TUNER INTERNSHIP REPORT

Muhammad Farhan

<u>Table of Contents</u>

Preface

In this internship, I designed and tested a software solution for the design and testing of automation of a High-Frequency Amplifier via the use of a Microwave Tuner using the LabVIEW software, which is a GUI based Programming Language.

The first phase was the design of tuner characterization module which would characterize the Maury Microwave Tuner at every position of the probe along the slider, denoted by L, P1 and P2 by measuring the Scattering parameters using a Rhode and Schwarz network analyzer. The information was then stored in a file with extension (.tun) which was also specifically designed for this purpose. This phase broadly involved creating a software on LabVIEW for purpose of creating interface between Maury Microwave Tuner and Rhode and Schwarz Network Analyzer, and make them operate in synchronization while storing all the measurement data to be exported later as a file.

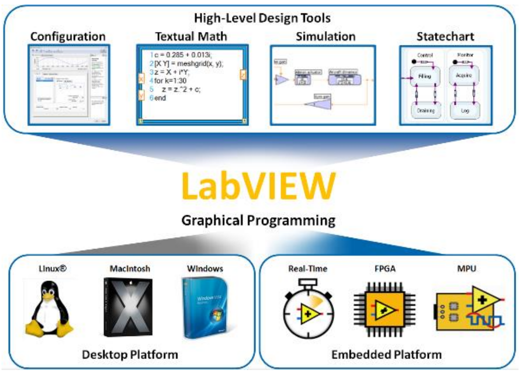
The second phase was concerned with the measurement of reflected power and transmitted power from the operational amplifier under test, for that purpose we used the Power Meter, Marconi signal generator for the purpose of generating Input signal for the amplifier and the DC power supplies to bias the amplifier, all coupled with the microwave tuner to create the desired S-Parameters at the output of the amplifier. This signal was generated by Marconi signal generator at varying frequencies with the power meter measuring the Power parameters and the tuner moving at a particular position as mentioned in the (.tun) file, the HP power supplies were used to bias the amplifiers.

In both of the cases an automation regime was developed so as to eliminate the need for any human intervention or measurement, with the end result being a (.tun) or (.spl) file generated by the software at the end, as was specified by my employer.

Equipment Used

In the course of this setup design, the following pieces of equipment were utilized:

1. Labview Software with DAC

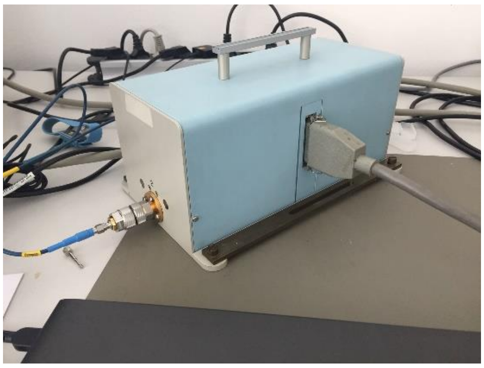


Labview is a graphical programming language which is used mainly for development of GUI for instrumentation systems. The DAC or data acquisition here is connected to GPIB bus where each instrument is given a unique identity to communication with the Labview software installed. The version of labview used is labview 2015 student edition.

2. Rhode and Schwarz Network Analyzer

The network analyzer is used to generate sp2 files or to measure the values of S-parameters at one or many frequencies as per the mode selected in its memory. The model used was R&S VNA ZVC with range 20 khz to 8 Ghz.

3. Maury Microwave Tuner



A microwave tuner is used to provide desired S-parameter values by being moved alog the along to desired position. The model used here is Maury Tuner MT982B.

4. HP Power Supply (HP 4142B)

A DC source is used here to give a desired voltage at the output that doesn’t exceed the tolerance current specified individually for every port. The supply module used here is HP 4142B)

5. Marconi Signal Generator

A frequency generator is used to create a desired sine wave with specified amplitude, phase and frequency to act as an input to the amplifier. The model which we have used is Marconi 10khz to 8Ghz 2032.

6. Power Meter

The power meter is used here to measure the power at port A and port B as per the calibration factor and the offset specified. The model which we have used is HP 438A.

