**Educational Objective:**

The objective of this lab is to gain a better understanding of JFET characteristic using a microprocessor to automate the measurements. Important concepts reinforced in this lab include: 1) JFET characteristics, 2) microprocessor scripting, 3) Excel and graphing and 4) scope skills.

**Pre-Laboratory:**

1. Read and completely understand the entire procedure portion of this laboratory.
2. This lab will be submitted prior to taking the lab practical and you will not have your report back. Keep a separate notebook to keep notes about the lab for the lab practical.
3. *The Transistor*:

Sketch the JFET device characteristics in **Figure 1.**. Use Idss = 8mA and Vp = -6V.

* 1. Identify the following: Ohmic, saturation and pinch-off regions.
  2. In the saturation region identify the curve where:
     1. Vgs = 0 and Id = Idss.
     2. Vgs = -1V and Id is determined by Idss(1- Vgs/Vp)2
     3. Vgs = Vp and Id = 0.

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| BJT Device Characteristic |

Figure 1

**Overview:**

The lab will be similar to the BJT curve tracer made earlier in the semester.

The lab will have you:

1. Build a Transistor Circuit in Section 1,
2. Verify the Automated Measurement Circuit in Section 2,
3. Setup and use the curve tracer in Section 3.

Two Automated Measurement Circuits were built earlier in the semester. Both circuits utilize the Arduino Uno microprocessor.

Do not remove the Automated Measurement Circuits from your breadboard after this lab. These circuits will be used again later in the semester.

**Procedure:**

1. Complete the quiz handed out in lab. The quiz will only be available for the first ten (10) minutes of your laboratory session. The content of this quiz is based on the knowledge you should have gained while completing the pre-lab section of this laboratory activity. You may use your pre-lab as a reference while taking the quiz.

Section 1: The JFET Circuit

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|  |
| FET Circuit |

Figure 2

1. *FET Characteristic – manual measurement*:
   1. Construct the JFET circuit (Figure **2**).
   2. Adjust V2 until 3mA follows through R1.2.58”V Record this value, you will need it later in the lab.
   3. Use the multi-meter to measure VDS and VGS.
   4. Record these values on Figure **2**.

**NOTE: These values will be used to verify the automatic measurements taken later in the lab. Leave the circuit on your breadboard for use later in the lab.**

* 1. Obtain a sign-off for the above completed work. Sign-off sheet at end of lab.

Section 2: The Automated Measurement Circuit – Print this page

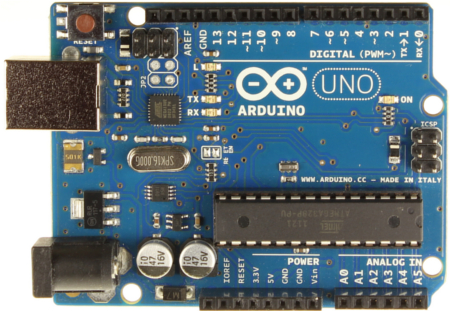
The automated measurement circuit in Figure 3 was built during the first week of lab and used to measure the BJT characteristics. The Circuit uses a simple voltage divider to reduce the measured voltage by ½ and a buffer (gain = 1) to isolate the divider from the Arduino microprocessor.

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| Voltage Divider with Buffer - “Automated Measurement Circuit” |

Figure 3

1. *Automated Measurement Circuit setup.*
   1. Use the bench power supply to power your Voltage Divider with Buffer circuits (Figure 3) using V3 = 3V and V4 = 12V.
   2. Verify the correct operation of Figure 3 by completing the measurements in the table below. You will need to determine and fill in some of the expected values.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Vin0+ | Vin1+ | AnalogInA0 | AnalogInA1 | Vcc | Gnd |
| Located | U1A pin 3 | U1D pin 12 | U1A pin 1 | U1A pin 14 | U1A pin 4 | U1D pin 11 |
| Expected |  | 1.4 - 1.6V |  | 1.4 - 1.6V | 12V |  |
| Actual |  |  |  |  |  |  |



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| Voltage Divider with Buffer - “Automated Measurement Circuit” |

* 1. Connect AnalogInA0 to Arduino A0 and AnalogInA1 to Arduino A1.
  2. Connect the Arduino ground to the breadboard ground.
  3. Use the program below (Figure 4) to read the input voltage.

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| void setup()// routine used to setup the system, only runs once  { Serial.begin( 9600); // initialize serial communication:  delay(100); // wait for 100 ms, so output can stabilize  }  void loop() {  Serial.print("AnalogInA0 voltage = ");  delay(100);  unsigned int vin0=analogRead(0);  delay(100);  Serial.println(vin0);  delay(200);  Serial.print("AnalogInA1 voltage = ");  delay(100);  unsigned int vin1=analogRead(1);  delay(100);  Serial.println(vin1);  delay(200);  exit(1);  } |
| PWM out and Measure Code |

Figure 4

Note: The Arduino command analogRead(0) will report a digital value: 1023 for a value of 5V and 0 for 0V. By multiplying the digital value by 5/1023 the voltage at A0 can be determined.

