Lab 1: PN Junction Diode Parameter Extraction

ELEC 3908A – A3

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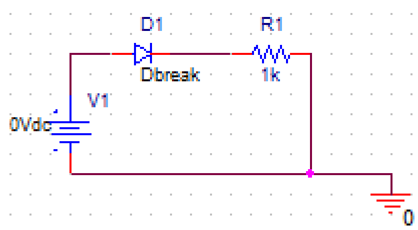
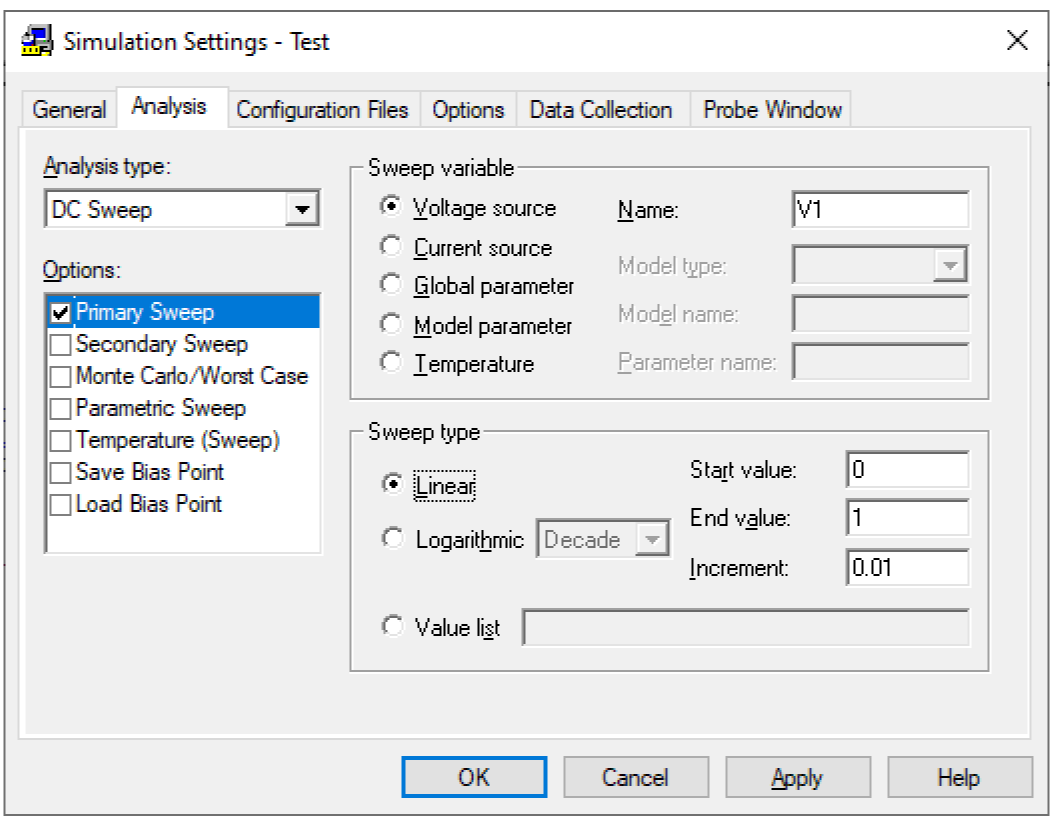
1.0 INTRODUCTION

The purpose of this lab is to use ORCAD Pspice 17.2 software to simulate current-voltage (I-V) characteristics of some generic P-N junction diodes. Then, the data collected will be used to extract the physical parameters of these devices. Then, create a neural-net based model to the data and compare it to the physical model.

