=class1)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 7',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



In [29]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel8',data=class1)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 8',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



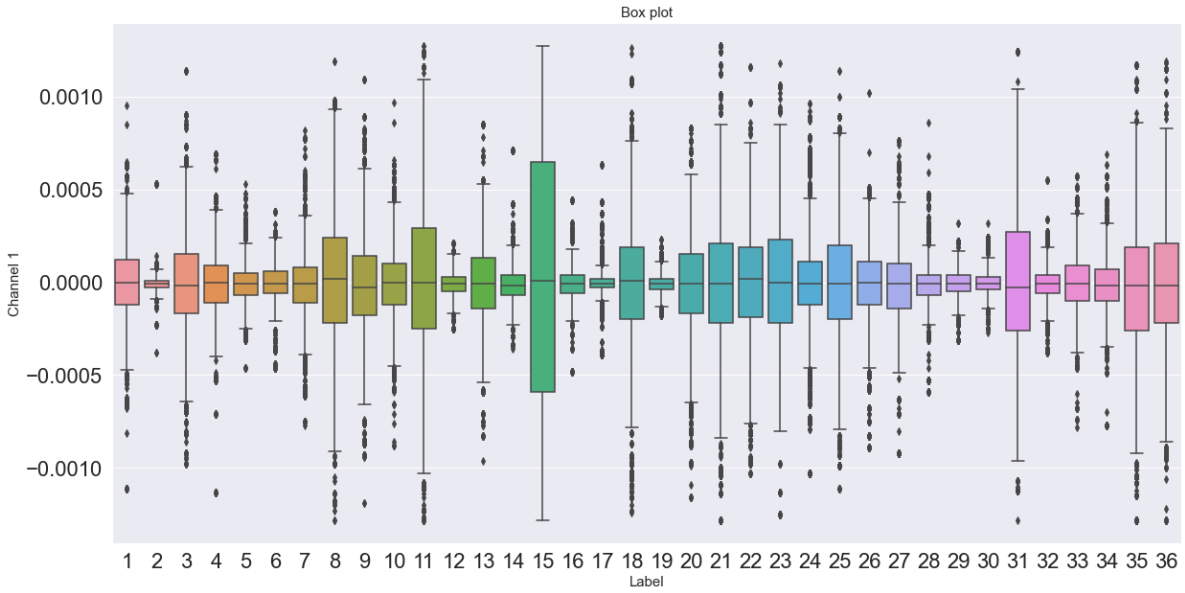
Boxplots of Class 2

In [30]:

```
class2=df[df['class']==2] # matrix with the class=2
```

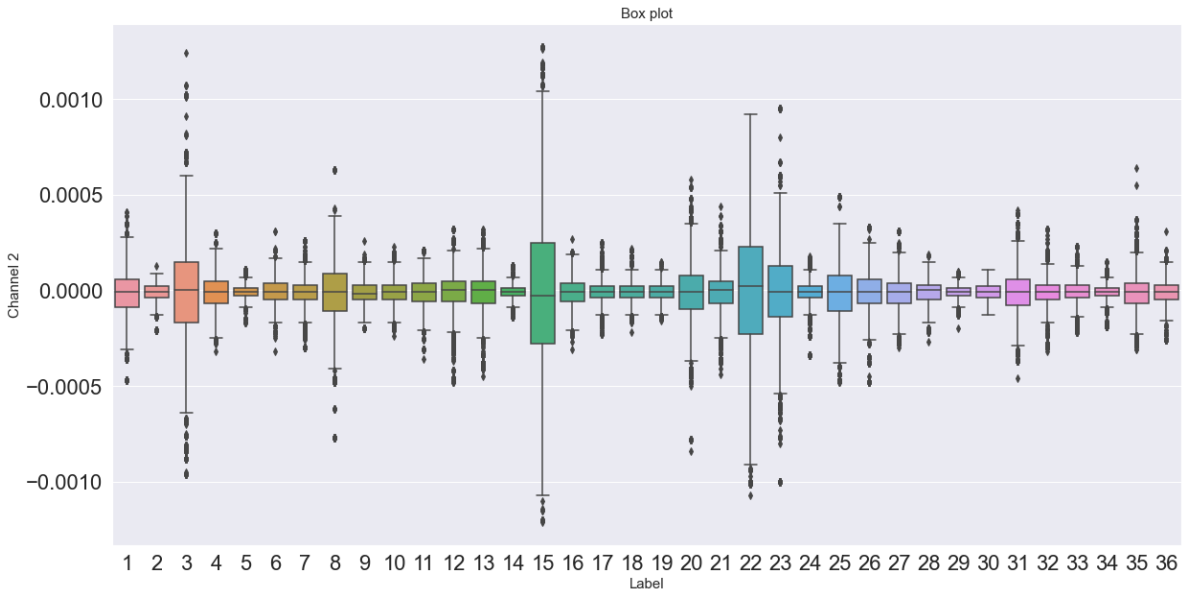
In [31]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel1',data=class2)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 1',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



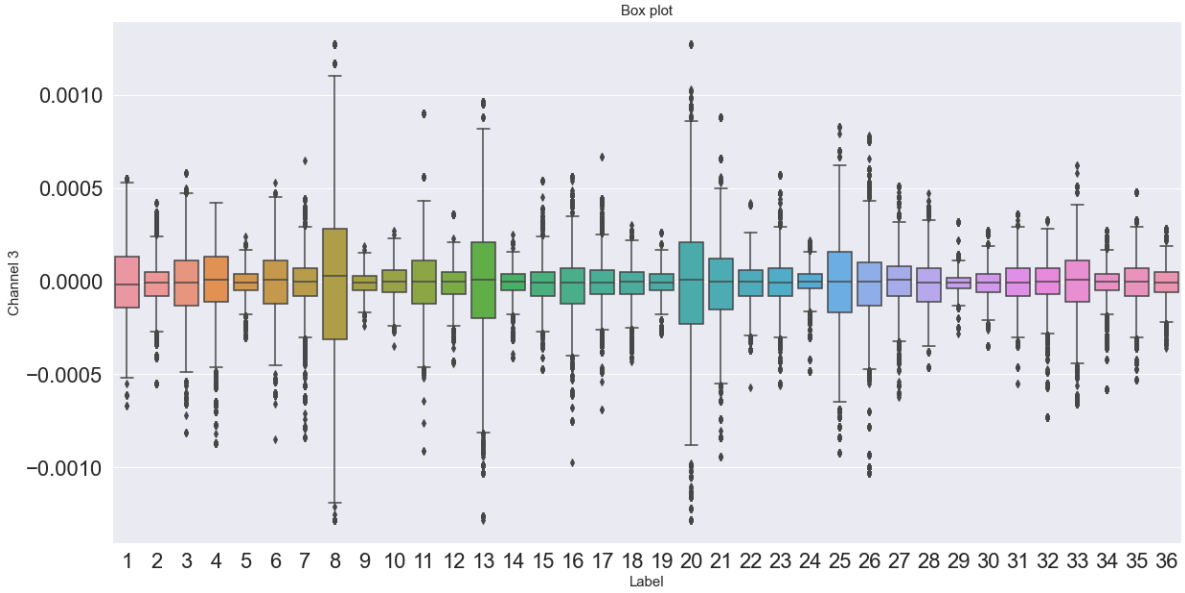
In [32]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel2',data=class2)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 2',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



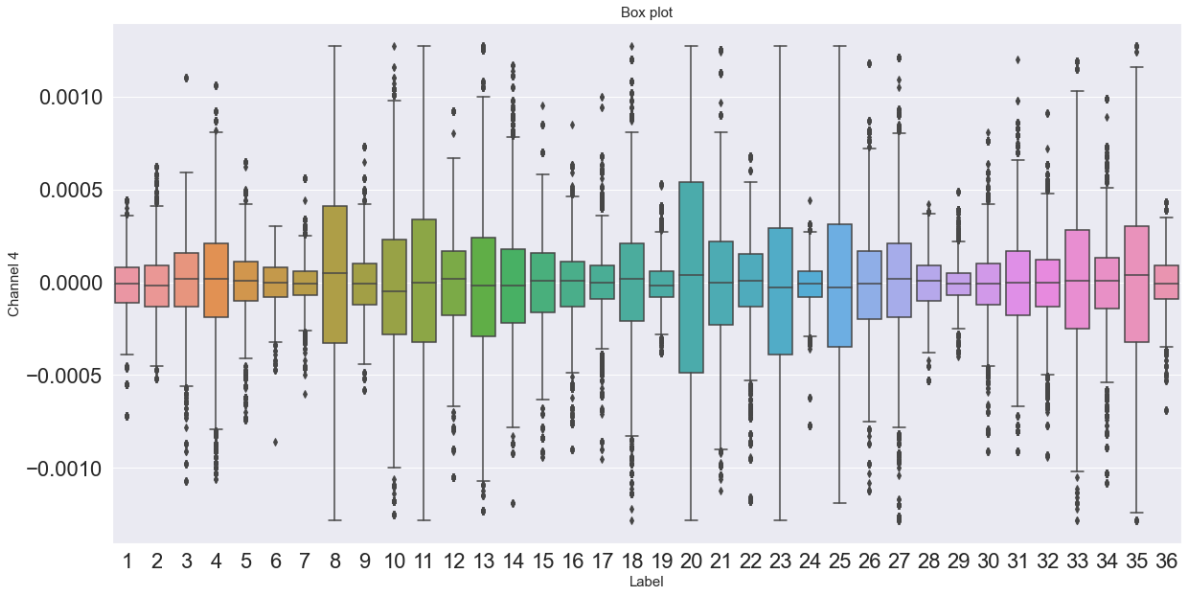
In [33]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel3',data=class2)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 3',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



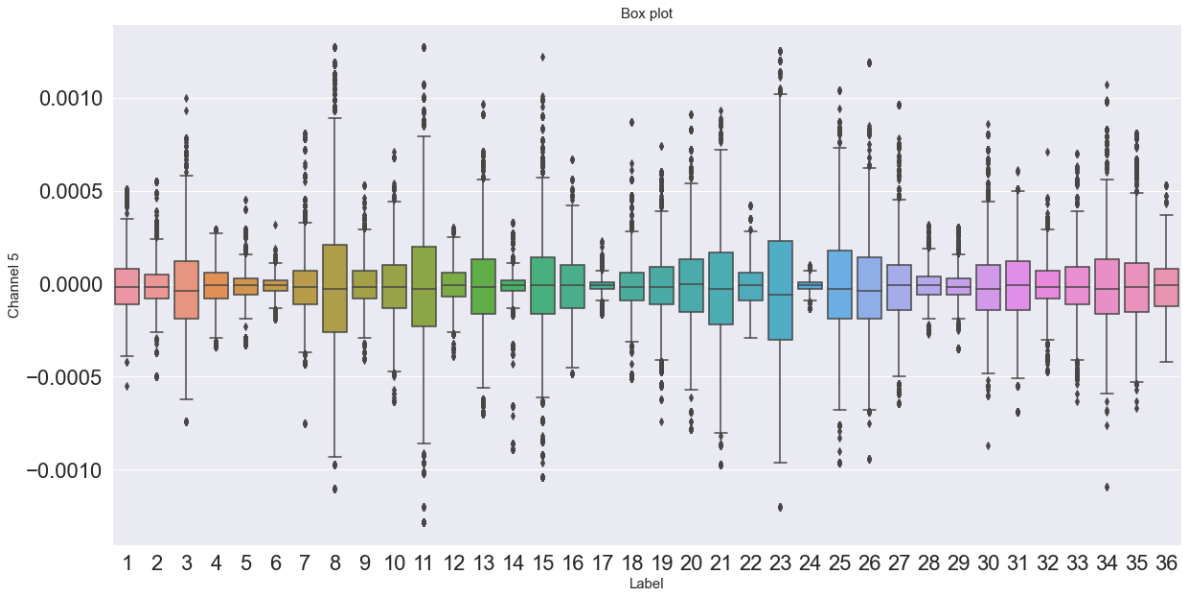
In [34]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel4',data=class2)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 4',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