* 1. Complete the table below. You need to complete the expected values.

|  |  |  |
| --- | --- | --- |
|  | AnalogIn0 | AnalogInA1 |
| Located | Serial Monitor | Serial Monitor |
| Expected |  |  |
| Actual |  |  |

* 1. Obtain a sign-off.

Section 3: The Curve Tracer.

1. *Curve Tracer: Bring the three circuits together and verify the setup*
   1. Replace the DC supply for V1 in Figure **2** with a 0 to 8V peak triangle wave input at 1/10 Hz. Setup the function generator:
      * Press the CH1/2 button until the CH2 page is front.
      * Select Ramp. The top blue portion of the ribbon should be front and say Ramp CH2.
      * Press the top right screen button to select Period. The button allows you to toggle between Frequency and Period. Enter 10 and then press the top right screen button for “s” (seconds).
      * Press the second screen button to select HLevel (high level), enter 8 and then select V.
      * Press the third screen button to select LLevel (low level), enter 0 and then select V.
   2. Adjust the vertical and horizontal scales on the scope so you see a triangle wave scroll across the screen.
   3. Set V2 to the value recorded to make ID = 3 mA as done in section 1.
   4. Connect the top of R1 to the left side of R6 and the bottom of R1 to the left side of R8 as shown by the arrows.
   5. Connect the Arduino A0 to AnalogInA0, Arduino A1 to AnalogInA1 and all grounds as shown by the arrows.

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| http://arduino.cc/en/uploads/Main/ArduinoUno_R3_Front_450px.jpg |
| Curve Tracer |

Figure 9

* 1. Download the new program below that measures the voltage at both A0 and A1 and calculates Vds and Id.
  2. Open the Serial Monitor to start the measures.

|  |
| --- |
| String output\_string;  void setup()  { Serial.begin( 9600); // initialize serial communication:  delay(100);  }  void loop() {  for (int i = 0; i < 100; i++) {  delay(100);  int a0 = analogRead(0); // read vdd  float vdd = 2.0 \* a0 \* 5.0 / 1023.0; // calculate voltage at vdd  int a1 = analogRead(1); // read vds  float vds = 2.0 \* a1 \* 5.0 / 1023.0; // calculate voltage at vds  float id = vdd - vds; // divided by 1K simply makes id in mA  Serial.print("vdd = ");  Serial.print(vdd);  Serial.print(" vds = ");  Serial.print(vds);  Serial.print(" id = ");  Serial.println(id);  }  exit(1);  } |

1. *Curve Tracer: Plotting in Excel.*
   1. Copy the displayed values into Excel. You may need to use Excel’s “Text to Column” function found in the data tab to separate the values into individual columns.
   2. Delete unneeded columns.
   3. Add a label to the top row describing the data as in Figure 6.
   4. Plot the Characteristic curves by selecting the Vds and Id columns and then Scatter under the Insert ribbon.
      * Add a title
      * Label the x and y axis

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  | | --- | --- | --- | | Vdd (V) | Vds (V) (Id = 3mA) | Id (mA) (Id = 3mA) | | 0.06 | 0.04 | 0.02 | | 0.12 | 0.06 | 0.06 | |
| Sample data |

Figure 6

* 1. Increase V2 (more negative) by -0.2V.
  2. Close and open the serial monitor so the program runs again.
  3. Copy the Vdd, Vds and Id data into an available column. Delete the extra columns and add a heading. Verify Vdd has not changed then delete this column.
  4. Increase (more negative) V2 by another -0.2V.
  5. Collect the data again and clean it up.
  6. Add the two new curves to the plot by doing the following:
     + Select the plot
     + Click on Select Data in the Chart Tools Design ribbon.
     + Click on Add to add additional legend, X data and Y data.
     + Figure 7 shows the typical results (your Vgs values will be different)
  7. Label the ohmic, saturation regions.

Figure 7

* 1. Obtain a sign-off for the above completed work:

1. *Sign-offs Name*

Section 1: ID set to 3mA

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| --- | --- | --- |
|  |  | / / |
| Signature |  | Date |

Section 2: Measurement Circuit Verification

|  |  |  |
| --- | --- | --- |
|  |  | / / |
| Signature |  | Date |

Section 3: JFET Characteristic Curve

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|  |  | / / |
| Signature |  | Date |

1. *Post Lab Work*:

Provide a summary, all sign-offs and the labeled characteristic curve.