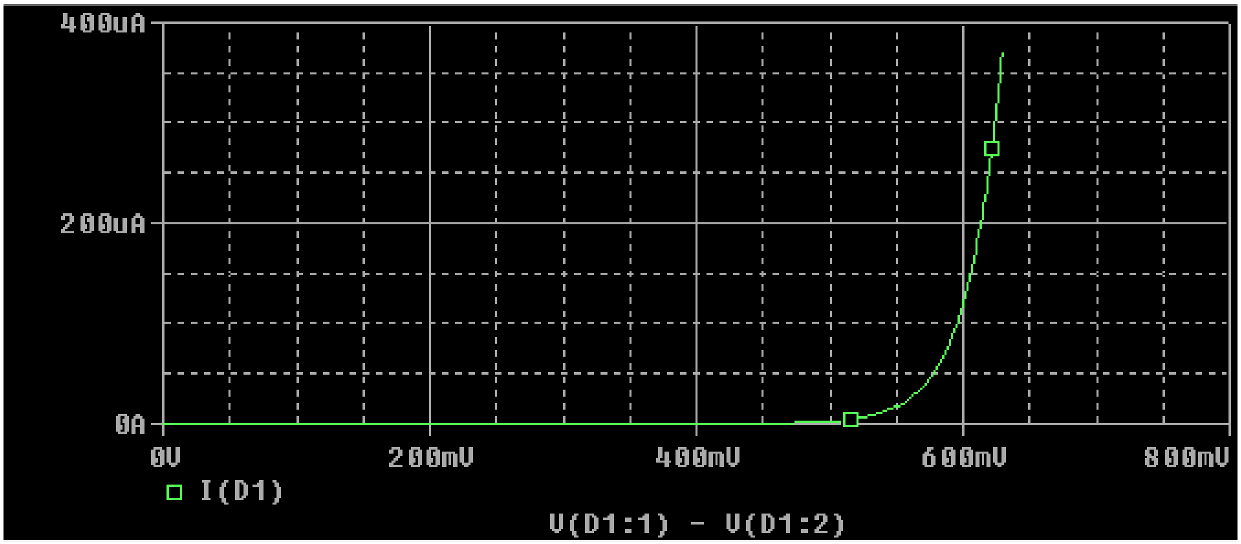
3.0 EXPERIMENT

3.1 Forward Linear I-V Characteristics

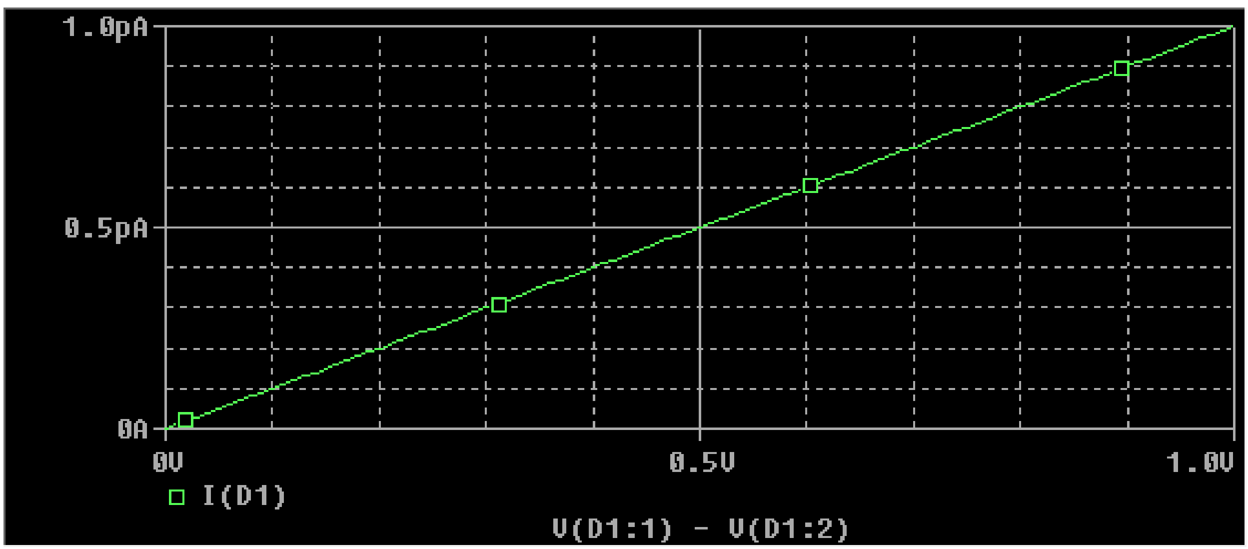




3.1.4

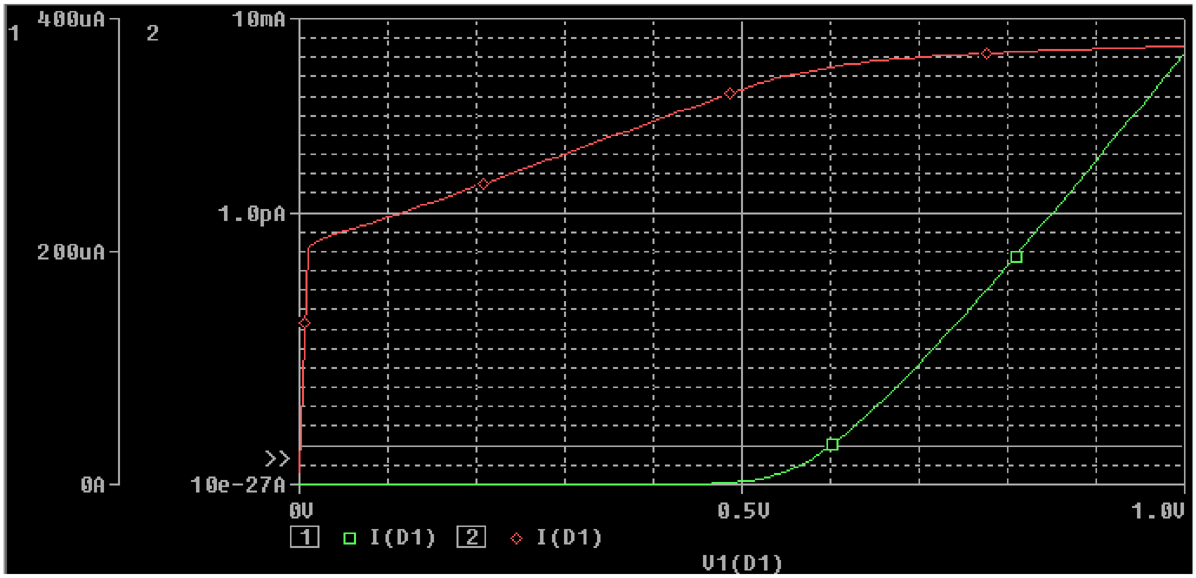


3.1.5 Is=3e - 42

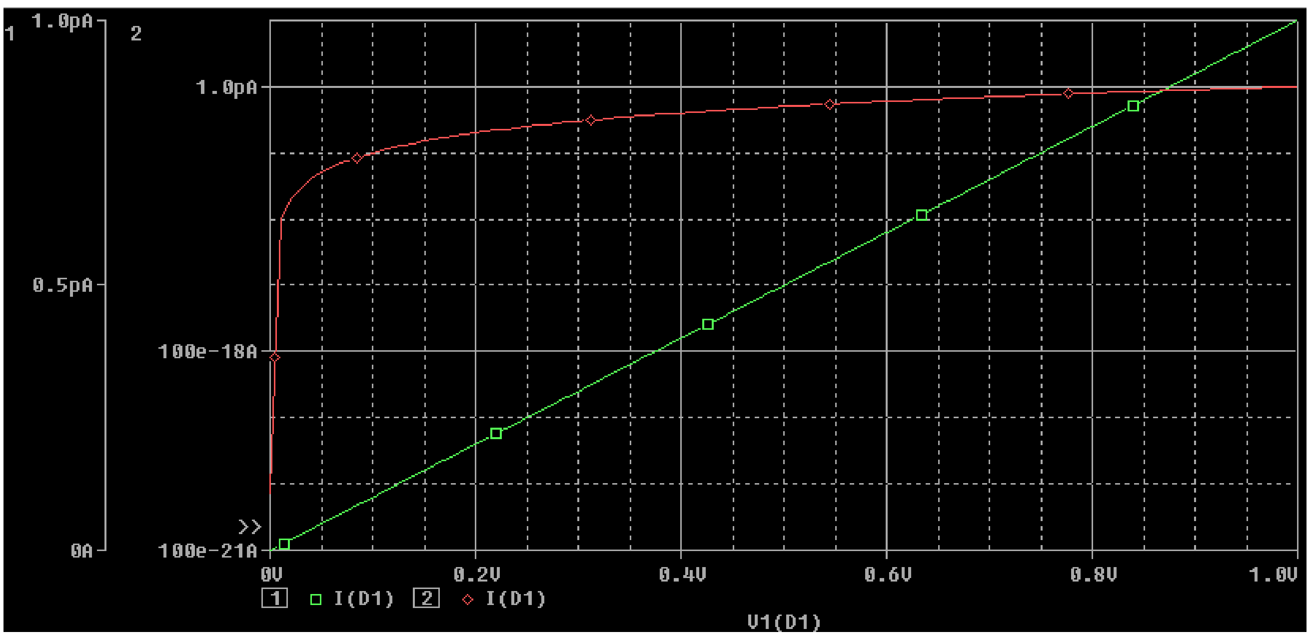


3.2 Forward Logarithmic I-V Characteristics

3.2.2