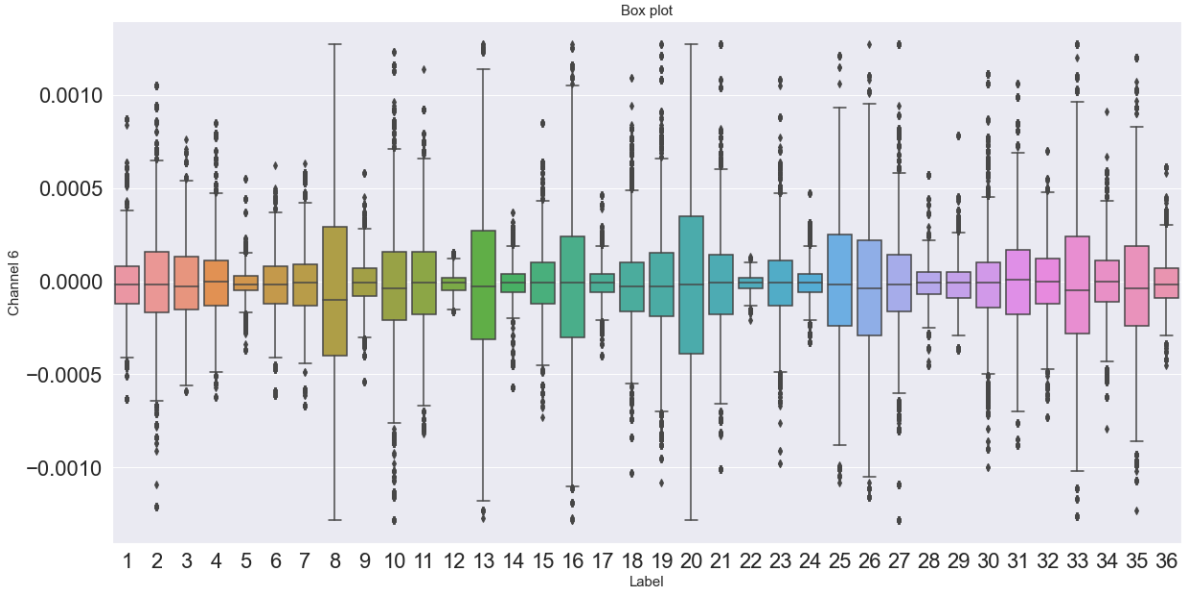
In [35]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel5',data=class2)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 5',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



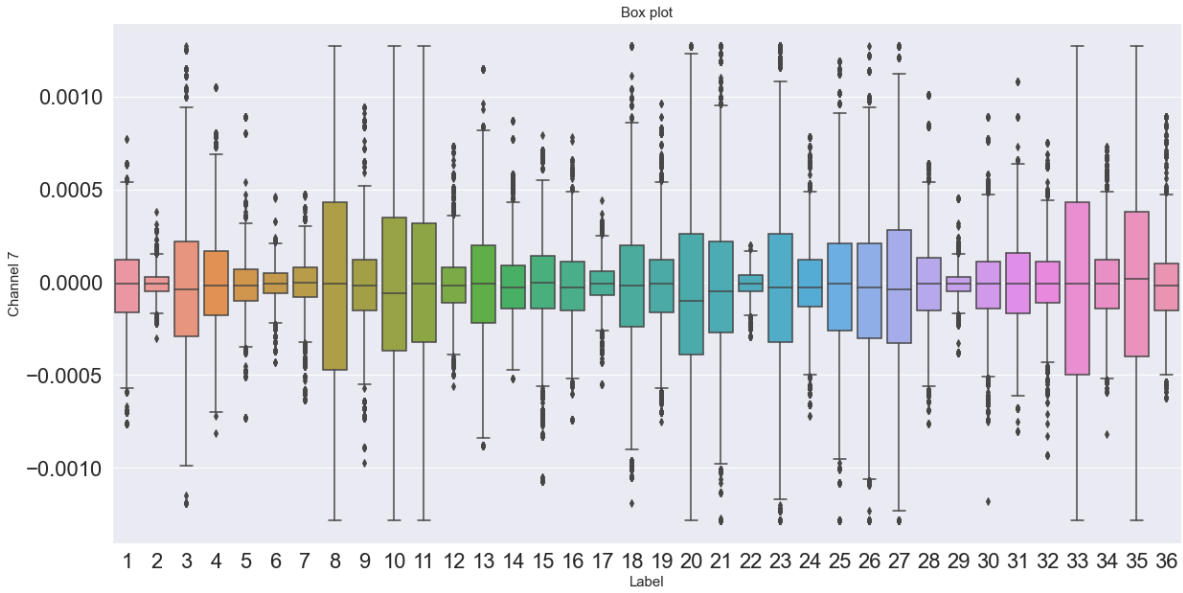
In [36]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel6',data=class2)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 6',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



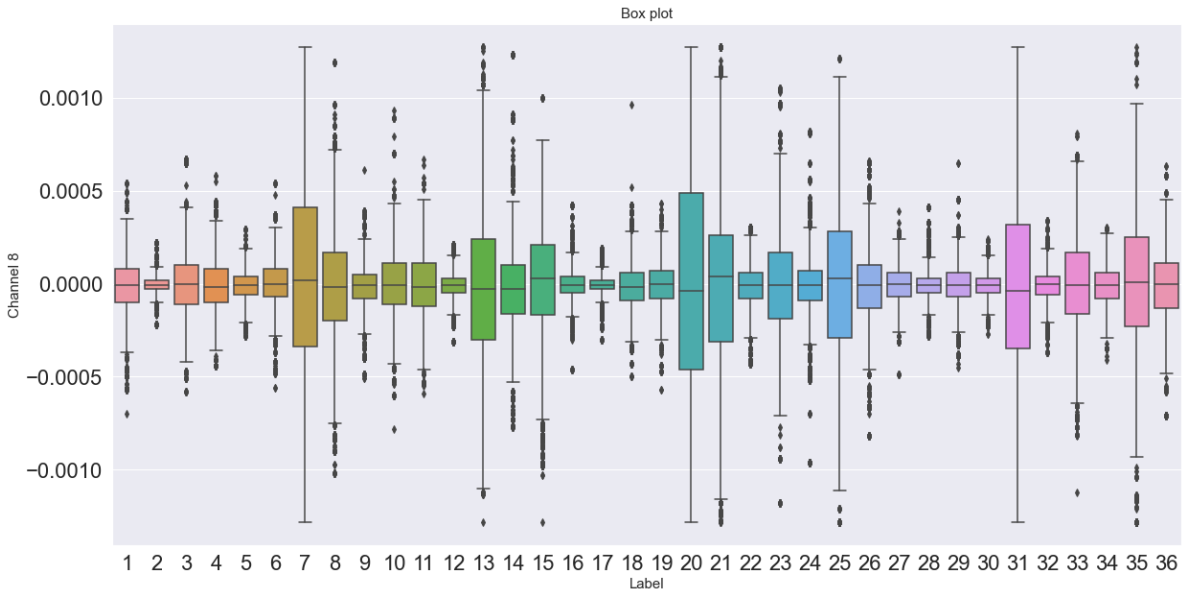
In [37]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel7',data=class2)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 7',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



In [38]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel8',data=class2)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 8',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



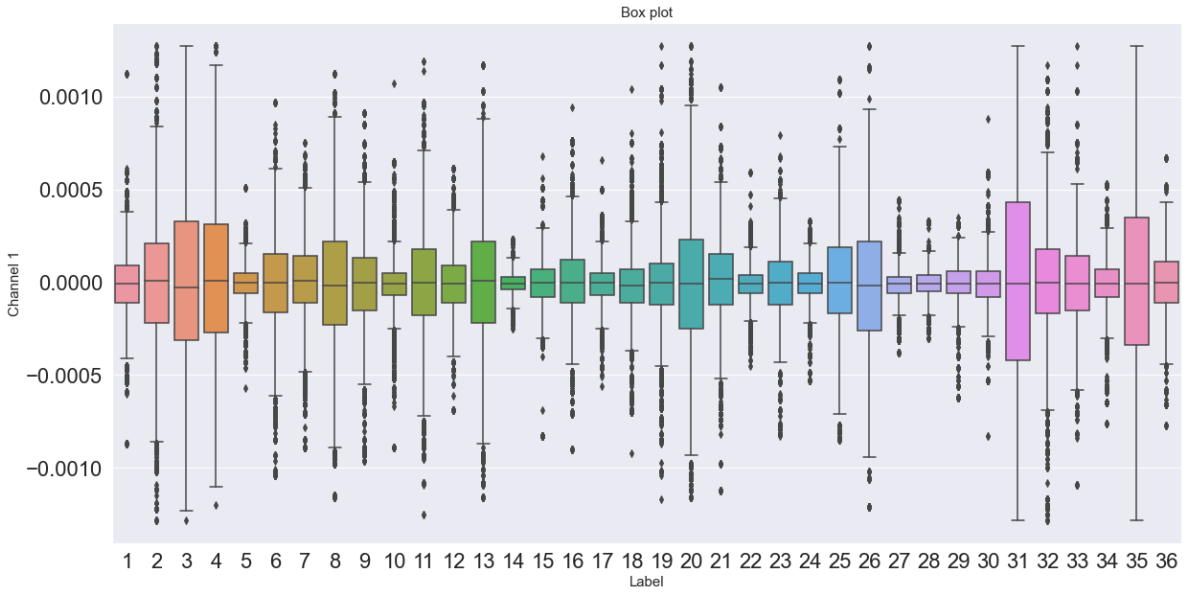
Boxplots of Class 3

In [39]:

```
class3=df[df['class']==3] # matrix with the class=3
```

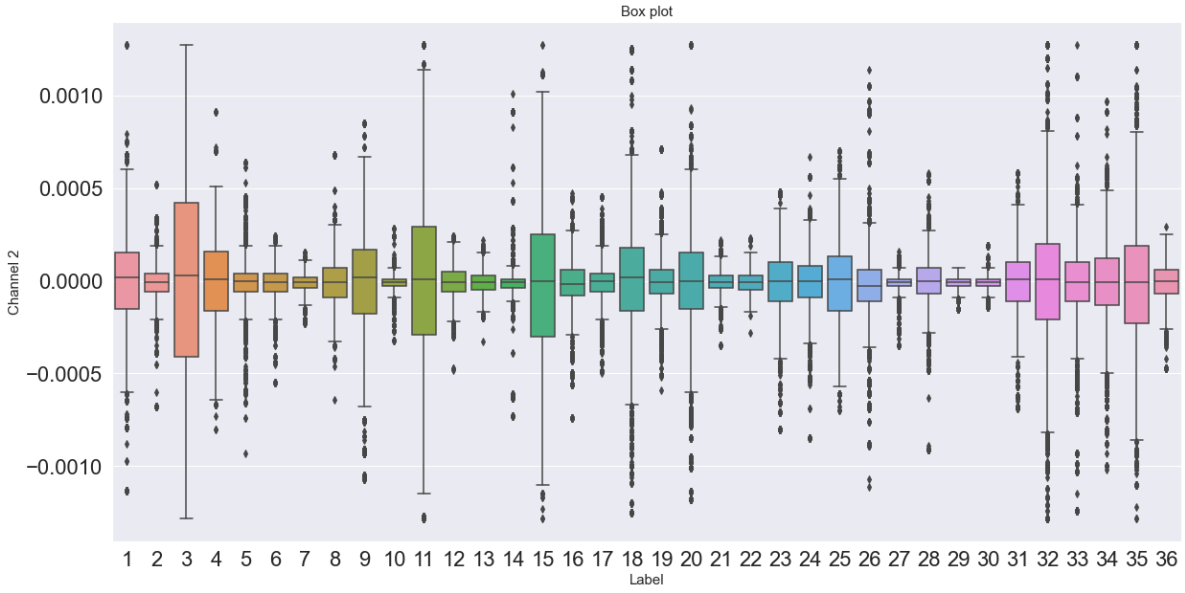
In [40]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel1',data=class3)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 1',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



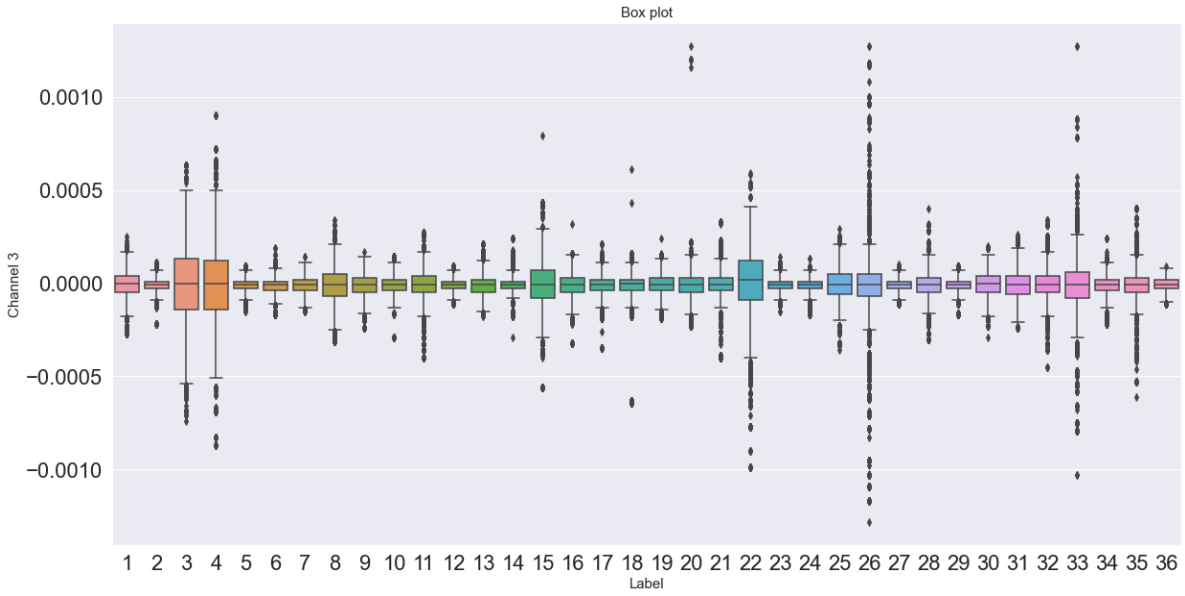
In [41]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel2',data=class3)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 2',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