Tuner Characterization Module

This objective of this part of the project was to develop a software to move the tuner probe to a desired position in terms of Length (L) and Probe Cross-section given by P1 and P2. This is followed by reading the stored instrument state in the Network Analyzer. The software then subsequently moves the tuner to a desired position on the railing and proceeds to record the values of S-Parameter while storing the values at every frequency in an array. Once all the position and all the frequencies at every position have been tested, the procedure terminates and the sub-module of the program needed for the file generation scans through the stored array and examines the limits on the length dimensions of L, P1 and P2 to give the file with fundamental up to third harmonic mentioned at every position.

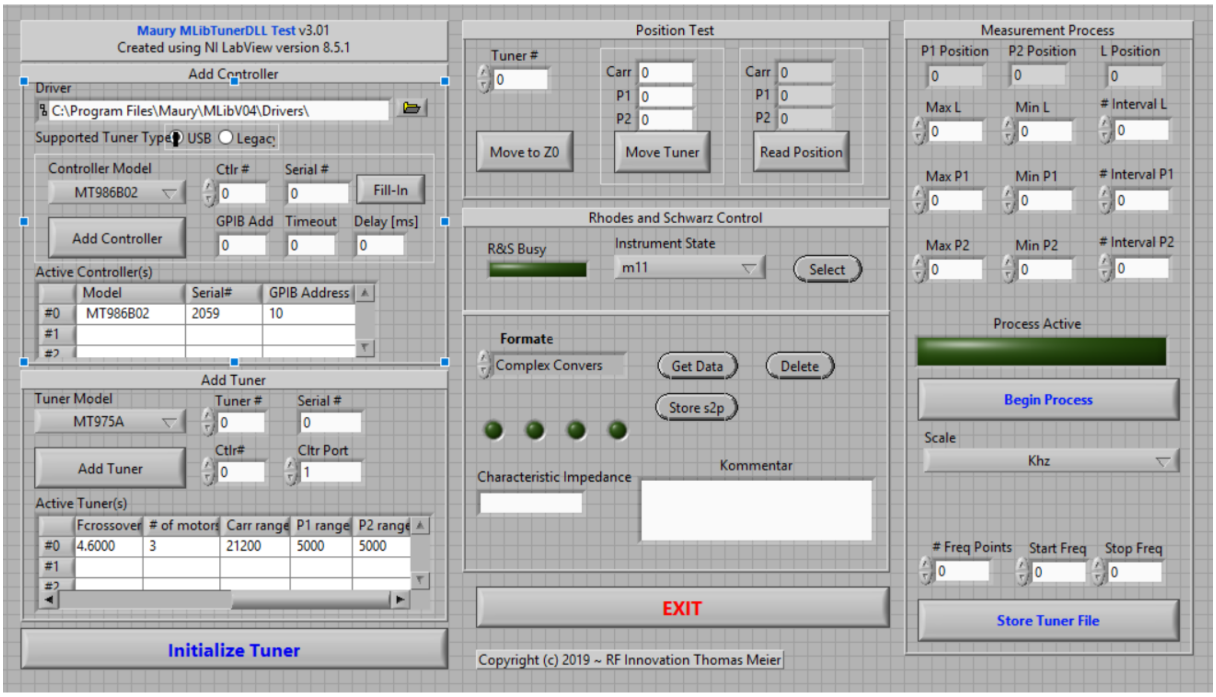
The Design Flow Algorithm:

The algorithm which we follow for the automation process can be summarized by the steps given below:

1. Upon execution of the software, a signal is send to the Vector network Analyzer to retrieve all the instrument states that have been stored in its memory.
2. The user then has option to initialize the tuner (i.e move it to position L = 1000, P1 = 250 and P2 = 250) or to move it to a desired position as shown in the GUI
3. The User also has the option to registering the scattering parameters at the particular position on the tuner by moving it to a particular position and pressing the button make .s2p.
4. The user then inputs the range and increment of L,P1 and P2 parameters to be moved by the tuner and the position where the readings are to be taken as well.
5. Once the procedure has ended, the user specifies the start, end and the increments of the frequency to publish the results onto a tuner file

The GUI

The screenshot of the GUI is as shown below:



File Format for .tun

The file format for the .tun file is as shown below

```
Tuner file
MT982EU30 demo mode
MT982EU30
Date/time Mon Sep 23 18:40:06 2019
Embedding: None
fstart,fstop,numfreq:  2.2000  2.6000  5 (Ghz)

Freq     2.200000 GHz,  1 positions,  default Gamma = 0.00000 0.00000
Range L P1 P2
Position   2000   2000   2000,  nselect = 1, pselect = 1
0.023117  -0.041748  -0.453370  -0.611563  -0.459289  -0.622368  0.053335  -0.026766
0.008360  -0.061775  -0.284304  0.597480  -0.290068  0.619379  -0.072708  0.034287
-0.040268  -0.023122  0.608396  0.012648  0.617424  -0.009975  0.075604  -0.008652

Freq     2.300000 GHz,  1 positions,  default Gamma = 0.00000 0.00000
Range L P1 P2
Position   2000   2000   2000,  nselect = 1, pselect = 1
-0.030433  0.004606  -0.730025  -0.202741  -0.742236  -0.202877  0.026094  0.034373
0.045659  0.045279  0.515709  0.411930  0.520058  0.428359  -0.081281  -0.018803
-0.052199  -0.012313  -0.255255  -0.552553  -0.252069  -0.559926  -0.015227  0.009998

Freq     2.400000 GHz,  1 positions,  default Gamma = 0.00000 0.00000
Range L P1 P2
Position   2000   2000   2000,  nselect = 1, pselect = 1
0.049646  0.009399  -0.695119  0.285711  -0.701510  0.298210  -0.025926  0.023468
-0.047536  0.020564  0.522717  -0.387244  0.552950  -0.375796  0.026557  -0.026181
-0.027789  0.026220  -0.405160  0.438774  -0.451754  0.380387  0.092244  -0.005691

Freq     2.500000 GHz,  1 positions,  default Gamma = 0.00000 0.00000
Range L P1 P2
Position   2000   2000   2000,  nselect = 1, pselect = 1
0.006882  -0.001397  -0.366552  0.652487  -0.360863  0.669119  0.025766  0.020623
-0.046498  -0.061180  -0.248696  -0.600260  -0.247589  -0.620838  -0.001870  0.093164
-0.029489  0.045765  0.553375  0.187693  0.561243  0.198824  -0.041361  0.056979

Freq     2.600000 GHz,  1 positions,  default Gamma = 0.00000 0.00000
Range L P1 P2
Position   2000   2000   2000,  nselect = 1, pselect = 1
-0.021324  0.011758  0.120112  0.736852  0.117934  0.748536  -0.018566  -0.008043
0.072178  -0.008129  -0.634838  0.103411  -0.655266  0.104057  -0.060611  0.028306
0.006785  0.046754  -0.063226  -0.558948  -0.105944  -0.581178  0.036132  -0.067285
```

The above shown Tuner file records all the values of S-Parameters at every frequency along all the selected positions on the GUI. The result is then organized as a list and published as a .tun file to be later used in Amplifier testing procedure by the following GUI.