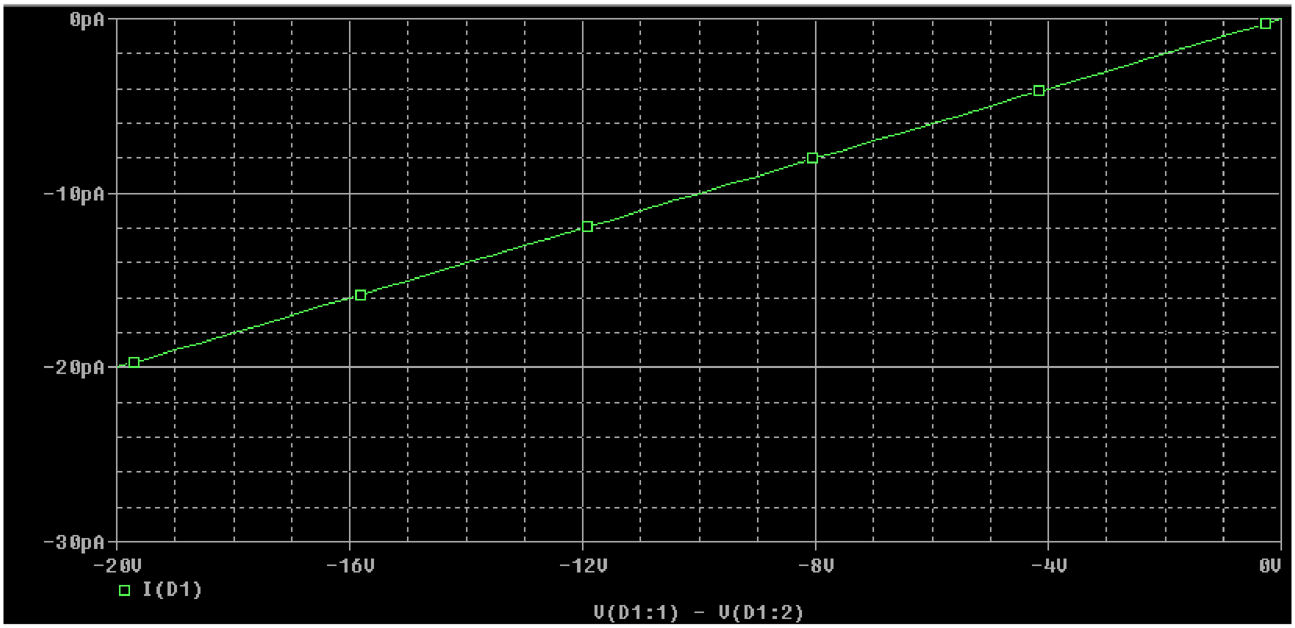


3.2.3 Is=3e - 42

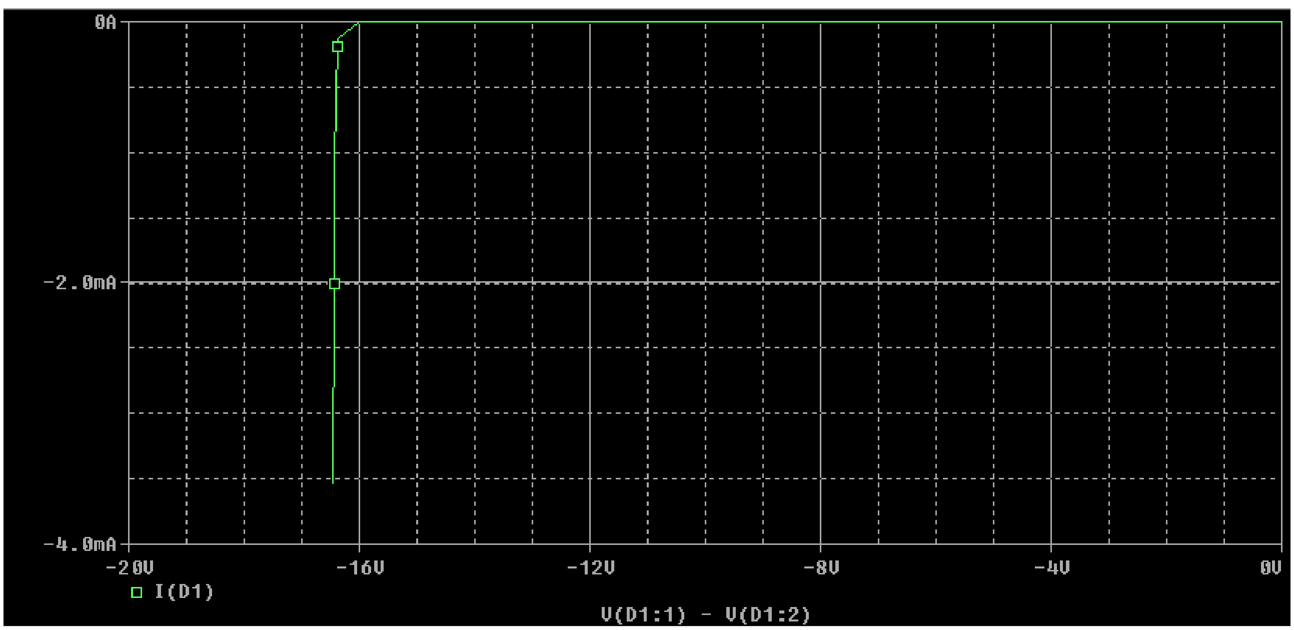


3.3 Reverse Linear I-V Characteristics

3.3.4

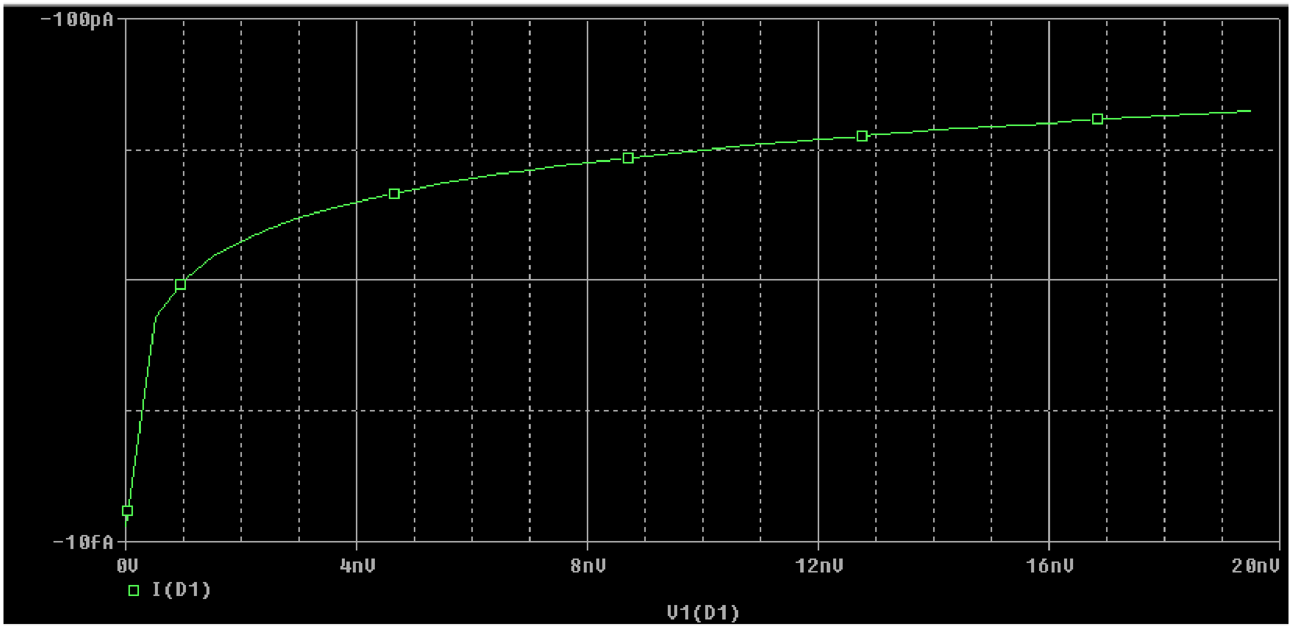


3.3.5 BV = 16

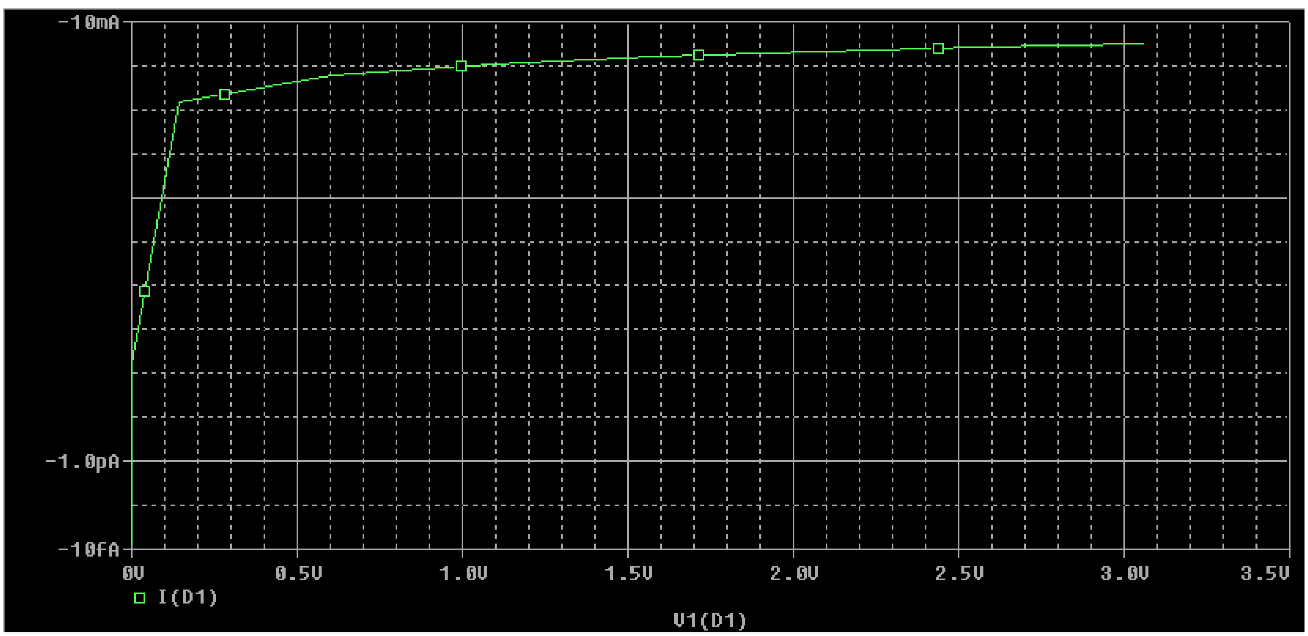


3.4 Reverse Logarithmic I-V Characteristics

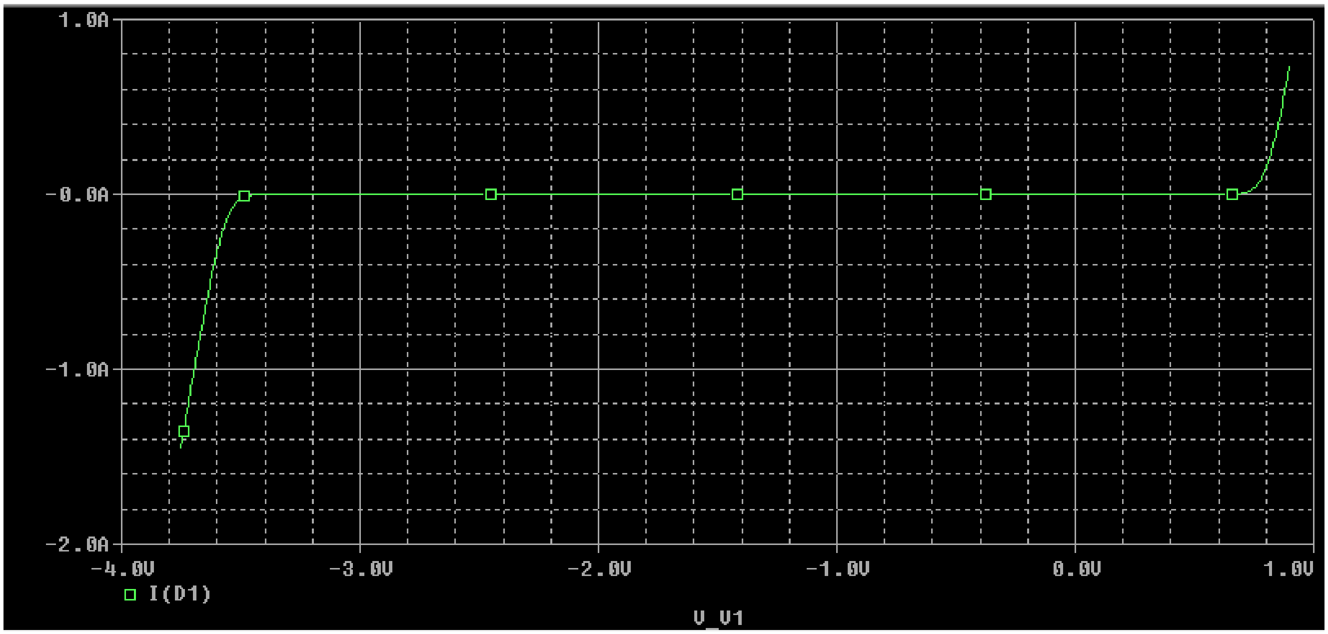
3.4.2