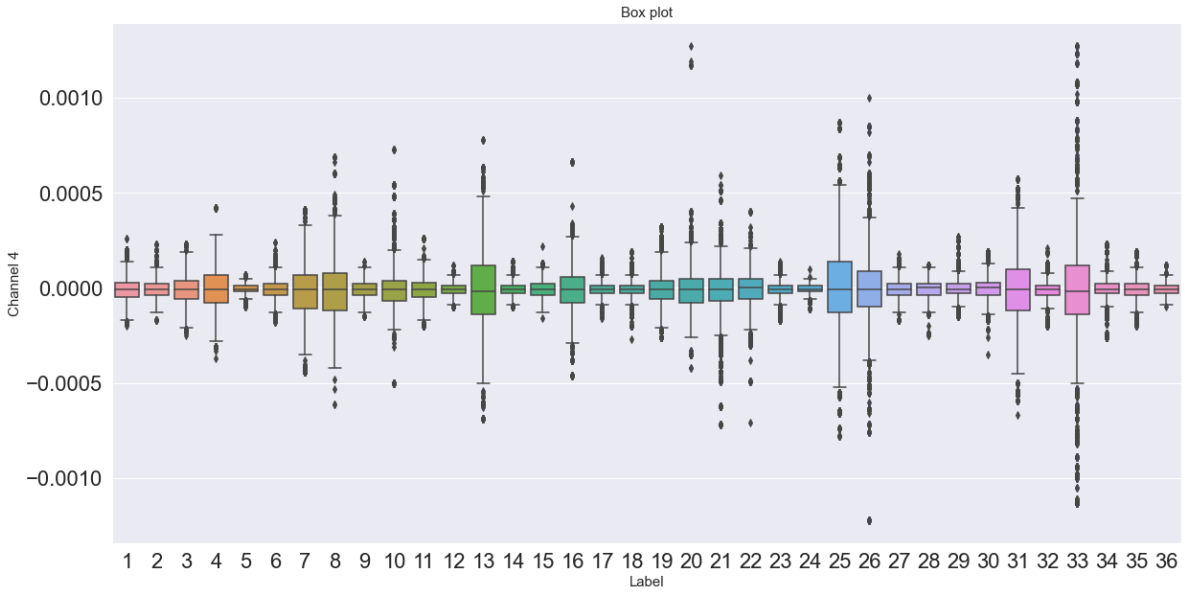
In [42]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel3',data=class3)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 3',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



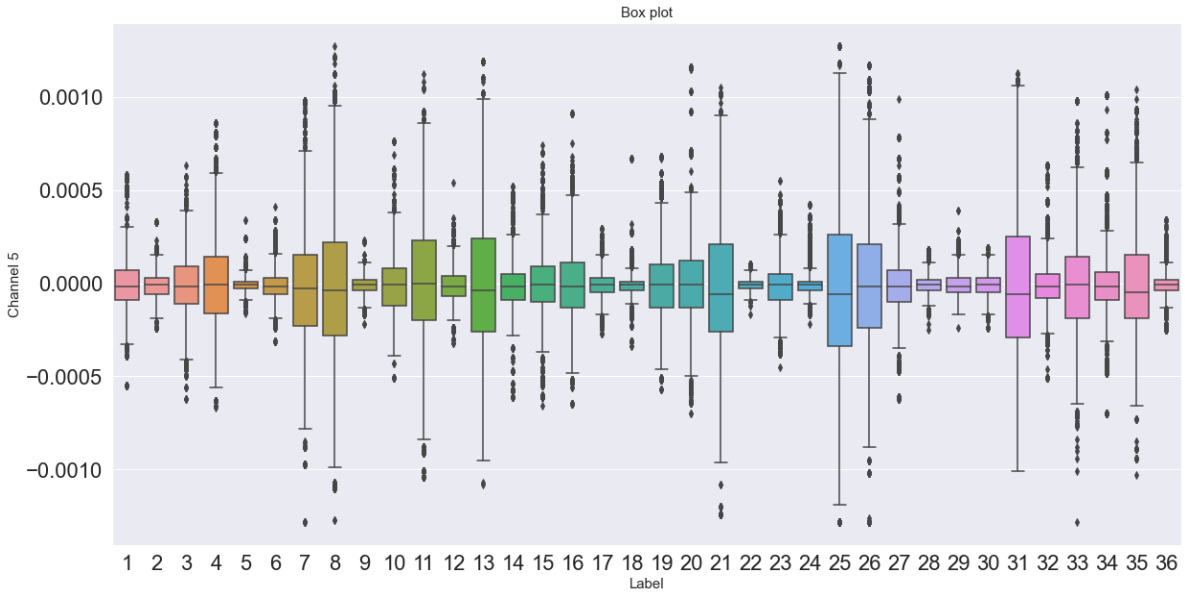
In [43]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel4',data=class3)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 4',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



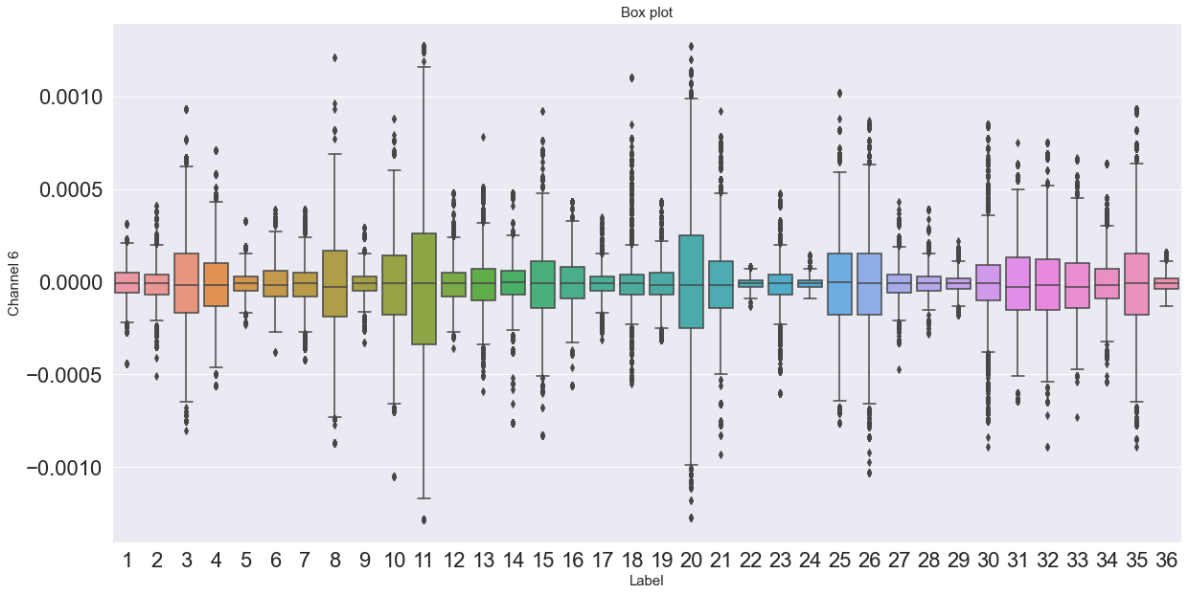
In [44]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel5',data=class3)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 5',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



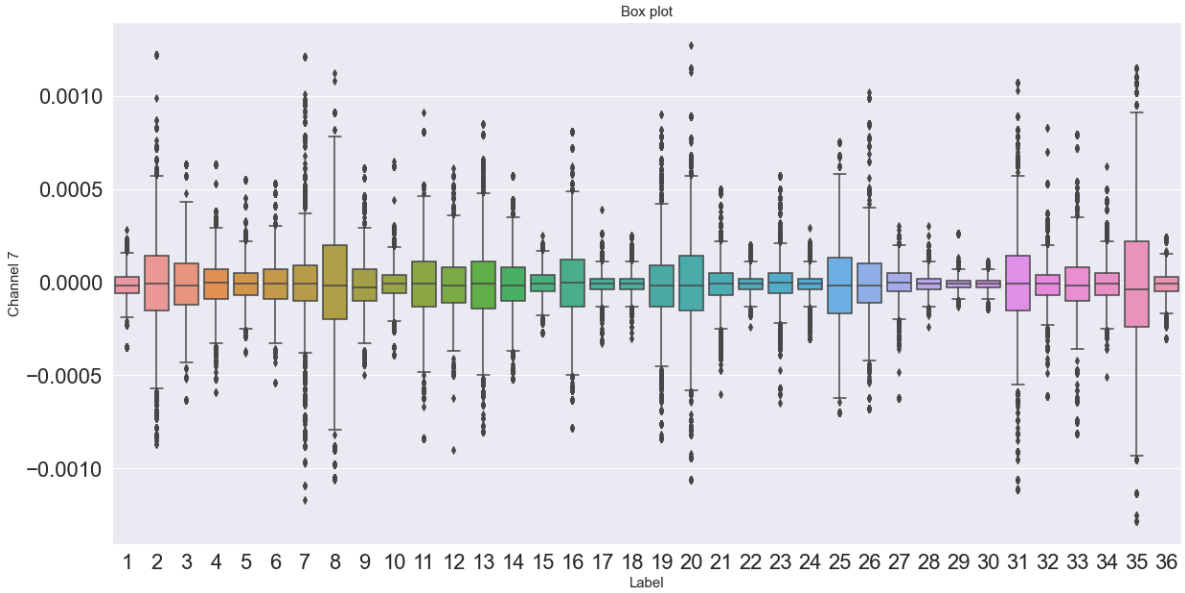
In [45]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel6',data=class3)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 6',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



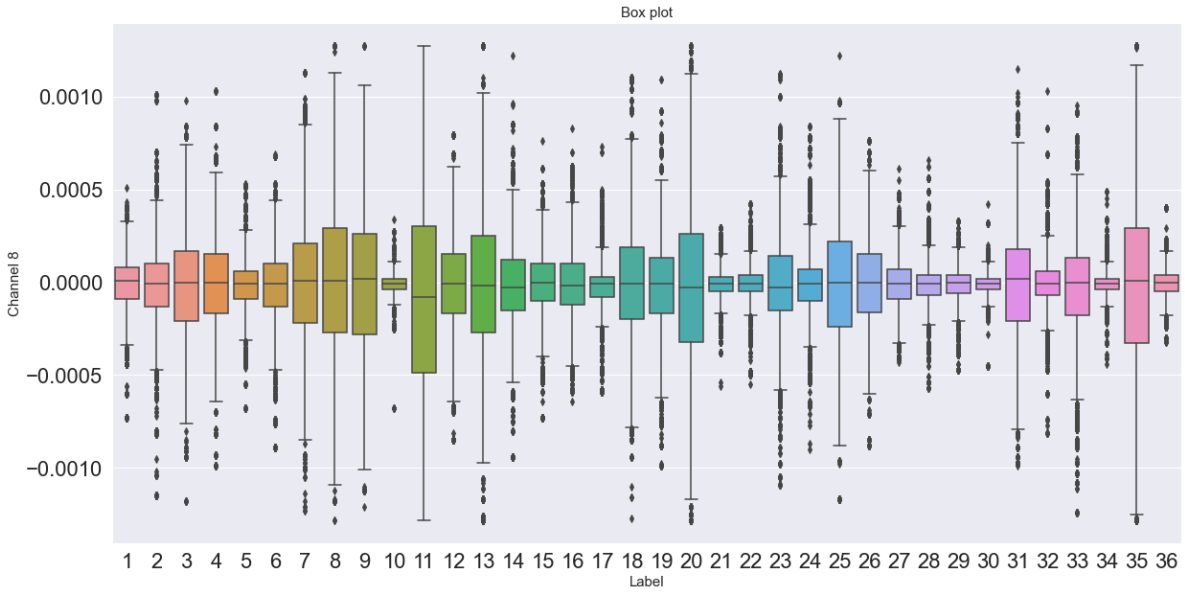
In [46]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel7',data=class3)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 7',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



In [47]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel8',data=class3)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 8',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