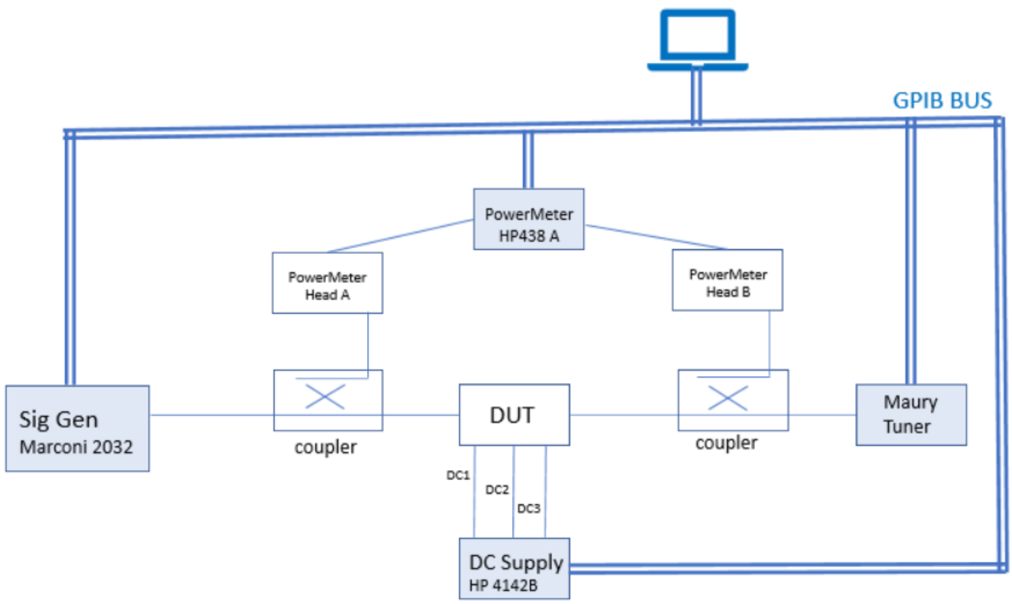
File Format for .s2p

```
! 11.12.2019 16:06:38
! C:\Users\Thomas\Desktop\the file.s2p
!
! Startfrequenzy: 8,500000E+8 Hz    Endfrequenzy: 2,850000E+9 Hz    Steps: 82
!
! Channel:              1                       2                       3
! Force Setting:        OFF                     OFF                     OFF
!
! Forced Start:
! Forced End:
! Read Start:
! Read End:
!
!
!
# GHz S RI R 50
! Freq.GHz      S11RE           S11IM           S12RE           S12IM           S21RE           S21IM           S22RE           S22IM
0.850000        -0.001279       -0.008891       -0.812459       0.170875        -0.849135       0.165698        0.002151        -0.017594
0.900000        0.008086        -0.016029       0.481253        -0.672853       0.506162        -0.695860       -0.001894       0.000983
0.950000        -0.028249       -0.006411       0.103244        0.816281        0.099834        0.851085        -0.030301       -0.001161
1.000000        -0.009808       -0.045819       -0.627305       -0.526514       -0.642905       -0.555441       0.034888        -0.008899
1.050000        -0.004431       0.010208        0.814663        -0.038652       0.844918        -0.032628       0.006466        0.013444
1.100000        -0.008032       -0.006321       -0.571748       0.581045        -0.594836       0.594673        -0.011811       -0.020072
1.150000        -0.032394       -0.006633       0.027288        -0.807091       0.041996        -0.834988       -0.040504       -0.004046
1.200000        0.001582        -0.001140       0.524091        0.609958        0.532010        0.638667        -0.009787       -0.019328
1.250000        0.003990        -0.015007       -0.797534       -0.091083       -0.822322       -0.104715       0.002140        -0.017889
1.300000        0.004922        -0.020680       0.644933        -0.472144       0.673264        -0.479454       -0.019166       -0.008495
1.350000        0.016838        0.027759        -0.151785       0.777964        -0.168521       0.802503        0.021656        -0.042171
1.400000        -0.007441       0.005630        -0.409642       -0.674961       -0.421804       -0.702999       -0.015075       -0.013515
1.450000        -0.016939       -0.016614       0.755786        0.219490        0.781376        0.231884        0.033299        -0.013025
1.500000        -0.018269       0.001175        -0.703561       0.350638        -0.731163       0.355548        0.020732        -0.005514
1.550000        0.020316        -0.017897       0.278283        -0.731655       0.298681        -0.750655       0.000691        0.011442
1.600000        0.007930        -0.003151       0.289906        0.723249        0.293584        0.750278        -0.002998       -0.018233
1.650000        0.016645        -0.035247       -0.697450       -0.336829       -0.718194       -0.348271       0.010119        -0.038115
1.700000        -0.022849       -0.011470       0.739064        -0.225232       0.764320        -0.229616       0.015605        -0.018619
1.750000        -0.023939       -0.020047       -0.395224       0.662610        -0.405962       0.681177        -0.026751       -0.017952
1.800000        0.014914        -0.014241       -0.161765       -0.750150       -0.161077       -0.773655       0.027502        -0.017708
1.850000        -0.004752       -0.015679       0.623106        0.441865        0.643136        0.458372        0.019304        -0.007201
1.900000        -0.025637       0.021670        -0.754048       0.099603        -0.777686       0.097679        0.038540        0.024733
1.950000        0.014813        0.012475        0.486246        -0.587040       0.501500        -0.602254       0.021296        0.017186
2.000000        0.033666        0.011434        0.032468        0.759663        0.037410        0.781045        0.040211        -0.020958
2.050000        0.017100        -0.032316       -0.534624       -0.533938       -0.537676       -0.556896       0.036538        -0.019593
```

The above file shows the the start, stopping and the frequency increments at which the measurements of the .s2p parameters are measured and stored.