3.4.3



3.5 Full Diode Characteristics



4.0 ANALYSIS

4.1 MATLAB Data Import and Plotting

3.1.4

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..
>> voltage = Diode_Data(:,3)-Diode_Data(:,4);
current = Diode_Data (: ,2) ;figure ('Name','Measured Diode Data');
plot (voltage, current);
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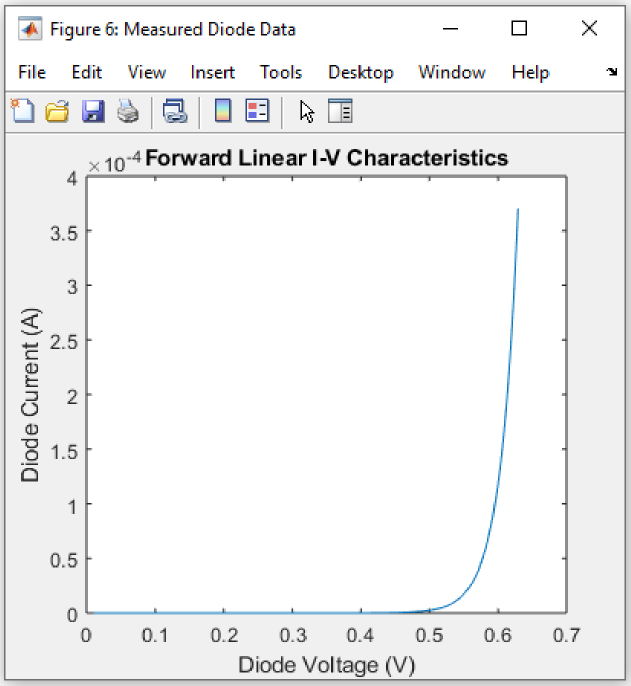

3.1.5

```
>> voltage = Diode_Data(:,3)-Diode_Data(:,4);
>> current = Diode_Data (: ,2) ;figure ('Name','Measured Diode Data');
plot (voltage, current);
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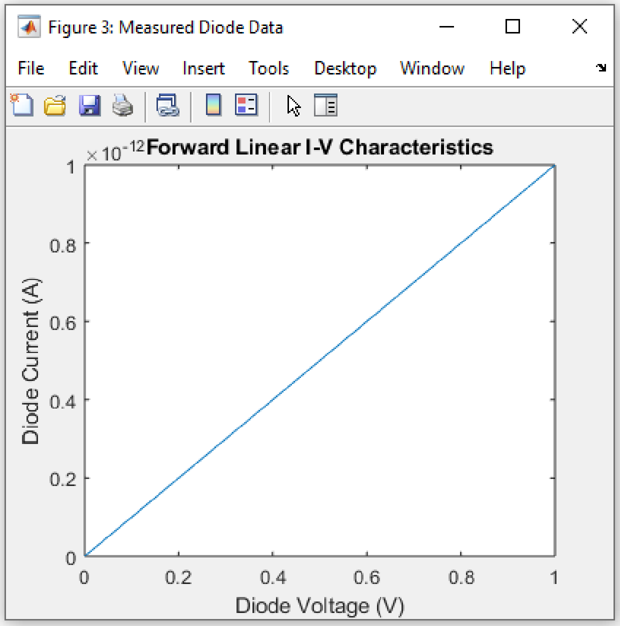

3.3.4