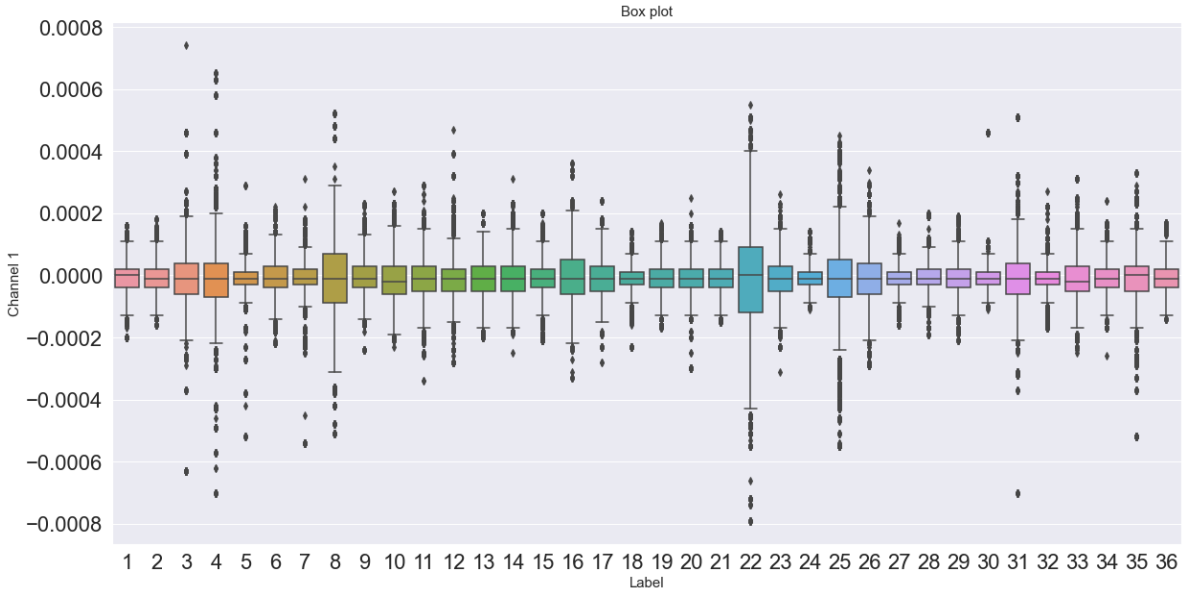
Boxplots of Class 4

In [48]:

```
class4=df[df['class']==4] # matrix with the class=4
```

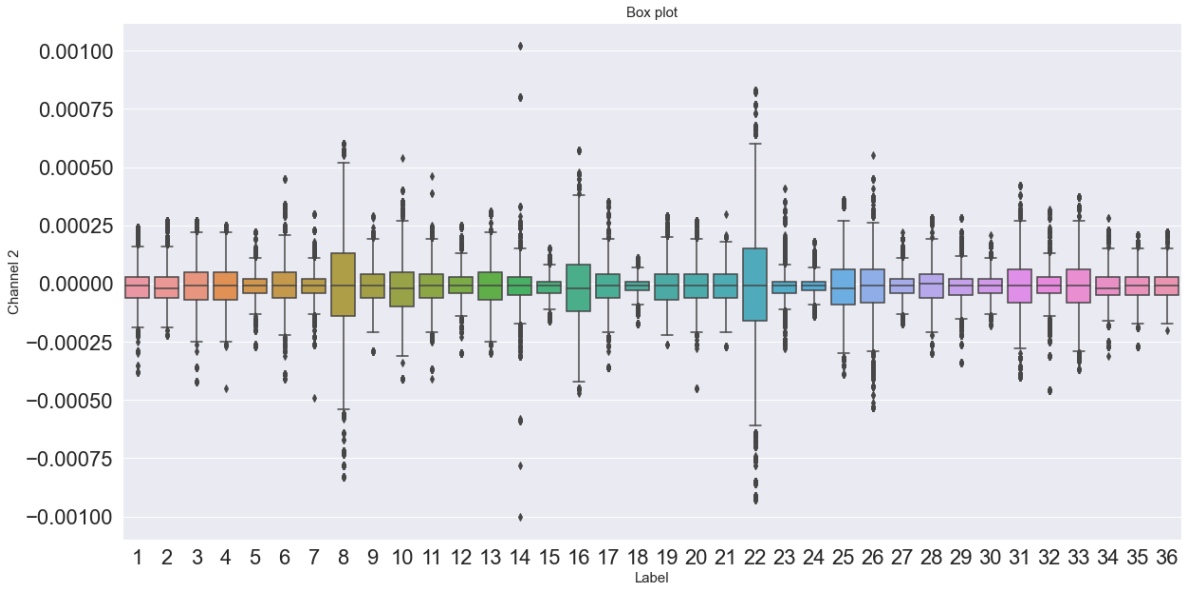
In [49]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel1',data=class4)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 1',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



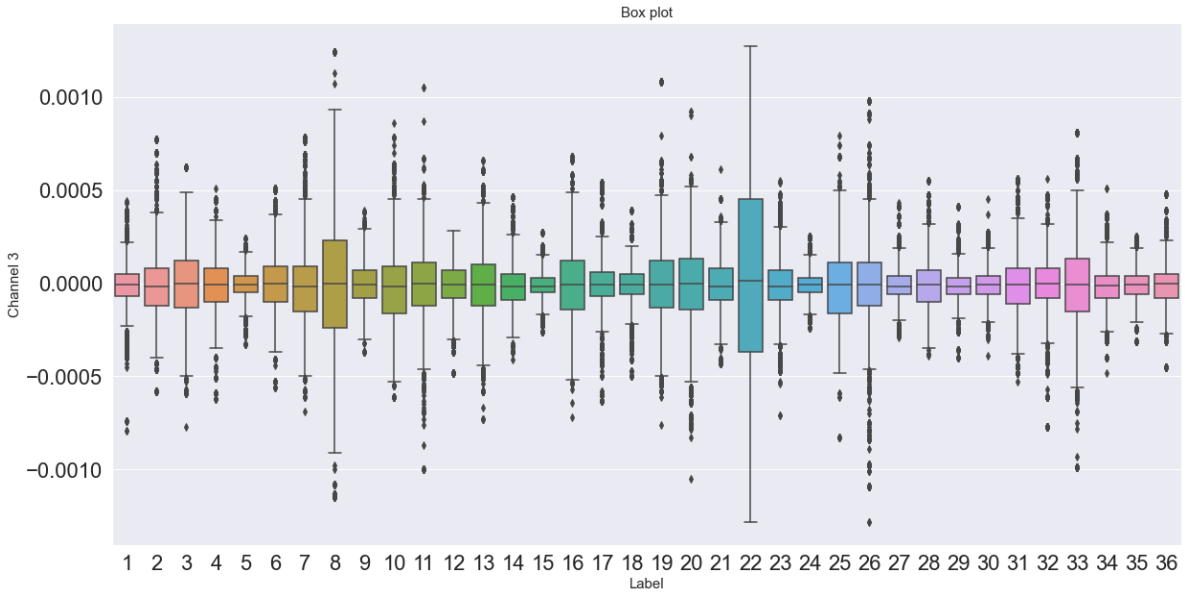
In [50]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel2',data=class4)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 2',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



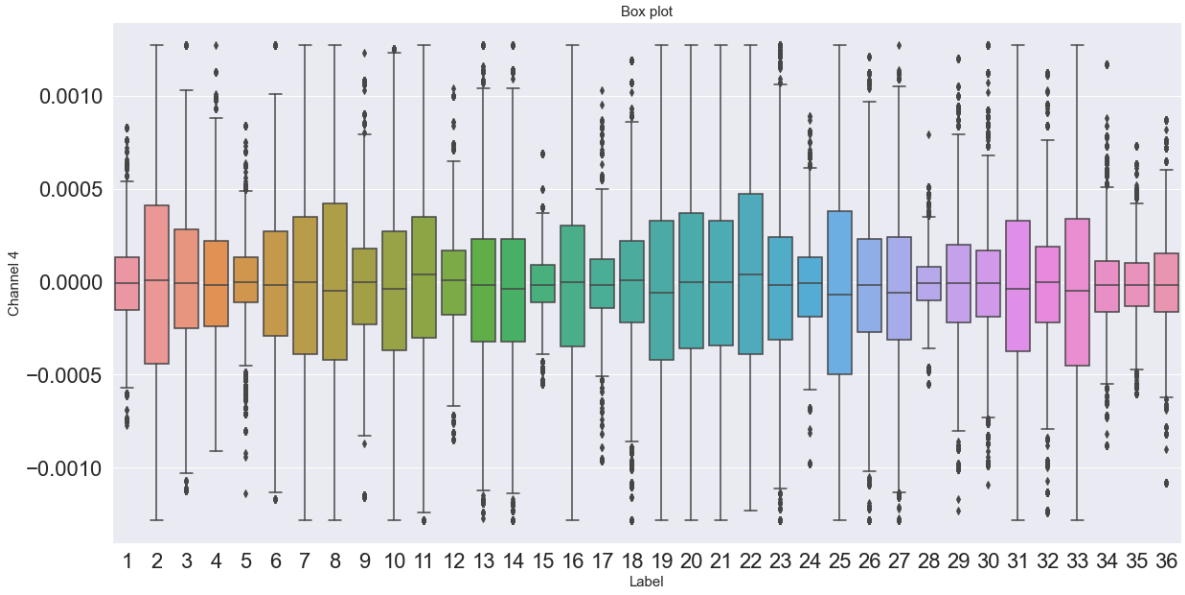
In [51]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel3',data=class4)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 3',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



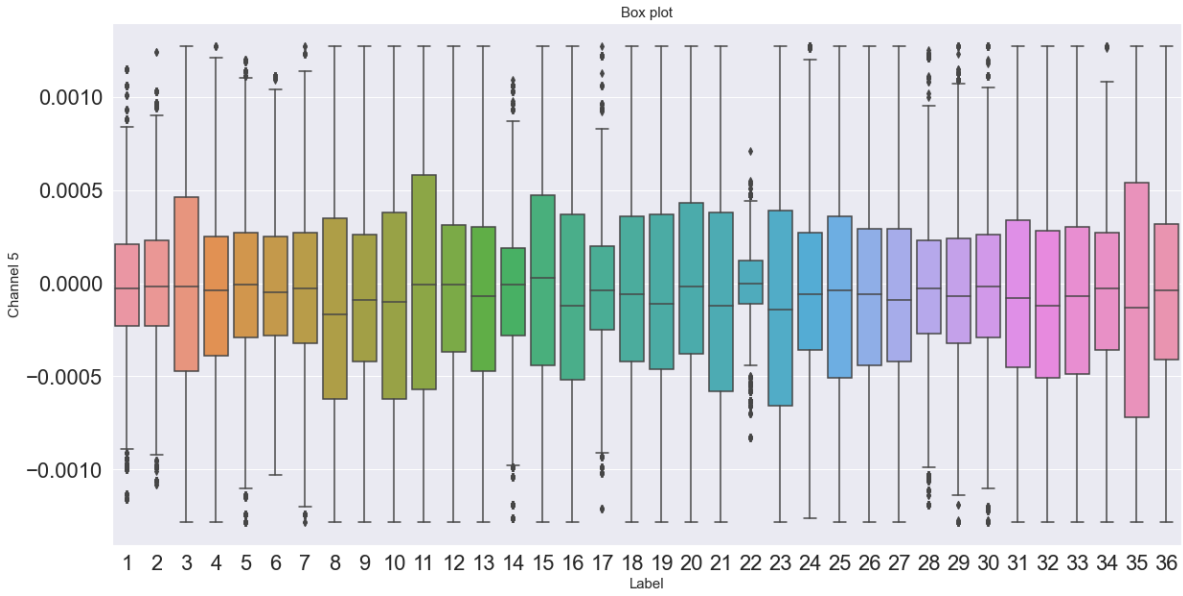
In [52]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel4',data=class4)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 4',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