Measurement Module

In this part of the project, the amplifier being tested was to be characterized as such the reflected and transmitted power was to be measured at every frequency with the Tuner acting as a load, which was already characterized. The broad setup is as shown below:



The Design Flow Algorithm:

1. The user inputs Tuner Calibration file location, then selects: span of L,P1 and P2 from the file; Frequencies to be tested; Pin-max, Pin-min and increment; Power Meter port A and B offsets; Power Meter port A and B calibration factors; values of I and V for DC1,DC2 and DC3.
2. The loop process then starts and is as follows:

   - Preset all instrument
   - Set Power meter parameters offsets and cal factor
   - Set frequency
   - DC1 on, wait 0.5sec DC2 on, wait 0.5sec DC3 on
   - Measure DC3: I3=Icq (no RF power!)
     - ➢ Loop for tuner settings L
       - • Loop for P1
         - o Loop for P
           - Loop for Pin = Pin, min to Pin, max
             - ▪ Find Pin: description given separately
             - ▪ Measure I1, V1, I2, V2, I3, V3
             - ▪ Measure Pout
             - ▪ Create data set for spl file, format below
         - o Next Pin
       - • Next P2
     - ❖ Next P1
   - ➢ Next L

3. Procedure for Pin is as follows:

Find Pin:

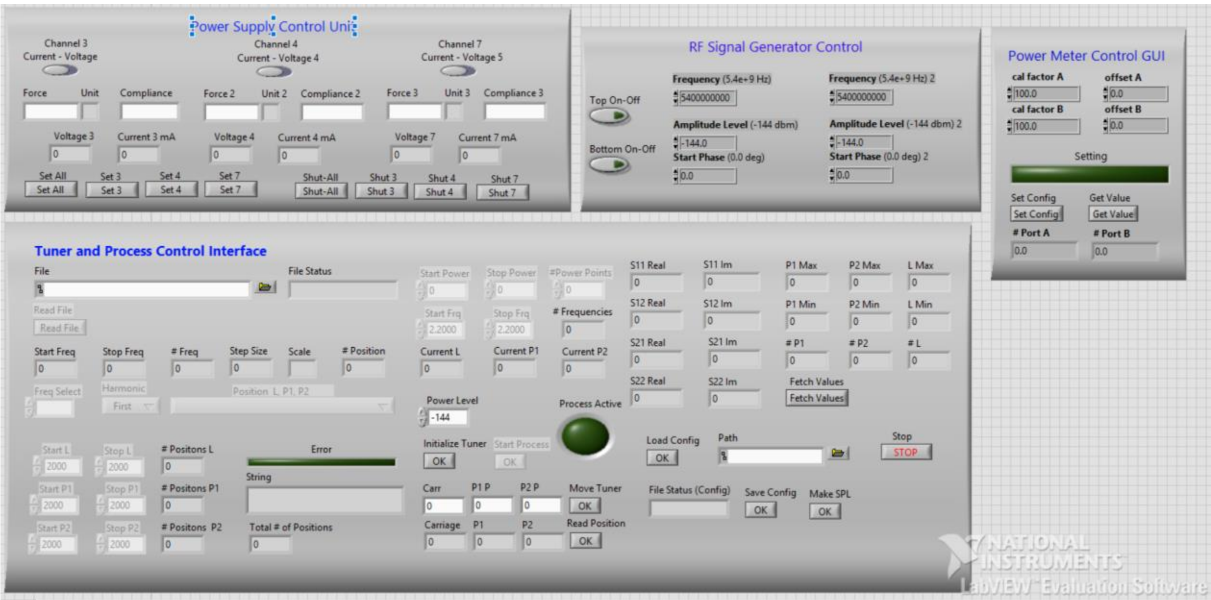
RF level= -100dBm

Set SigGen to RF level
Measure Power Head A
If measured power < (target Pin- 10dB) then RF level= RF level+10dB
elseif measured power < (target Pin- 1dB) then RF level= RF level+1dB
elseif measured power < (target Pin- .1dB) then RF level= RF level+.1dB
elseif measured power < (target Pin- .05dB) then RF level= RF level+.05
elseif exit loop
end if

4. Create .spl file as per format

The GUI

The screenshot of the GUI is as shown below:



File Format

The file format for the .spl file is as shown below

```
! Power sweep plan data file
!
!
Number of Frequencies = 1
Number of Variables = 2
VAR=<F1 Load Gamma>, Units=<>
VAR=<Pin_avail>, Units=<dBm>
! Freq  Points per VAR
2.500 122 25

Freq = 2.500 GHz
num_src_harmonics = 1, num_ld_harmonics = 1
valid gamma_src1 gamma_ld1 Freq Pin_avail_dBm Pin_deliv_dBm Refl_coef Refl_dB Pout_dBm Gt_dB Iq_out_mA Vout_v Iout_mA Vin_v Eff_% trans_phase Gamma_in_mag Gamma_in_phase
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   20.00000  19.89685   0.15320 -16.29459  41.01352  21.01352 851.00000  28.00500 3011.00000   2.54937  14.86009 -165.94282   0.82253   160.011
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   21.00000  20.90821   0.14462 -16.79572  42.19582  21.19582 851.00000  28.00700 3501.00000   2.54936  16.78316 -166.17258   0.81967   160.039
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   22.00000  21.91973   0.13533 -17.37228  43.39906  21.39906 851.00000  28.00700 4011.00000   2.54936  19.33212 -166.67264   0.81648   160.060
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   23.00000  22.93098   0.12557 -18.02248  44.57882  21.57882 851.00000  28.00700 4601.00000   2.54935  22.11946 -167.04006   0.81307   160.083
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   24.00000  23.94244   0.11474 -18.80557  45.77680  21.77680 851.00000  28.00700 5271.00000   2.54937  25.44817 -167.84215   0.80921   160.110
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   25.00000  24.95366   0.10302 -19.74143  46.93859  21.93859 851.00000  28.00700 6021.00000   2.54937  29.11797 -168.66895   0.80494   160.142
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   26.00000  25.96353   0.09145 -20.77623  48.03666  22.03666 851.00000  28.00700 6831.00000   2.54940  33.05282 -169.63804   0.80044   160.149
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   27.00000  26.97304   0.07867 -22.08421  49.11420  22.11420 851.00000  28.00700 7751.00000   2.54938  37.33636 -170.97705   0.79522   160.156
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   28.00000  27.98384   0.06095 -24.30095  50.13026  22.13026 851.00000  28.00700 8771.00000   2.54939  41.69166 -172.88043   0.78718   160.161
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   29.00000  28.99230   0.04208 -27.51779  50.96233  21.96233 851.00000  28.00700 9761.00000   2.54937  45.36291 -175.39514   0.77402   160.134
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   30.00000  29.98735   0.05392 -25.36430  51.61115  21.61115 851.00000  28.00700 10691.00000   2.54938  48.06502 -178.51142   0.75207   160.240
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   31.00000  30.95480   0.10175 -19.84909  52.08691  21.08691 851.00000  28.00700 11541.00000   2.54938  49.63850 178.30332   0.72648   160.335
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   32.00000  31.90651   0.14594 -16.71666  52.46247  20.46247 851.00000  28.00700 12331.00000   2.54935  50.59888 175.52184   0.70399   160.239
1 -0.72898 -0.24602 -0.88305 -0.00701 2.500   33.00000  32.85832   0.17915 -14.93555  52.77056  19.77056 851.00000  28.00700 13111.00000   2.54936  51.01479 173.20170   0.68721   159.795
0
0
0
0
```

Conclusion

At the end of this Internship I was able to complete all the assigned work and in future the improvements by integrating a spectrum analyzer are also possible to observe and record the harmonics, as now in the current setup, only the positions for the harmonics are used to test the amplifier.