```
>> voltage = Diode_Data (: ,3) - Diode_Data (: ,4);
>> current = Diode_Data (: ,2) ;figure ('Name','Measured Diode Data');
plot (voltage, current);
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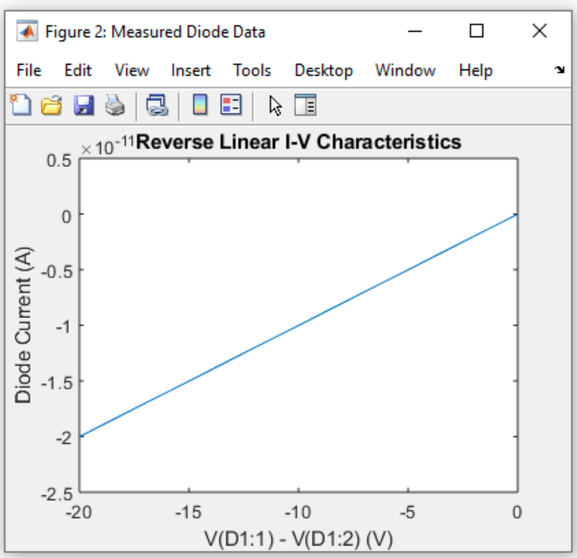
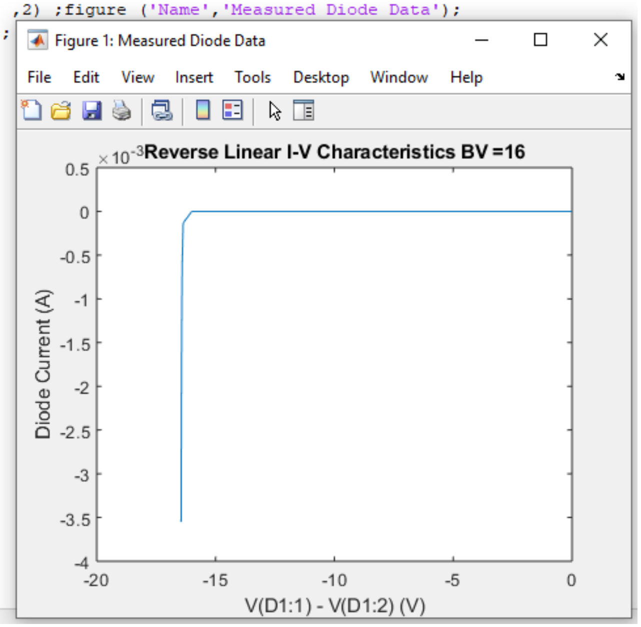


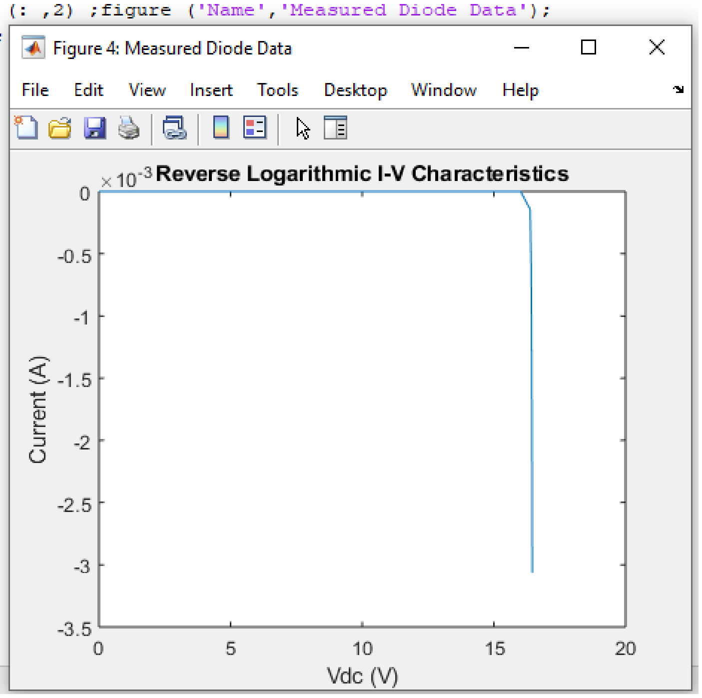
3.3.5

```
>> voltage = Diode_Data (: ,3) - Diode_Data (: ,4);
current = Diode_Data (: ,2) ;figure ('Name','Measured Diode Data');
plot (voltage, current);
>>
```



3.4.3

```
>> voltage = Diode_Data (: ,1) - Diode_Data (: ,3);
>> current = Diode_Data (: ,2) ;figure ('Name','Measured Diode Data');
plot (voltage, current);
>>
```



3.5

```
>> voltage = Diode_Data (: ,1) ;
>> current = Diode_Data (: ,2) ;figure ('Name','Measured Diode Data');
plot (voltage, current);
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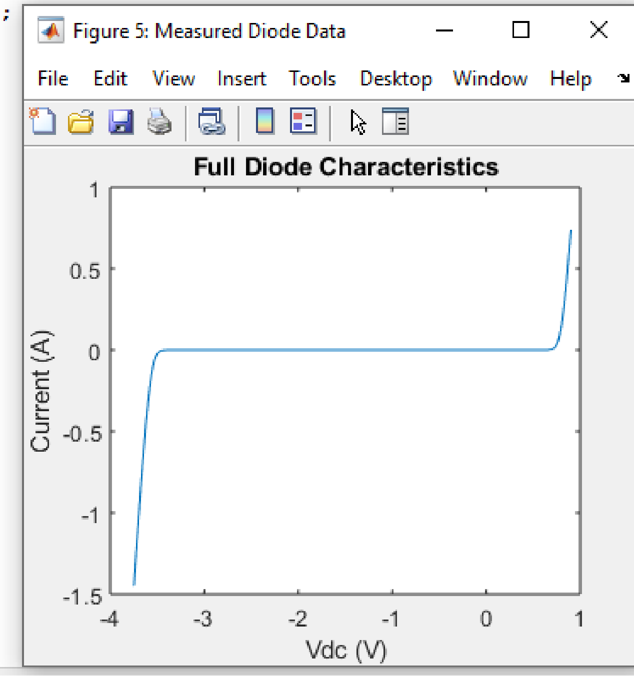


4.2 Parameter Extraction Using MATLAB

Forward

```
>> voltage = Diode_Data (: ,3) - Diode_Data (: ,4);logcurrentdata = log ( Diode_Data (: ,2) ) ;
>> linsectioncurrent = logcurrentdata ( 2 : 101 ) ;
>> linsectionvoltage = voltage ( 2 : 101 );
lincoefficients = polyfit ( linsectionvoltage , ...
linsectioncurrent , 1) ;
Slope = lincoefficients (1)
Yint = lincoefficients (2)