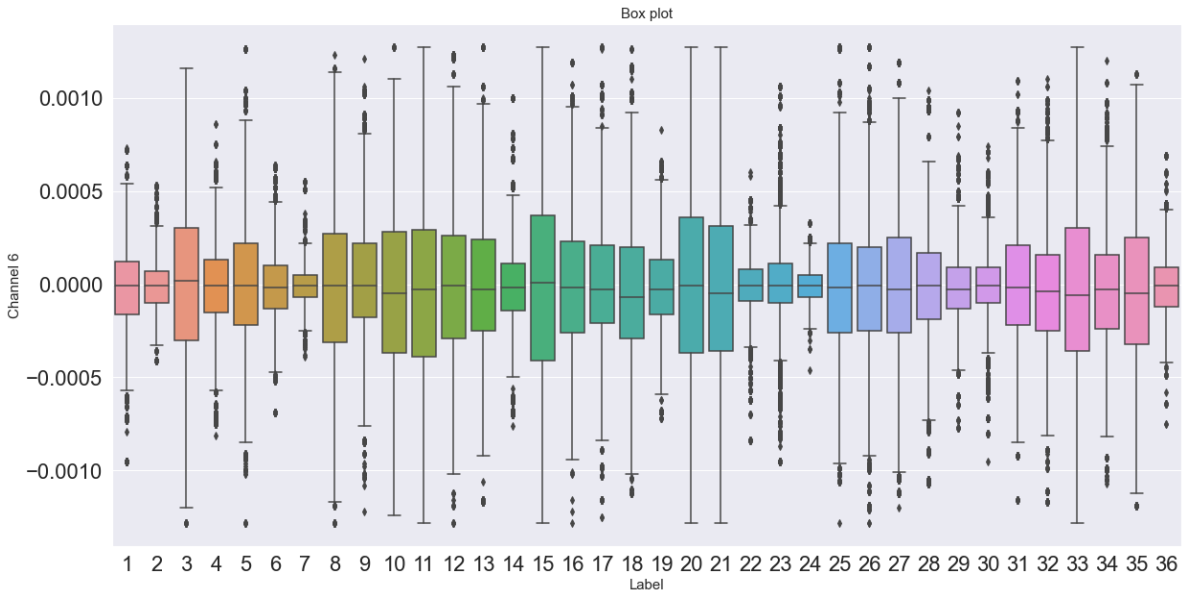
In [53]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel5',data=class4)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 5',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



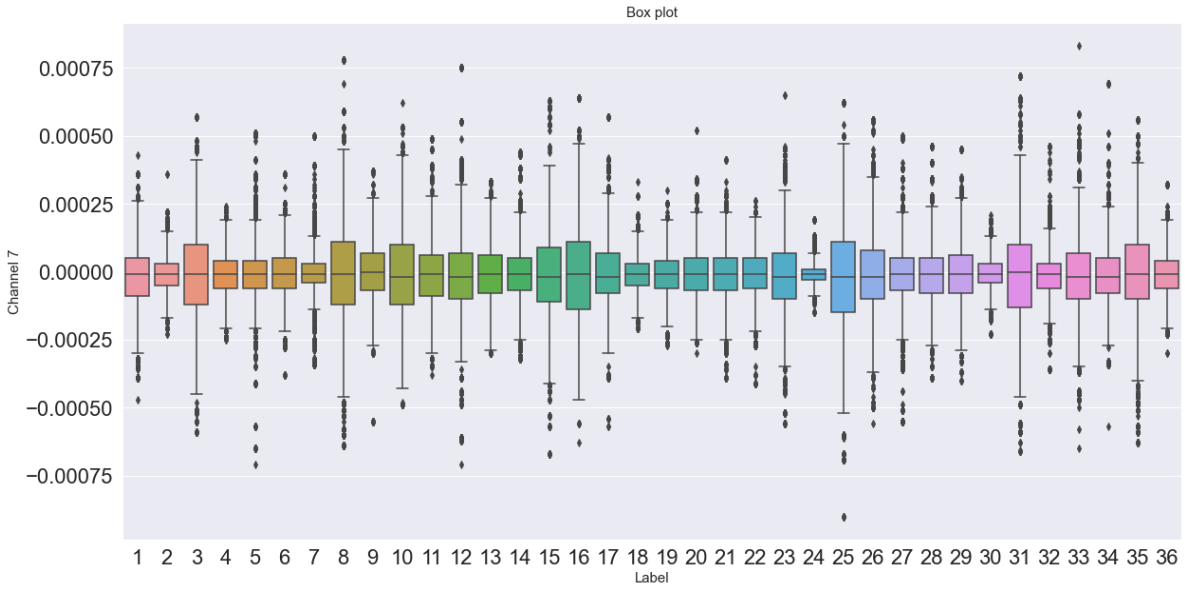
In [54]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel6',data=class4)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 6',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



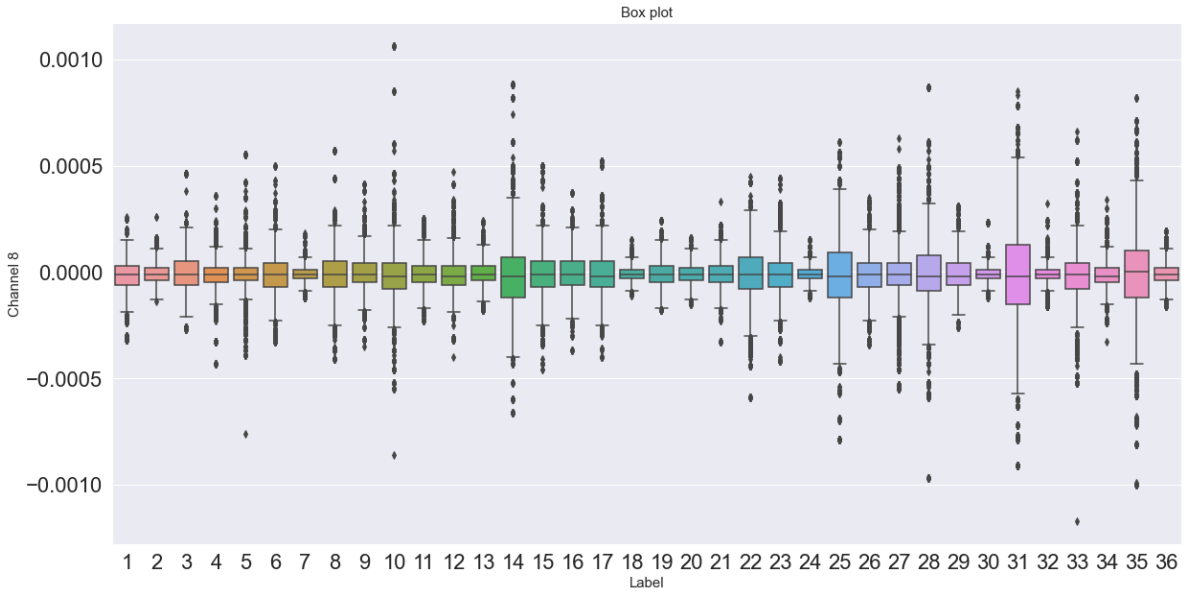
In [55]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel7',data=class4)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 7',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



In [56]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel8',data=class4)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 8',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



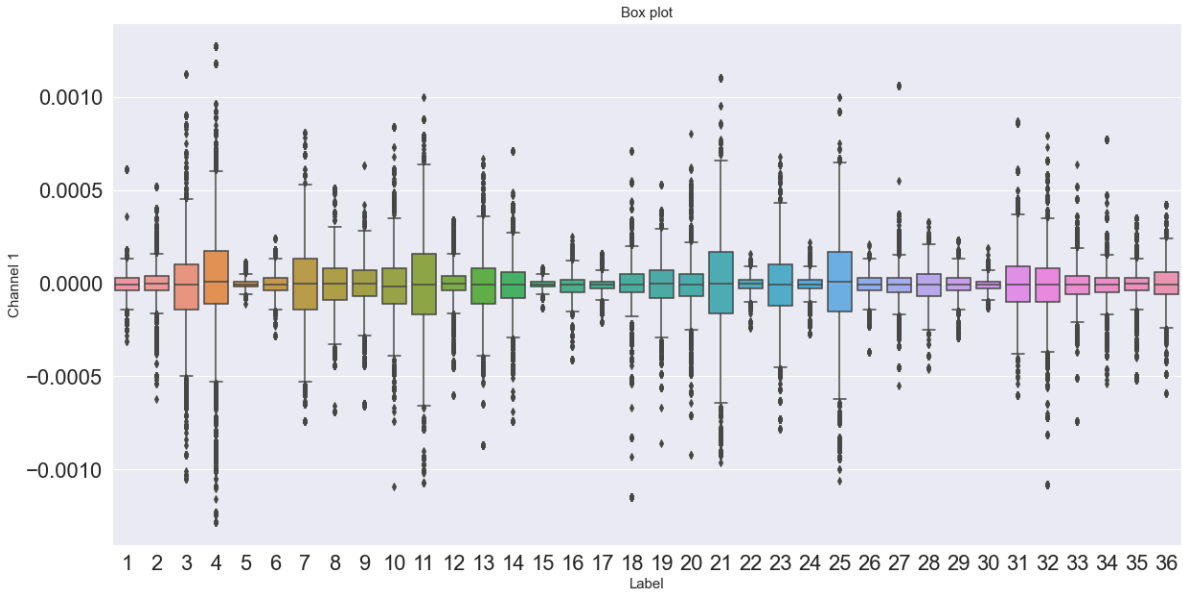
Boxplots of Class 5

In [57]:

```
class5=df[df['class']==5] # matrix with the class=5
```

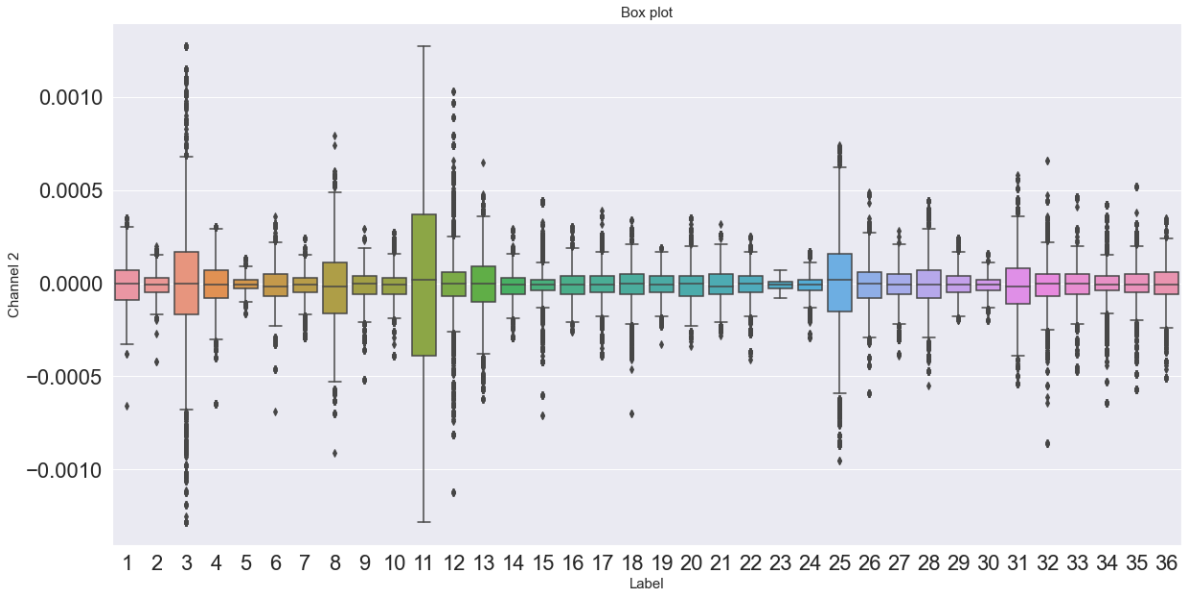
In [58]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel1',data=class5)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 1',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



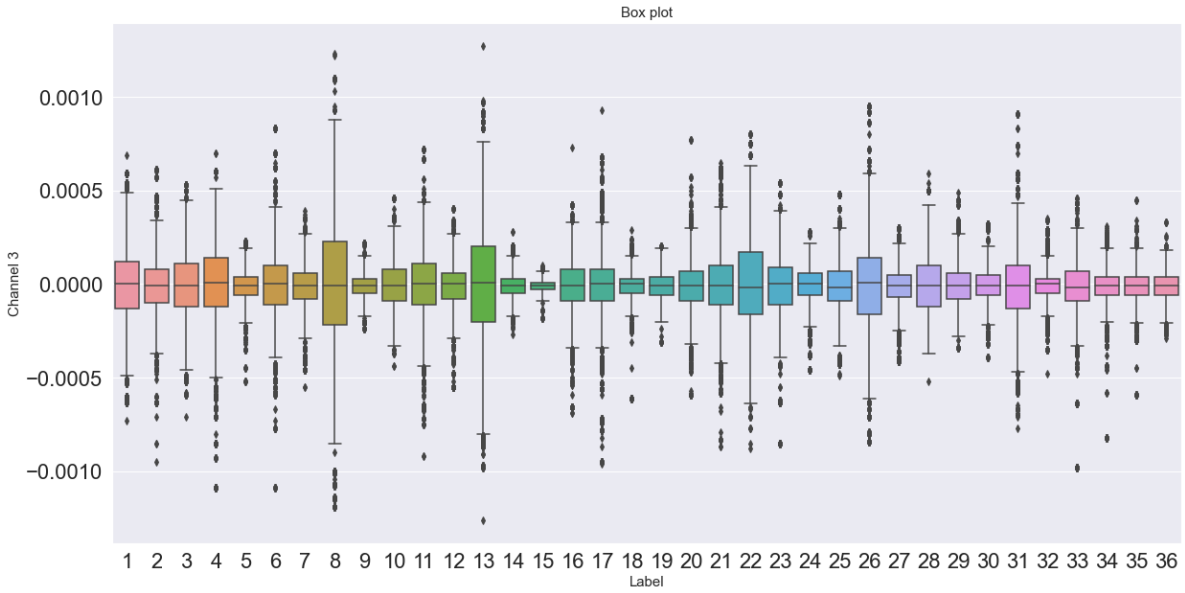
In [59]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel2',data=class5)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 2',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



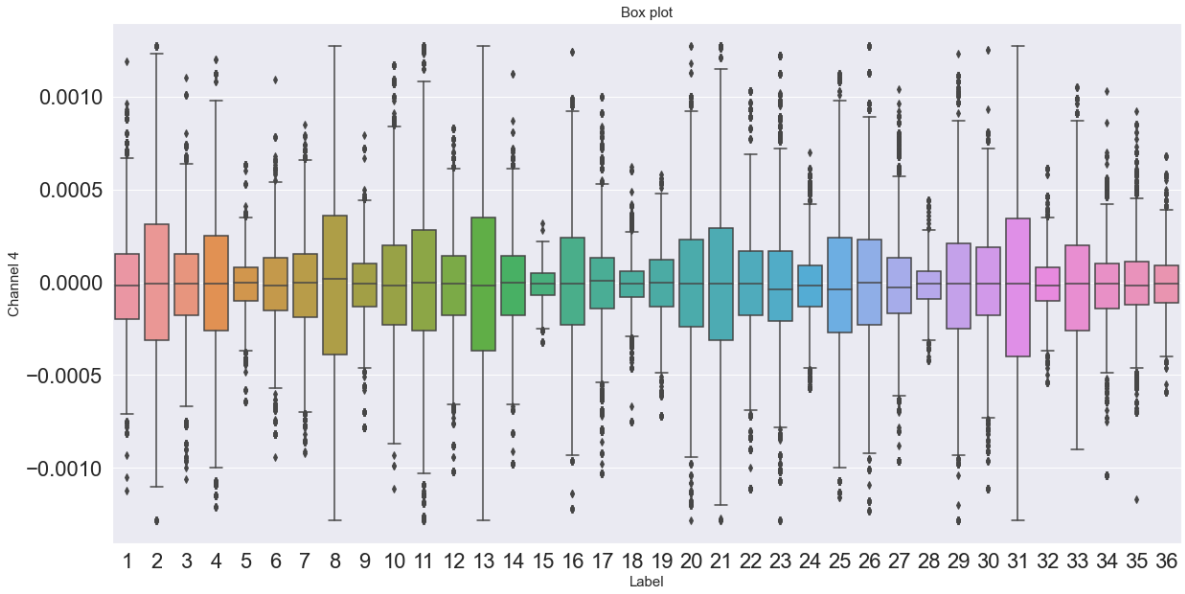
In [60]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel3',data=class5)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 3',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



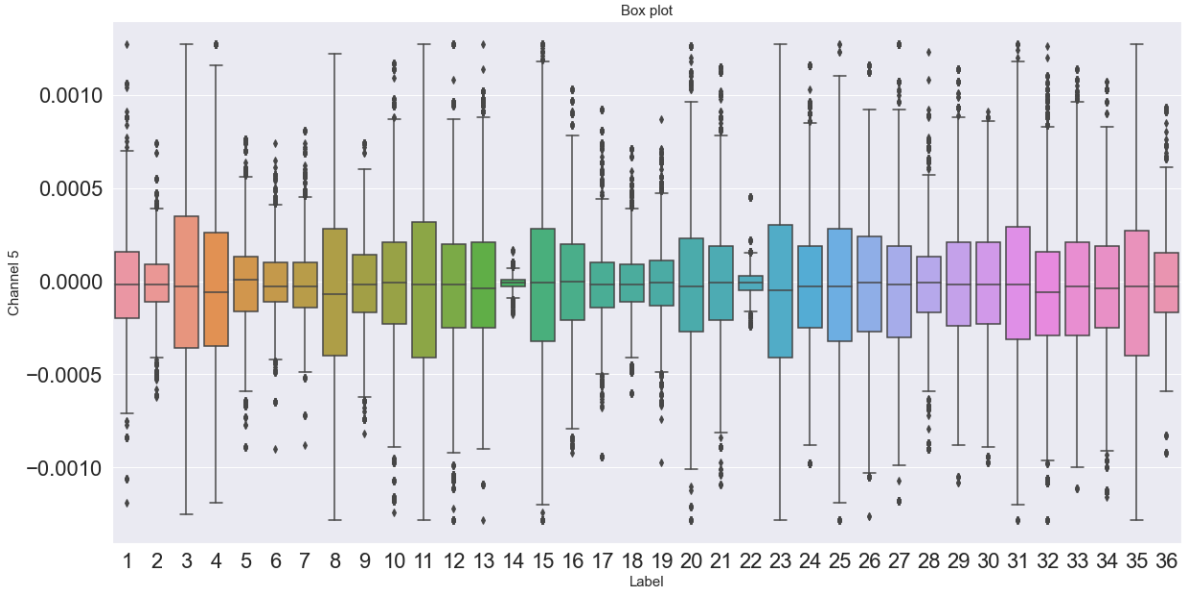
In [61]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel4',data=class5)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 4',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



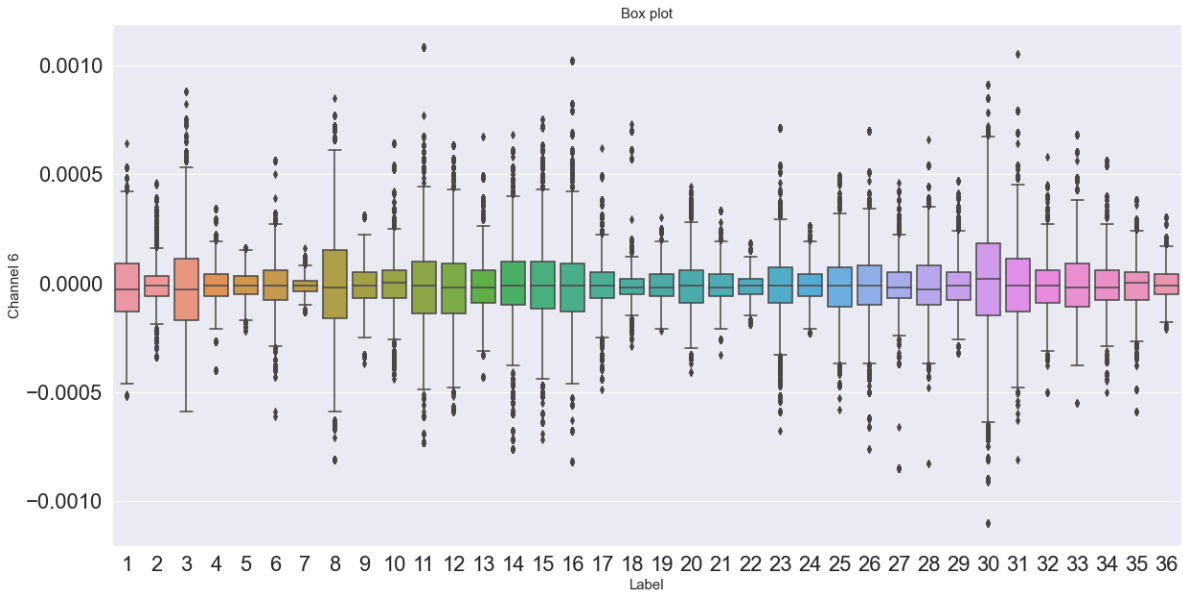
In [62]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel5',data=class5)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 5',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



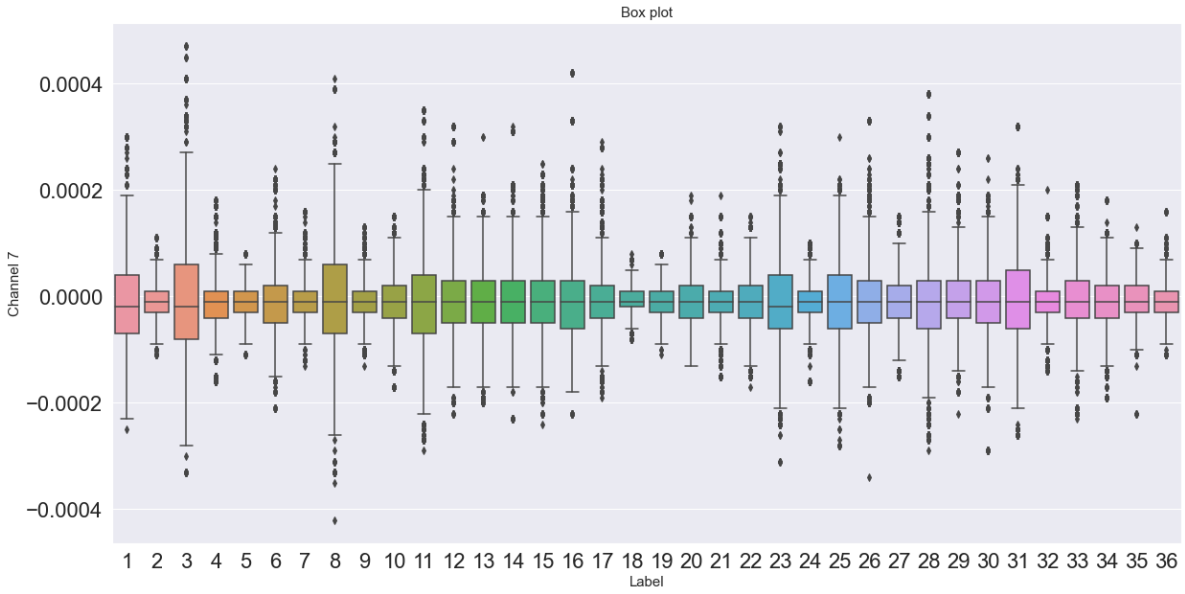
In [63]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel6',data=class5)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 6',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



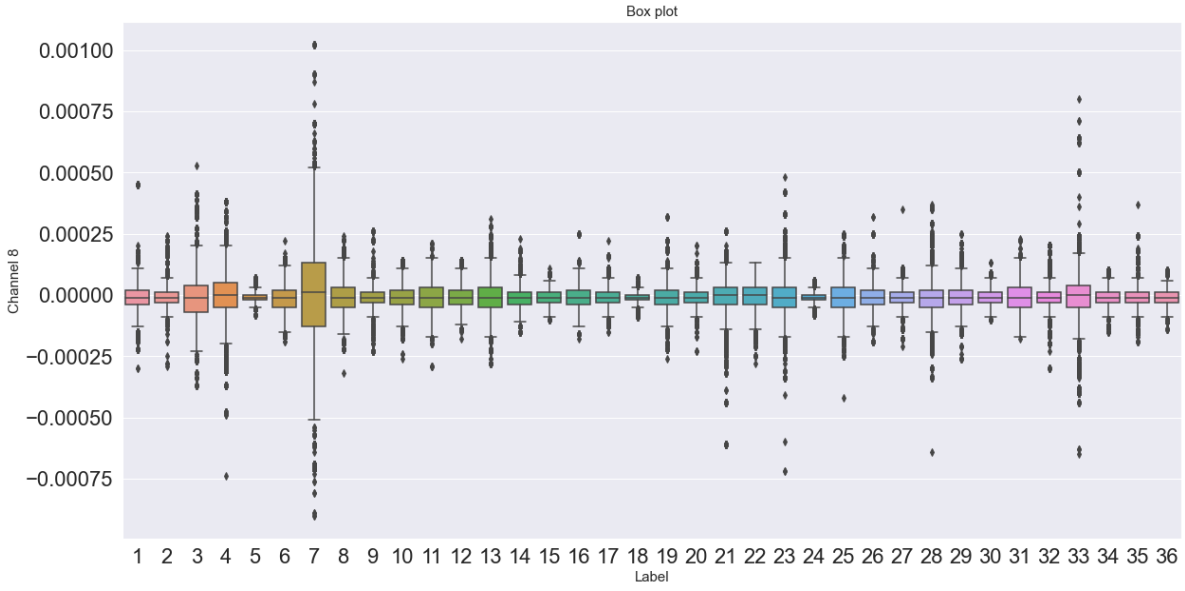
In [64]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel7',data=class5)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 7',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



In [65]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel8',data=class5)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 8',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