Slope =

    2.8658


Yint =

  -30.0461
```

Is = $e^{-30.0461}$ = 8.936 x 10^{-14}

Reverse

```
>> voltage = Diode_Data (: ,4) - Diode_Data (: ,3);
>> voltage = Diode_Data (: ,3) - Diode_Data (: ,4);
>> linsectioncurrent = logcurrentdata ( 2 : 41 );
>> linsectionvoltage = voltage ( 2 : 41 );
>> lincoefficients = polyfit ( linsectionvoltage , ...
linsectioncurrent , 1) ;
Slope = lincoefficients (1)
Yint = lincoefficients (2)

Slope =

   -0.1365


Yint =

  -30.8777
```

Is = $e^{-30.8777} = 3.890 \times 10^{-14}$

4.3 Forward Linear I-V Characteristics

1. Is there any evidence of series resistance in the forward linear I-V characteristics? If so, how does it manifest itself?

Looking at the forward linear I-V plot, it seems that there is no proof that the series resistance effect the plot, however at high voltages, it can be visible on the graph that series resistance does effect the forward linear I-V characteristics.

2. Estimate the “turn-on voltage” for the diodes? What would cause the turn-on voltage to differ between different diodes?

The turn-on voltage is approximately 0.65 V. The type of semiconductor used in the diode would cause the turn-on voltage to differ between different diodes.

4.4 Forward Logarithmic I-V Characteristics

1. Is the effect of series resistance in the forward logarithmic I-V characteristics more or less evident than in the linear characteristics?

The effect of series resistance in the forward logarithmic I-V characteristics is more evident than in the linear characteristics.

2. Are the log(ID) versus VD curves linear (for VD > 3kT q) as they would be in an ideal diode? What effects do you think would cause them to deviate from linear behavior

No, log(ID) versus VD curves are not linear for VD > 3kT q. Since the bulk resistance of the diode is at the higher currents that resistance effect the behavior of ID vs VD and hence current is reduced to a constant.

4.5 Reverse Linear I-V Characteristics

1. What important characteristics of the diodes were evident from the reverse linear characteristics?

The two important characteristics of diodes that were evident from the reverse linear characteristics is that the current stays very small until it reaches breakdown voltage, then the diode passes current in the reverse direction.

2. What conclusions can be draw between the forward bias data and the reverse bias data values?

The conclusion that can be drawn between the forward bias data and the reverse bias data values, is that during forward bias, there is a threshold voltage that needs to pass through the diode so the diode can allow current pass through it, before that threshold voltage is met, there is an infinite resistance in the diode which will not allow the current to get through, however in reverse bias, ideally no current will pass through the diode until breakdown voltage is reached.

4.6 Reverse Logarithmic I-V Characteristics

1. The diode equations in the theory section (equations 1,2 and 3) would indicate that we should expect a constant of IS that is independent of reverse bias voltage. Is this what we see? Give possible reasons for any discrepancies.