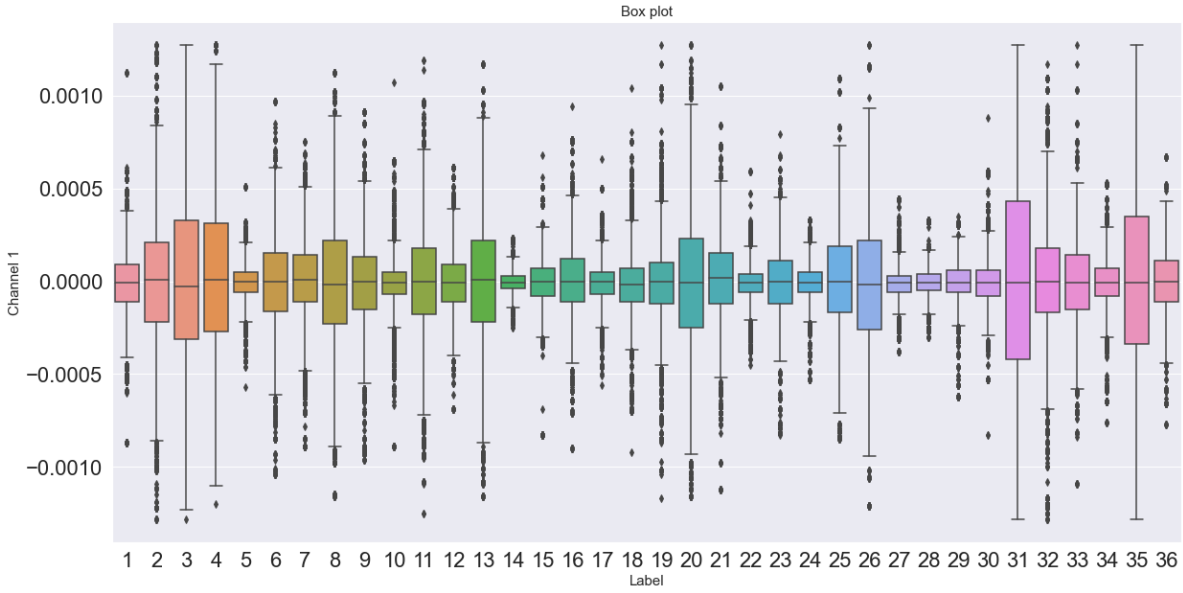
Boxplots of Class 6

In [66]:

```
class6=df[df['class']==3] # matrix with the class=6
```

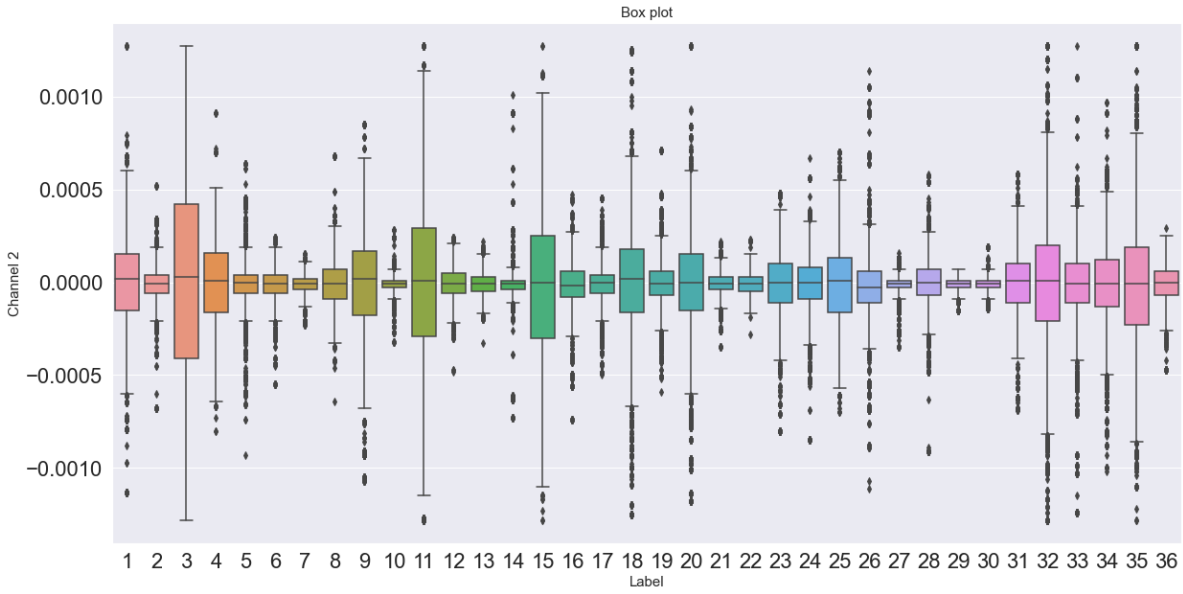
In [67]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel1',data=class6)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 1',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



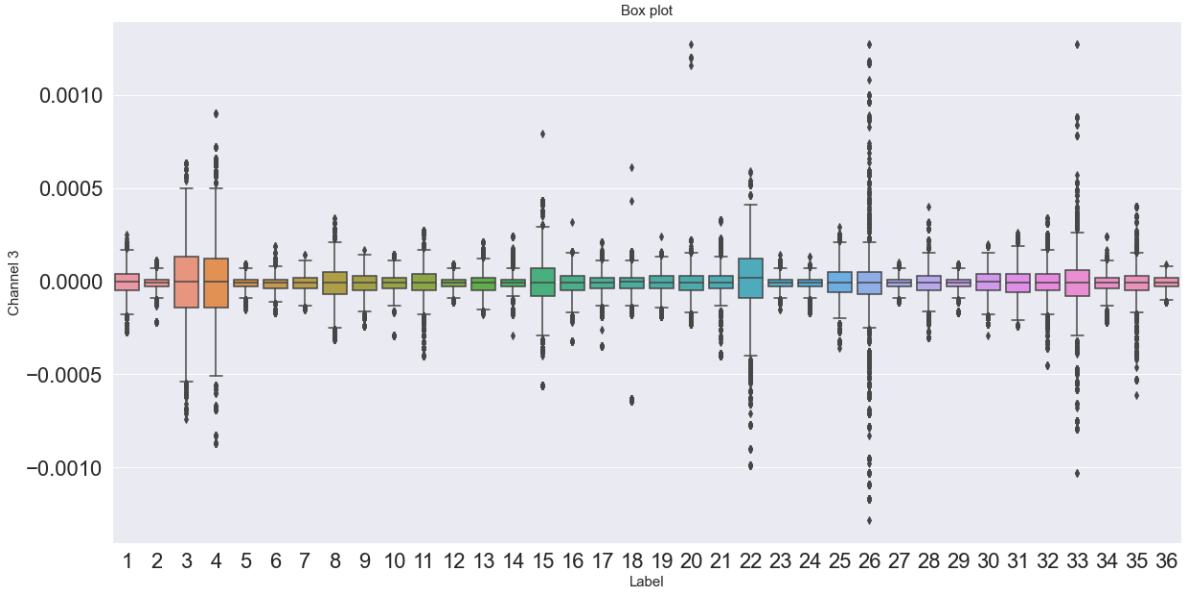
In [68]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel2',data=class6)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 2',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



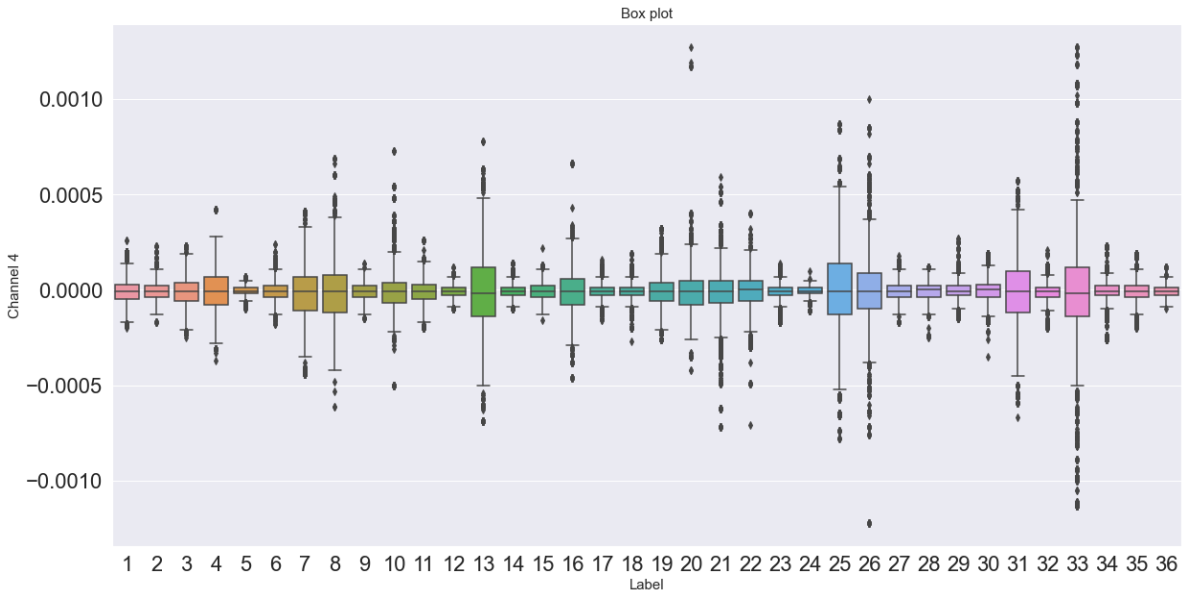
In [69]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel3',data=class6)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 3',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



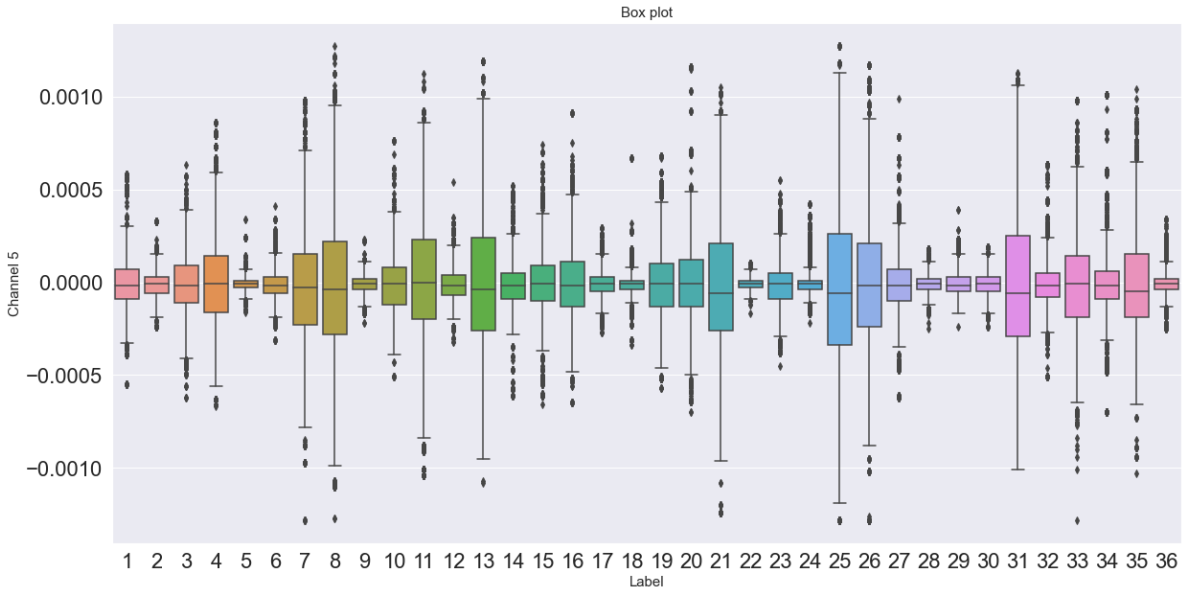
In [70]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel4',data=class6)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 4',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



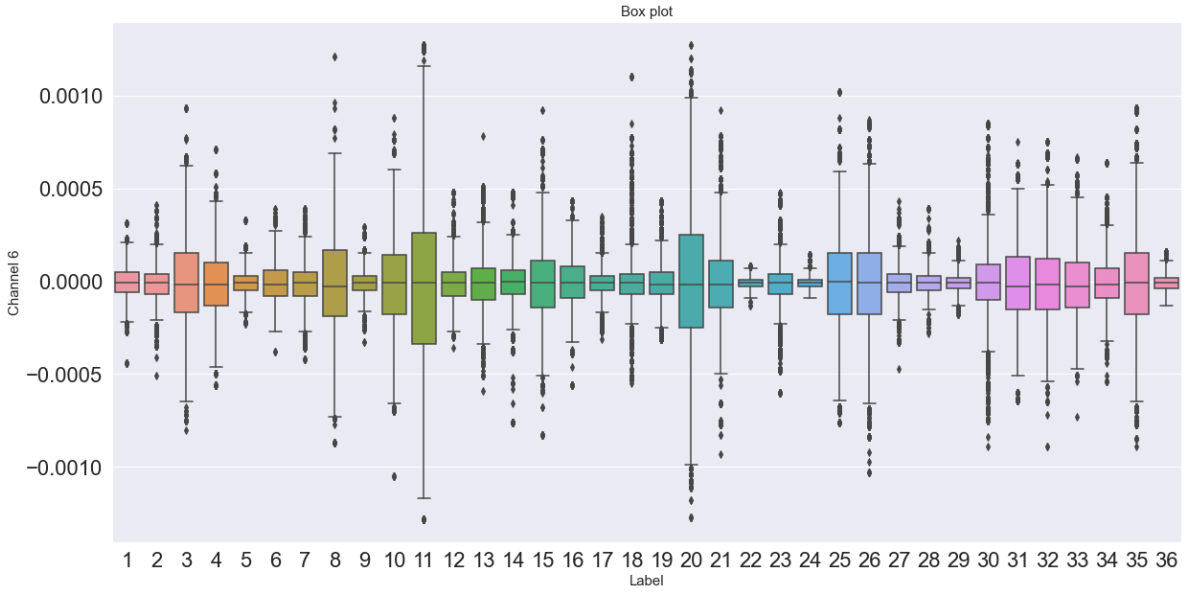
In [71]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel5',data=class6)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 5',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