IS is independent of reverse bias voltage until breakdown voltage is reached and the diode starts allowing current to pass through. The reason for discrepancies is the material of the insulator used in the diode.

2. What are the 5 general types of diodes, there unique characteristics, and what application that they are used in?

- Light Emitting Diode (LED): When the diode is connected in forward bias, current flows through the junction and generates light. LED's function at minimal voltage levels so having a resistor in series is beneficial to restrict the amount of current passing through. LED's are used in TV Backlighting.
- PN Junction Diode: Is a standard diode that can be applied as small-signal types for use in radio frequency, or other low current applications.
- Schottky Diode: Has a lower forward voltage drop compared to PN junction diodes, it has a metal to semiconductor contact. Schottky diodes are used in rectifier applications.
- Tunnel Diode: It has a negative resistance, hence when voltage increases, current decreases. Tunnel diodes are used in microwave applications.
- Zener Diode: It is used to provide a stable reference voltage, works under reverse bias and forward bias conditions. It is used in power supplies.

4.7 Reverse I-V Data Collection

1. Attempt to estimate a reasonable value for IS for each of the diodes from the collected reverse bias data.

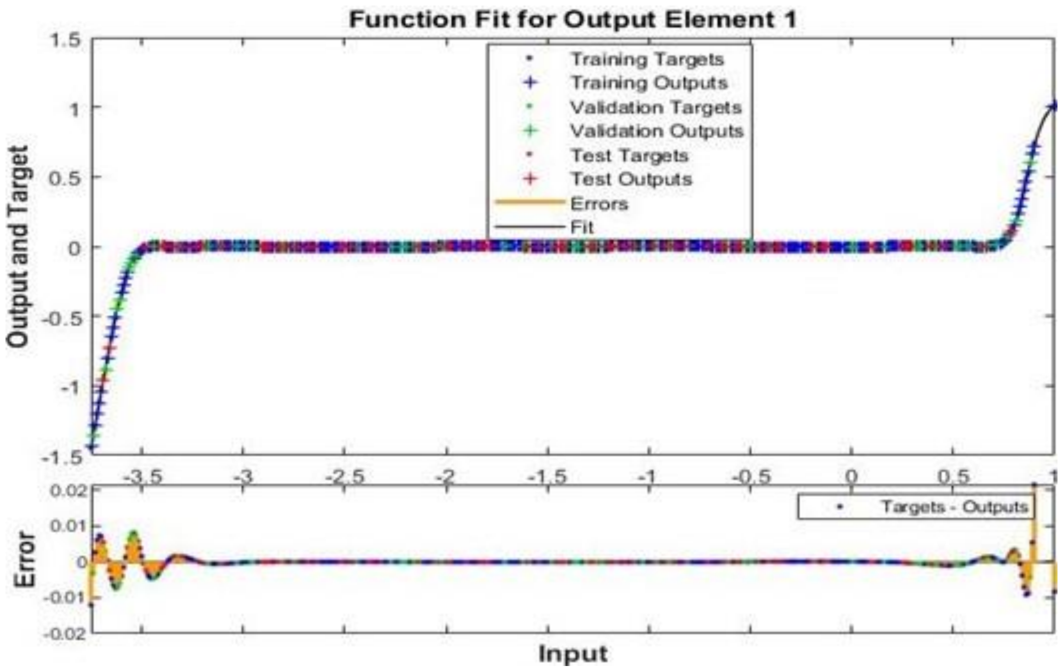
$$m = \frac{\Delta \ln\,(I_D)}{\Delta V_D}$$
$$m = \frac{ln(9\,pA) - ln(6\,pA)}{(9\,V) - (6\,V)}$$
$$m = 0.135$$

$$b = \ln(I_D) - m(V_D)$$
$$b = \ln(9\,pA) - 0.135(9\,V)$$
$$b = \ -26.649$$

$$I_S = e^b$$
$$I_S \ = e^{-26.649}$$
$$I_S \ = 2.670\ pA$$

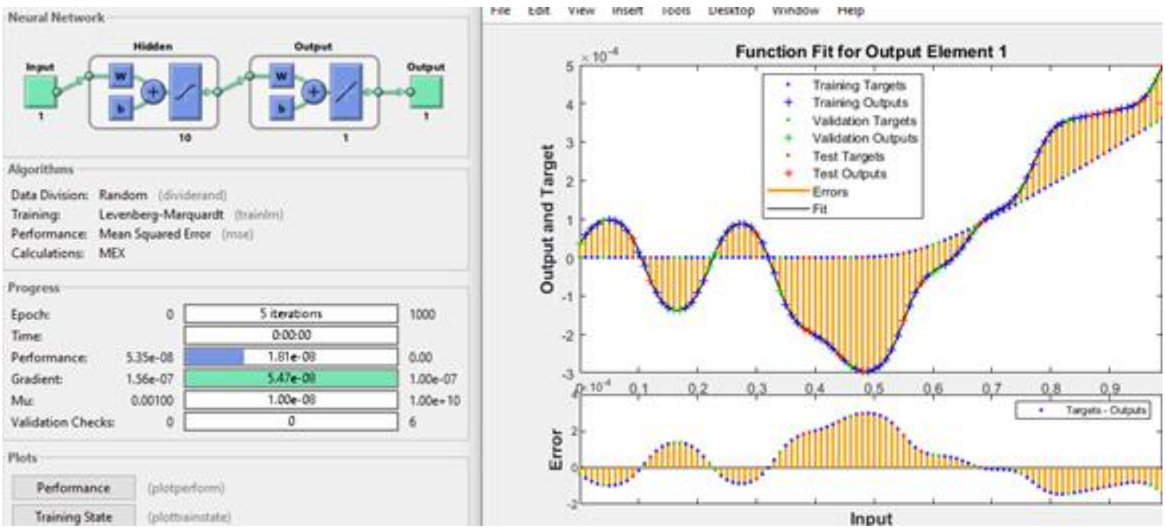
5.0 Neural-Network Model building

5.9

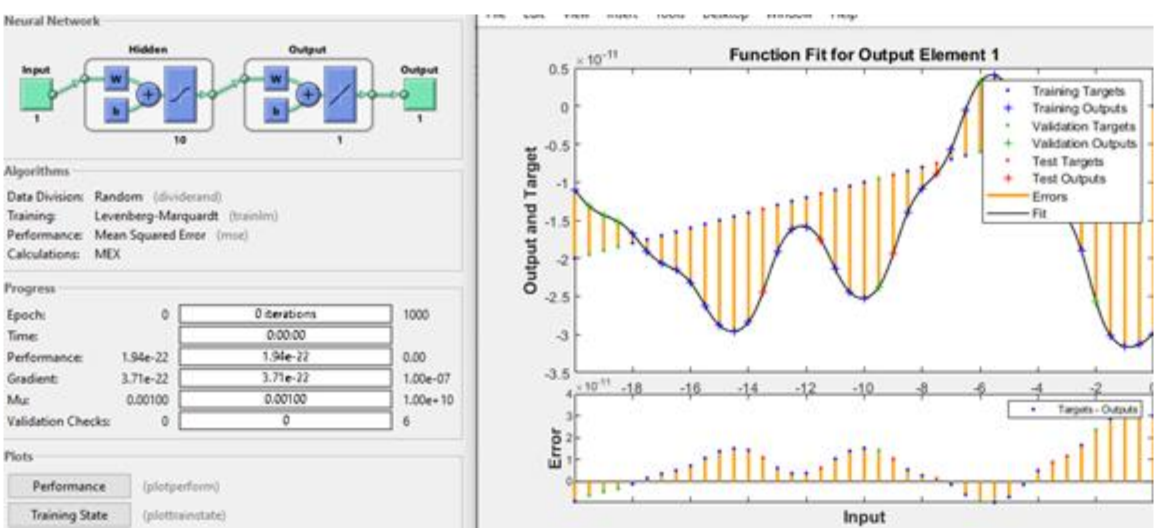


5.10 Output is similar to original data

3.1.5


Neural Network
Hidden
Output
Input
Output
Algorithms
Data Division: Random (dividerand)
Training: Levenberg-Marquardt (trainlm)
Performance: Mean Squared Error (mse)
Calculations: MEX
Progress
Epoch: 0 5 iterations 1000
Time: 0:00:00
Performance: 5.35e-08 1.81e-08 0.00
Gradient: 1.56e-07 5.47e-08 1.00e-07
Mu: 0.00100 1.00e-08 1.00e+10
Validation Checks: 0 0 6
Plots
Performance (plotperform)
Training State (plottrainstate)
Function Fit for Output Element 1
Training Targets
Training Outputs
Validation Targets
Validation Outputs
Test Targets
Test Outputs
Errors
Fit
Output and Target
Error
Targets - Outputs
Input

3.3.3


Neural Network
Hidden
Output
Input
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Algorithms
Data Division: Random (dividerand)
Training: Levenberg-Marquardt (trainlm)
Performance: Mean Squared Error (mse)
Calculations: MEX
Progress
Epoch: 0 0 iterations 1000
Time: 0:00:00
Performance: 1.94e-22 1.94e-22 0.00
Gradient: 3.71e-22 3.71e-22 1.00e-07
Mu: 0.00100 0.00100 1.00e+10
Validation Checks: 0 0 6
Plots
Performance (plotperform)
Training State (plottrainstate)
Function Fit for Output Element 1
Training Targets
Training Outputs
Validation Targets
Validation Outputs
Test Targets
Test Outputs
Errors
Fit
Output and Target
Error
Targets - Outputs
Input