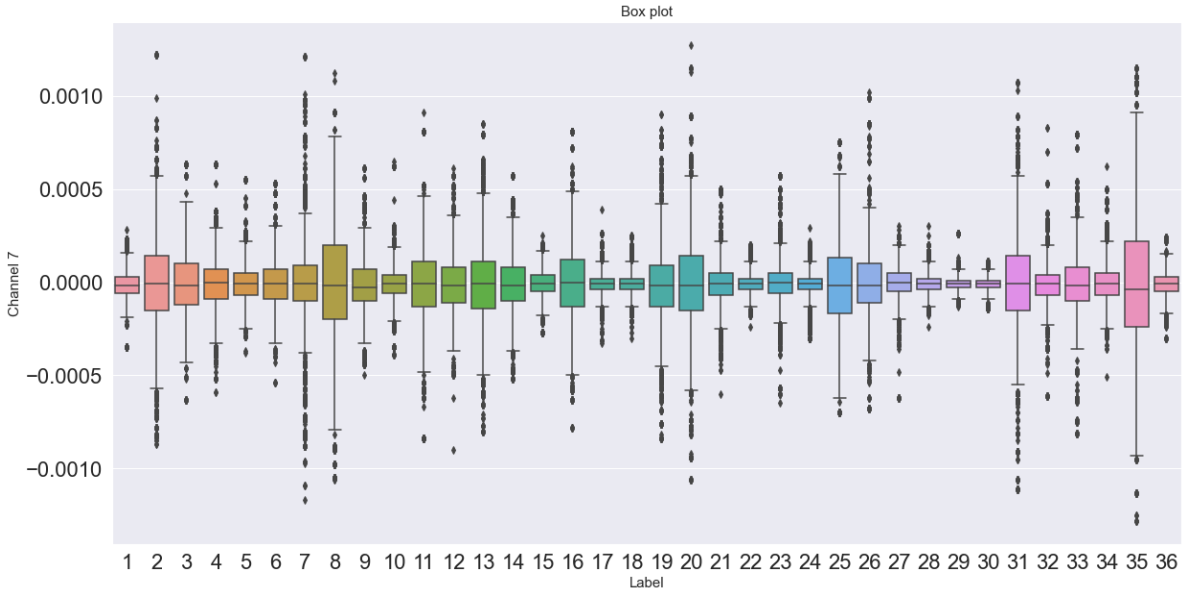
In [72]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel6',data=class6)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 6',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



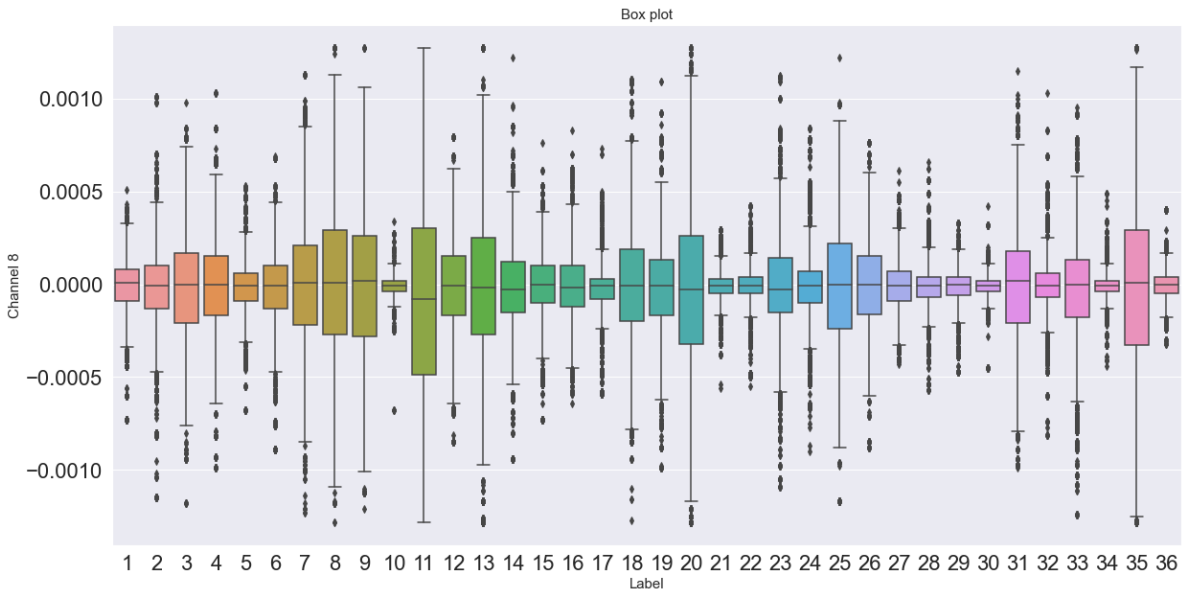
In [73]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel7',data=class6)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 7',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```



In [74]:

```
plt.figure(figsize=(20,10))
sns.boxplot(x='label',y='channel8',data=class6)
plt.xlabel('Label',fontsize=15)
plt.ylabel('Channel 8',fontsize=15)
plt.title('Box plot',fontsize=15)
plt.show()
```

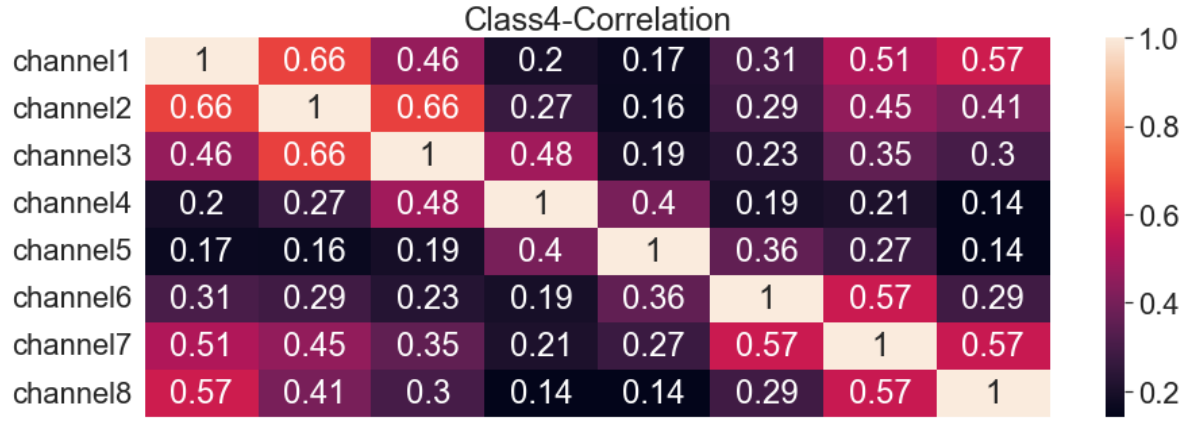


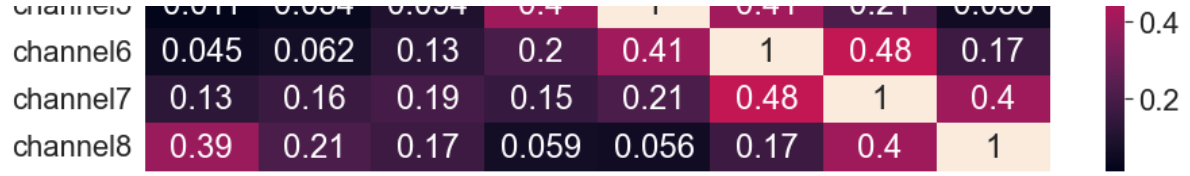
Data Analysis

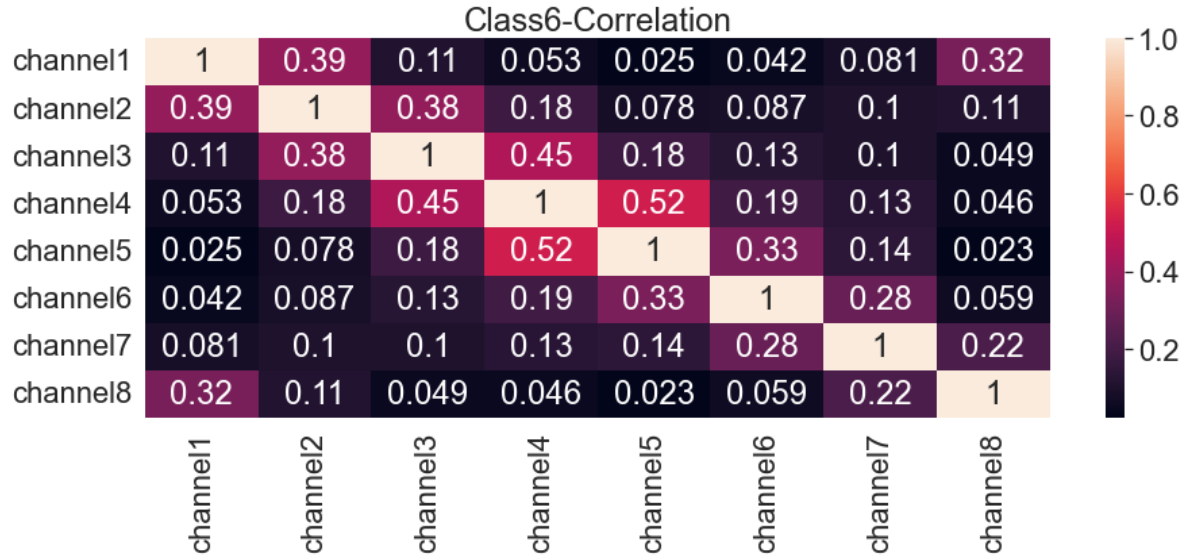
Heatmaps

In [75]:

```
fig, axes = plt.subplots(5,1, sharex=True,sharey=True, figsize=(15,30))
sns.heatmap(df[df['class']==2].drop(columns=['time','label','class']).corr(),annot=True,ax=
sns.heatmap(df[df['class']==3].drop(columns=['time','label','class']).corr(),annot=True,ax=
sns.heatmap(df[df['class']==4].drop(columns=['time','label','class']).corr(),annot=True,ax=
sns.heatmap(df[df['class']==5].drop(columns=['time','label','class']).corr(),annot=True,ax=
sns.heatmap(df[df['class']==6].drop(columns=['time','label','class']).corr(),annot=True,ax=
axes[0].set_title('Class2-Correlation');
axes[1].set_title('Class3-Correlation');
axes[2].set_title('Class4-Correlation');
axes[3].set_title('Class5-Correlation');
axes[4].set_title('Class6-Correlation');
```




channel6 0.045 0.062 0.13 0.2 0.41 1 0.48 0.17
channel7 0.13 0.16 0.19 0.15 0.21 0.48 1 0.4
channel8 0.39 0.21 0.17 0.059 0.056 0.17 0.4 1
0.4
0.2


Class6-Correlation
channel1 1 0.39 0.11 0.053 0.025 0.042 0.081 0.32
channel2 0.39 1 0.38 0.18 0.078 0.087 0.1 0.11
channel3 0.11 0.38 1 0.45 0.18 0.13 0.1 0.049
channel4 0.053 0.18 0.45 1 0.52 0.19 0.13 0.046
channel5 0.025 0.078 0.18 0.52 1 0.33 0.14 0.023
channel6 0.042 0.087 0.13 0.19 0.33 1 0.28 0.059
channel7 0.081 0.1 0.1 0.13 0.14 0.28 1 0.22
channel8 0.32 0.11 0.049 0.046 0.023 0.059 0.22 1
1.0
0.8
0.6
0.4
0.2
channel1
channel2
channel3
channel4
channel5
channel6
channel7
channel8

In [ ]: