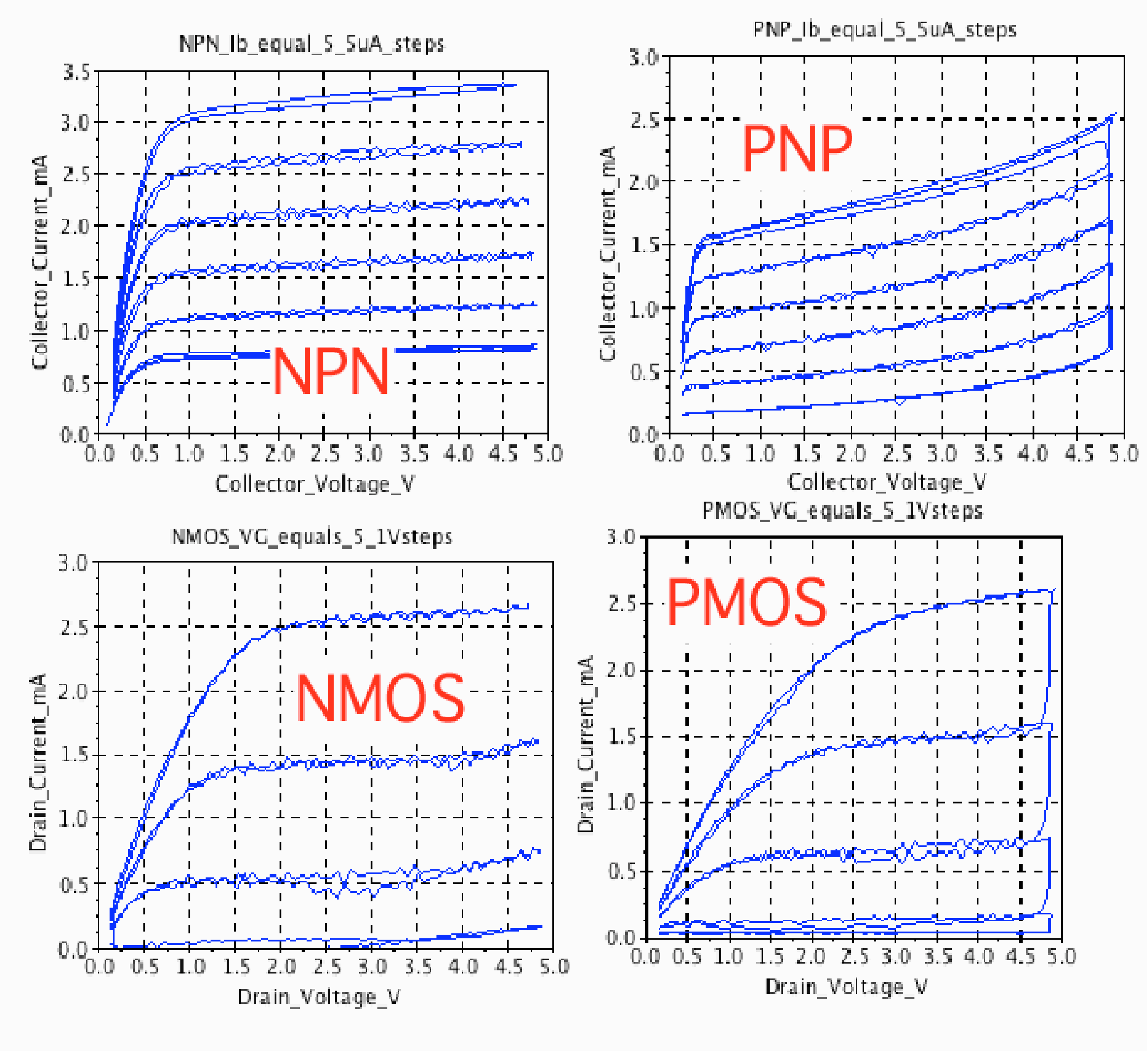
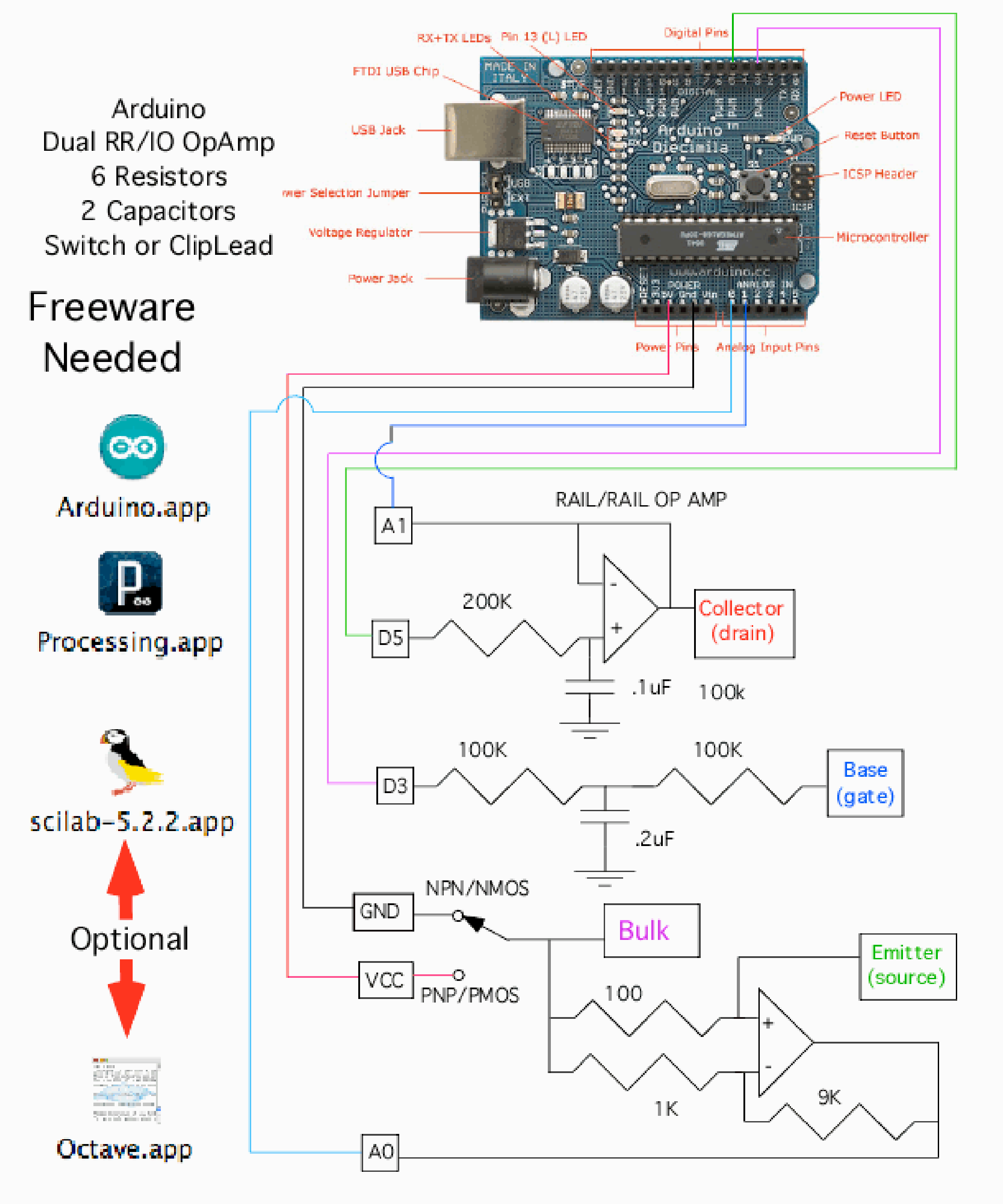
Arduino BiCMOS Curve Tracer



The curves above can be done with a Arduino board, a solderless breadboard, a dual Rail to Rail Input/Output Op amp, a few resistors and capacitors, and some free software. Everything needed is shown below.

The graphs above are produced by either Scilab or Octave.
The curves are also viewed using the Processing application.

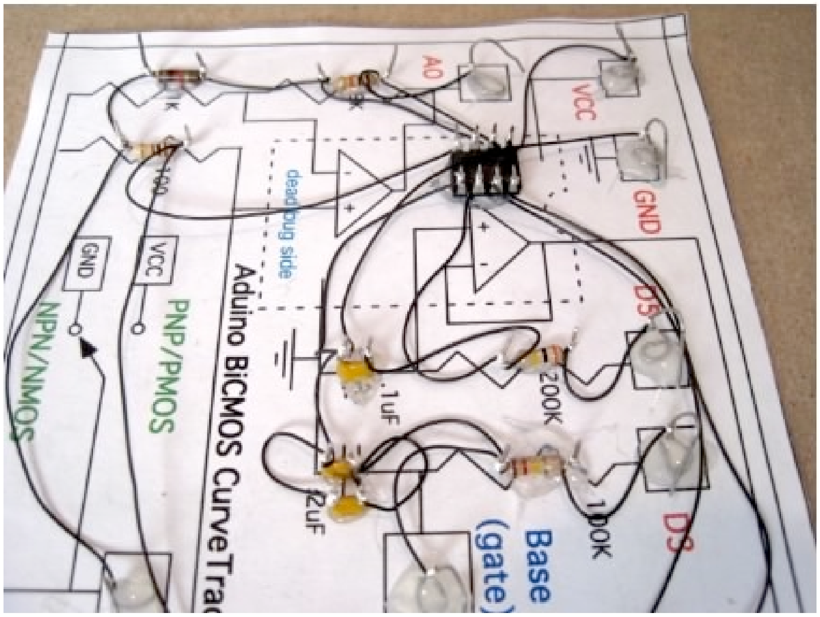
ARDUINO BICMOS CURVE TRACER
5V X 5mA



This is a circuit which may want to be used more than once. Solderless bread boards are not usually meant for long term use. An easy alternative is to build up a CardBoard printed circuit board. This involves printing out a layout. Gluing the printout to cardboard. Hot gluing all the components in place. Then wire wrap up this simple circuit.

Optional Cardboard PCB

(Hot glue components then wire wrap)



Optional Tools Needed

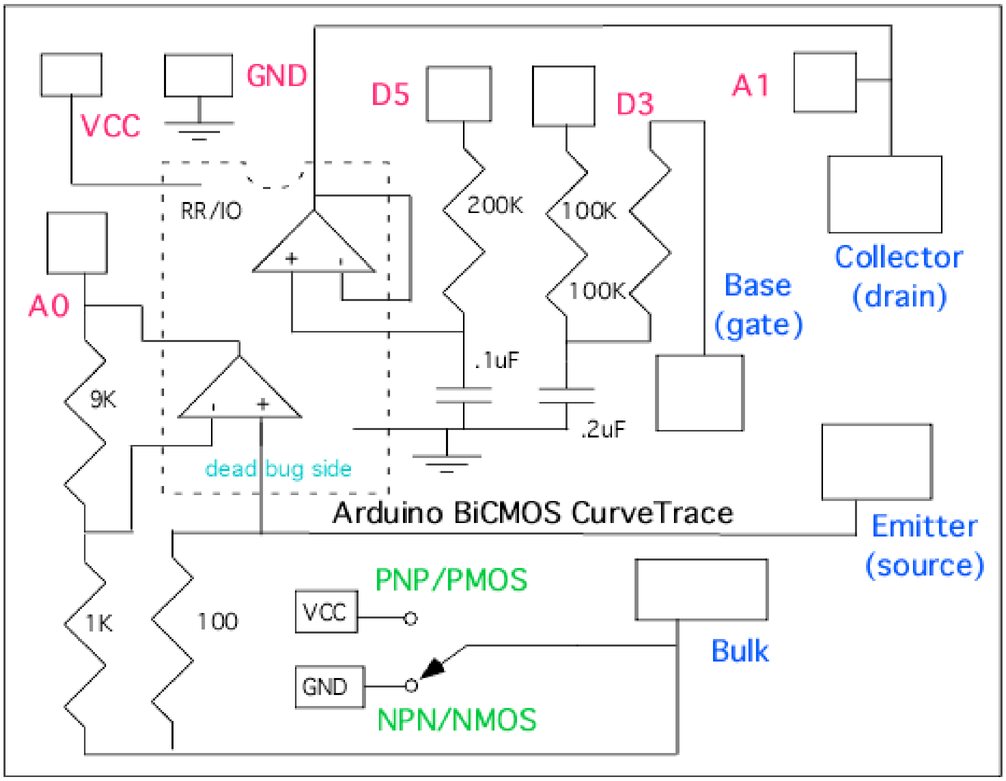
Can solder wire wrap leads one lead at a time
after everything is working
(yes it works)

A hand wire wrap tool and wire wrap wire are needed to do this. After the circuit is completely working, solder can be added to all the wire wrap points. As long as only one lead of a component is soldered at a time, melting the hot glue does not seem to be much of a problem.

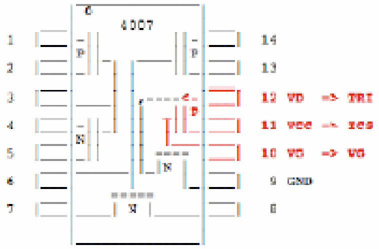
The layout for the CardBoard printed circuit board is below.

(for optional Cardboard PDB)

Print Out This and Mount On Cardboard



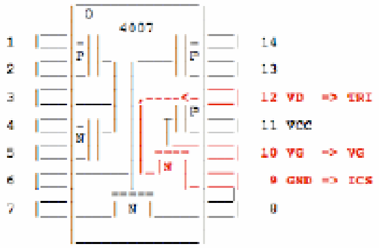
NMOS and PMOS transistors are hooked up the same as NPNs and PNPs. Usually the bulk to CMOS transistors are connected to the source. A Bulk terminal is provided otherwise. The same NPN/PNP polarity switch provides the proper Bulk voltage.



PMOS Bulk needs to be at Vcc

cd4007.PMOS

Bulk and Source are often tied together



cd4007.NMOS

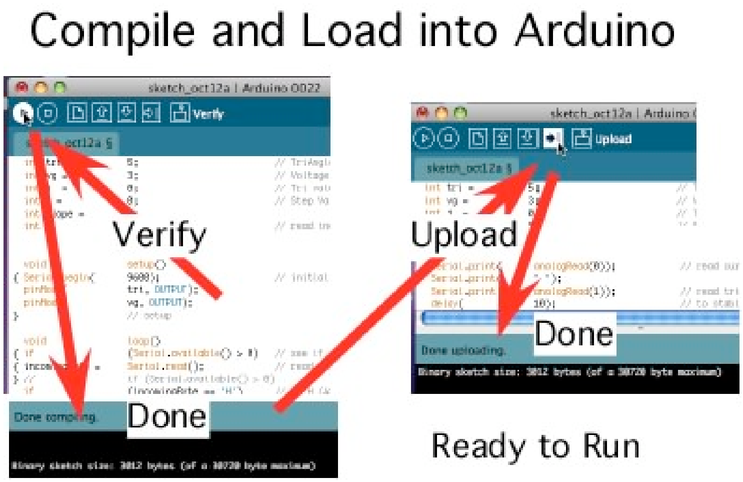
NMOS Bulk needs to be at Gnd

Arduino.app

Open this application, then paste in the code below.

```
================Curve_Tracer_Arduino_Code_Below===================
  int tri =           5;                         // TriAngle Wave      at D5
  int vg =            3;                         // Voltage step port  at D3
  int j  =            0;                         // Tri value
  int k =             0;                         // Step Value
  int slope =         4;
  int                 incomingByte;              // read incoming serial data into


  void                setup()
{ Serial.begin(       9600);                     // initialize serial communication:
  pinMode(            tri, OUTPUT);
  pinMode(            vg,  OUTPUT);
}                     // setup

  void                loop()
{ if                  (Serial.available() > 0)   // see if incoming serial data:
{ incomingByte =      Serial.read();             // read oldest byte in serial buffer:
} //                  if (Serial.available() > 0)
  if                  (incomingByte == 'H')      // if H (ASCII 72), printoutput
{ delay(              10);
  j =                 j+slope;
  analogWrite(        tri, j);                   // will be PWM 488 Hz
  analogWrite(        vg, k);                    // will be PWM 488 Hz
  Serial.print(       analogRead(0));            // read current         at A0
  Serial.print(       " ");
  Serial.println(     analogRead(1));            // read tri voltage     at A1
  delay(              10);                       // to stabilize adc:
  if                  (j > 251) slope = -4 ;
  if                  (j < 1)
{ slope =             4 ;
  k =                 k + int(255/5);
} //                  if (j > 251) slope = -4 ;
  if                  (k > 255 )   k = 0 ;
} //                  if  (incomingByte == 'H')
} //                  loop()
```

Then it is a simple matter of compiling the code and uploading it to the hardware.



Done compiling.

Binary sketch size: 3812 bytes (of a 30720 byte maximum)

Done uploading.

Binary sketch size: 3812 bytes (of a 30720 byte maximum)

The same thing is true for Processing code. But this processing code is also set up to be able to control the Arduino hardware.

Processing.app

Open this application, then paste in the code below.

```
================Curve_Tracer_Processing_Code======================
import                processing.serial.*;
PrintWriter           output;                                     // output file
Serial                myPort;                                     // The serial port
int                   xPos = 1;                                   // hor position  graph

  void                setup ()
{ size(               300, 300);                                  // set the window size:
  println(            Serial.list());                             // List serial ports
  myPort =            new Serial(this, Serial.list()[0], 9600 );  // initialize to 9600 baud
  myPort.bufferUntil('\n');                                       // serialEvent() @ \n:
  background(         0);                                         // set inital background:
  println(            "Click on image and hit s to start");       // will start serial data
  println(            "Hit w to write to file");                  // dump to file ad stop
  String file =       String.valueOf(year());
  file =              file +"."+String.valueOf(month());
  file =              file +"."+String.valueOf(day());
  file =              file +"."+String.valueOf(hour());
  file =              file +"."+String.valueOf(minute());
  file =              file +"."+String.valueOf(second())+".mat";
  println(            file);
  output =            createWriter(file);                        // Sketch->Show_Sketch_fie
}                     // setup

  void                draw ()
{ if(                 keyPressed)
{ if                  (key == 's' || key == 'S')
{ myPort.write(       "H");
}                     //if (key == 's' || key == 'S')
  if                  (key == 'w' || key == 'W')
{ output.flush();     // Writes the remaining data to the file
  output.close();     // Finishes the file
  exit();             // Stops the program
}                     // if (key == 'w' || key == 'W')
}                     // if( keyPressed)
}                     // draw ()

  void                serialEvent (Serial myPort)
{ String inString =   myPort.readStringUntil('\n');               // get the ASCII string:
  if                  (inString != null)
{ inString =          trim(inString);                             // trim whitespace:
  int[] vv =          int(split(inString, ' '));
  // println(         inString );
  output.println(     inString );
  float val0 =        float(vv[0]);
  float val1 =        float(vv[1]);
  val0 =              map(val0, 0, 1023, 0, height*.95);
  val1 =              map(val1, 0, 1023, 0, height*.95);
  stroke(             127,34,255);                                    // color to draw
  line(               val1, height - val0-1, val1+1, height - val0);  // draw the line:
  if                 (xPos >= 6*width)
{ xPos =              0;                                              // auto redraw
  background(         0);
}                     // if (xPos >= 2*width)
  else
{ xPos=               xPos+1;
}                     // else
}                     // if (inString != null)
}                     // serialEvent (Serial myPort)
```

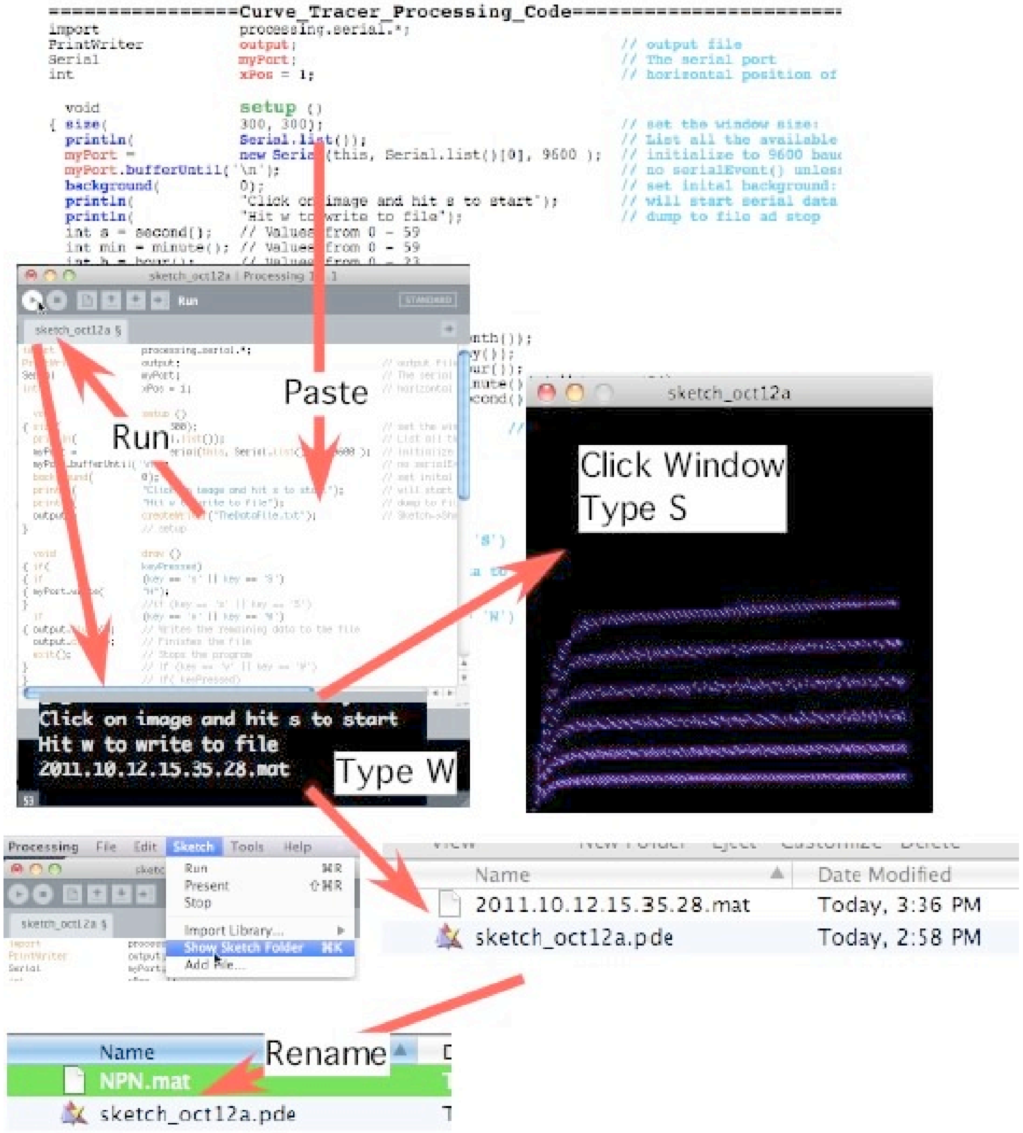
After the code is pasted into the Processing window, hit the run

button. At first a list of serial ports gets printed out. The Arduino board and the Processing application should be using the same port be default. The available serial ports are listed the the array Serial.list()[0]. The number 0 can be changed to match the arduino port to the Processing port if there is a problem.

It takes a while for the graph window to come up. When it does, the curve tracing is started by first clicking the graph window, and then typing "s".

The tracing of the transistor is a little slow because the analog outputs of a Arduino are really low pass filter PWM digital outputs at 488Hz.

Processing Code will start by typing S
Write Data to file by typing W



```
=================Curve_Tracer_Processing_Code========================
import              processing.serial.*;
PrintWriter         output;                                       // output file
Serial              myPort;                                       // The serial port
int                 xPos = 1;                                     // horizontal position of

  void              setup ()
{ size(             300, 300);                                    // set the window size:
  println(          Serial.list());                               // List all the available
  myPort =          new Serial(this, Serial.list()[0], 9600 );    // initialize to 9600 bau
  myPort.bufferUntil('\n');                                       // no serialEvent() unles
  background(       0);                                           // set inital background:
  println(          "Click on image and hit s to start");         // will start serial data
  println(          "Hit w to write to file");                    // dump to file ad stop
  int s = second(); // Values from 0 - 59
  int min = minute(); // Values from 0 - 59
  int h = hour();   // Values from 0 - 23
```

```
Click on image and hit s to start
Hit w to write to file
2011.10.12.15.35.28.mat
```

The Processing Code also writes the curve tracer data to a text file. The Sketch/Show_Sketch_Folder menu will open up the proper folder. The file initially gets named the exact time the data was taken. Not a bad idea to rename that file.

The following are template text that can be copied and pasted into a Scilab window to generate the plots. SciLab will need to know where the data files are located. So the paths shown below in light blue need to be set to the correct path.

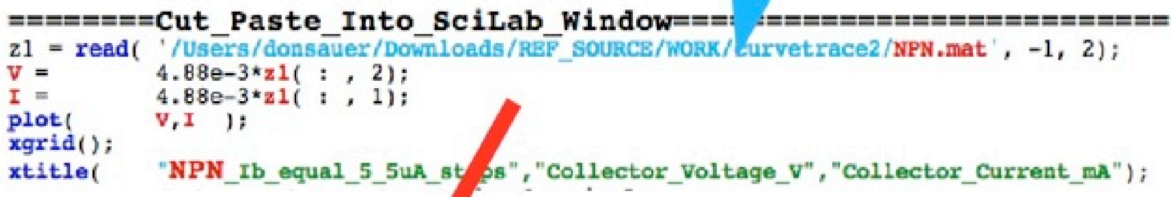
scilab-5.2.2.app

Open this application, then paste in code below.

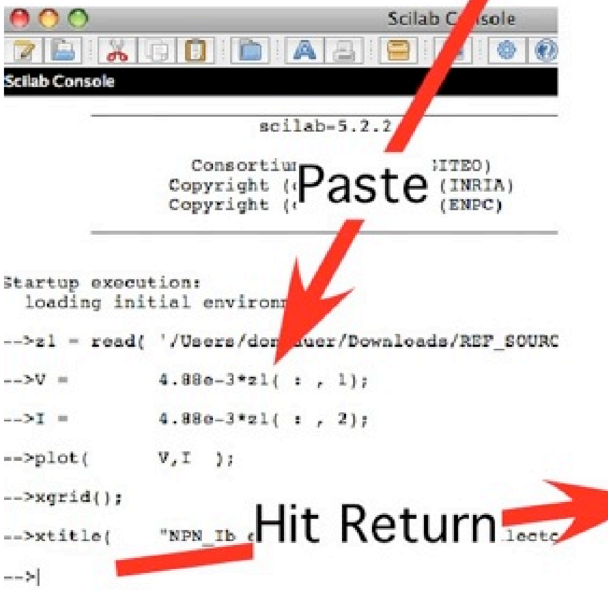
```
========Copy_Paste_Into_SciLab_Window===========================
z1 = read( '/Users/donsauer/Downloads/REF_SOURCE/WORK/curvetrace2/NPN.mat', -1, 2);
V =        4.88e-3*z1( : , 2);
I =        4.88e-3*z1( : , 1);
plot(      V,I  );
xgrid();
xtitle(    "NPN_Ib_equal_5_5uA_steps","Collector_Voltage_V","Collector_Current_mA");
========Copy_Paste_Into_SciLab_Window===========================
z1 = read( '/Users/donsauer/Downloads/REF_SOURCE/WORK/curvetrace2/PNP.mat', -1, 2);
V = 5      -4.88e-3*z1( : , 2);
I = 5      -4.88e-3*z1( : , 1);
plot(      V,I  );
xgrid();
xtitle(    "PNP_Ib_equal_5_5uA_steps","Collector_Voltage_V","Collector_Current_mA");
========Copy_Paste_Into_SciLab_Window===========================
z1 = read( '/Users/donsauer/Downloads/REF_SOURCE/WORK/curvetrace2/NMOS.mat', -1, 2);
V =        4.88e-3*z1( : , 2);
I =        4.88e-3*z1( : , 1);
plot(      V,I  );
xgrid();
xtitle(    "NMOS_VG_equals_5_1Vsteps","Drain_Voltage_V","Drain_Current_mA");
========Copy_Paste_Into_SciLab_Window===========================
z1 = read( '/Users/donsauer/Downloads/REF_SOURCE/WORK/curvetrace2/PMOS.mat', -1, 2);
V = 5      -4.88e-3*z1( : , 2);
I = 5      -4.88e-3*z1( : , 1);
plot(      V,I  );
xgrid();
xtitle(    "PMOS_VG_equals_5_1Vsteps","Drain_Voltage_V","Drain_Current_mA");
==============================================================
```

The templates are set up to translate the data into voltages and currents. There are four templates for each type of transistor. They produce the curves show below.

Rename to your path for NPN.mat



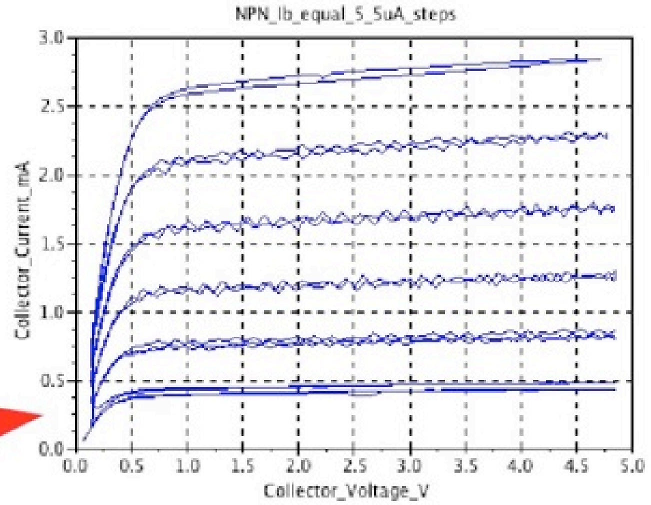
```
=========Cut_Paste_Into_SciLab_Window=============================
z1 = read( '/Users/donsauer/Downloads/REF_SOURCE/WORK/curvetrace2/NPN.mat', -1, 2);
V =          4.88e-3*z1( : , 2);
I =          4.88e-3*z1( : , 1);
plot(        V,I   );
xgrid();
xtitle(      "NPN_Ib_equal_5_5uA_steps","Collector_Voltage_V","Collector_Current_mA");
```

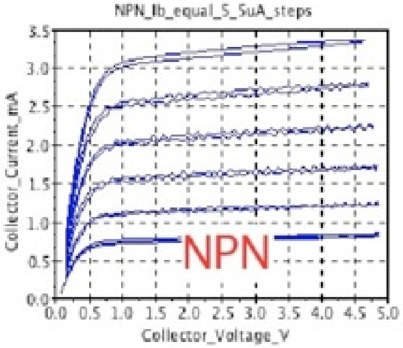


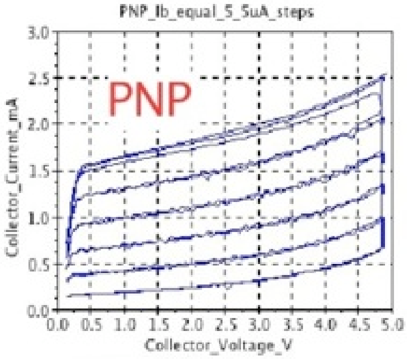
```
                     scilab-5.2.2

              Consortiu        ITEO)
             Copyright (       (INRIA)
             Copyright (       (ENPC)

Startup execution:
  loading initial environ

-->z1 = read( '/Users/don  uer/Downloads/REF_SOURC

-->V =         4.88e-3*z1( : , 1);

-->I =         4.88e-3*z1( : , 2);

-->plot(       V,I   );

-->xgrid();

-->xtitle(     "NPN_Ib_               lecto

-->|
```

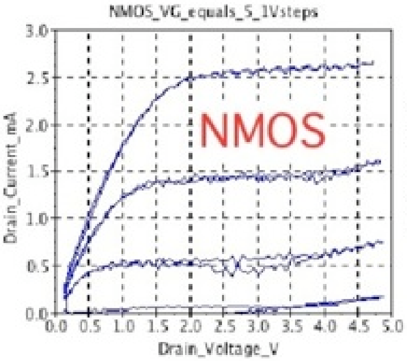
Paste

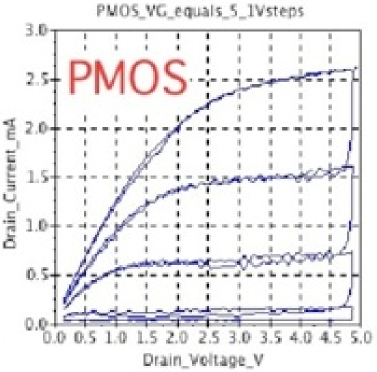
Hit Return











The templates for Octave are almost the same and are given below. They produce the same curves.

Octave.app

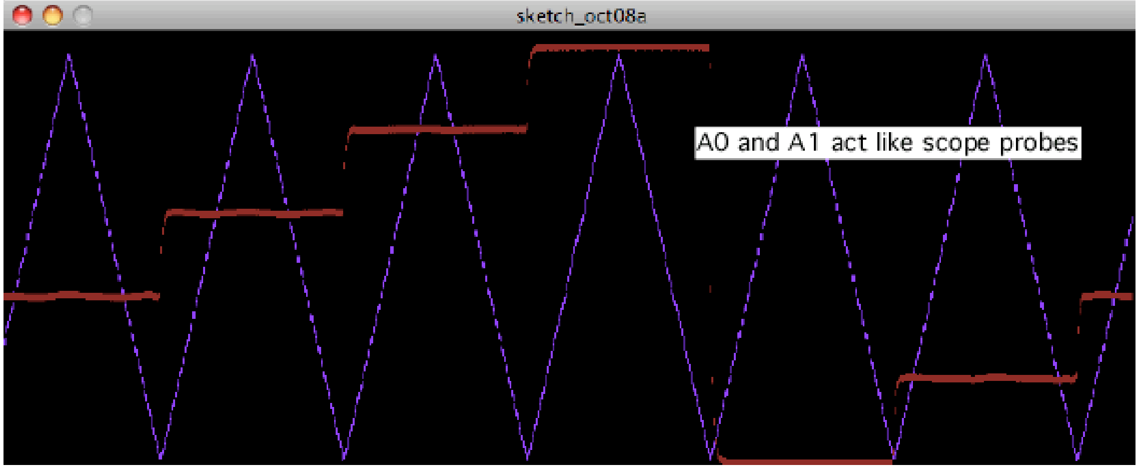
Open this application, then paste in code below.

```
===========Cut_Paste_Into_Octave_Window===========================
load -ascii    /Users/donsauer/Downloads/REF_SOURCE/WORK/curvetrace2/NPN.mat
V =            4.88e-3* NPN( : , 2);
I =            4.88e-3* NPN( : , 1);
plot(          V,I  );
grid
title  (      "NPN Ib equal 5 5uA steps")
xlabel (      "Collector Voltage V")
ylabel (      "Collector Current mA")

===========Cut_Paste_Into_Octave_Window===========================
load -ascii    /Users/donsauer/Downloads/REF_SOURCE/WORK/curvetrace2/PNP.mat
V =  5         -4.88e-3*PNP( : , 2);
I =  5         -4.88e-3*PNP( : , 1);
plot(          V,I  );
grid
title  (       "PNP Ib equal 5 5uA steps")
xlabel (       "Collector Voltage V")
ylabel (       "Collector Current mA")

===========Cut_Paste_Into_Octave_Window===========================
load   -ascii /Users/donsauer/Downloads/REF_SOURCE/WORK/curvetrace2/NMOS.mat
V =           4.88e-3*NMOS( : , 2);
I =           4.88e-3*NMOS( : , 1);
plot(         V,I  );
grid;
title  (     "NMOS Vg equal 5 1V steps") ;
xlabel (     "Drain Voltage V");
ylabel (     "Drain Current mA");

===========Cut_Paste_Into_Octave_Window===========================
load   -ascii /Users/donsauer/Downloads/REF_SOURCE/WORK/curvetrace2/PMOS.mat
V = 5         -4.88e-3*PMOS( : , 2);
I = 5         -4.88e-3*PMOS( : , 1);
plot(         V,I  );
grid
title  (      "PMOS Vg equal 5 1V steps")
xlabel (      "Drain Voltage V")
ylabel (      "Drain Current mA")
=================================================================
```

There is a free feature to the hardware. The curve tracer can be converted into a dual trace oscilloscope by loading in some different Processing code. The analog inputs A0 and A1 will act like scope probes. These probes can be placed at different places in the circuit to things like view things like triangle and step waveforms. Simply copy and paste the following Processing code. It starts up the same as the curve tracer.

Load Scope Processing Code

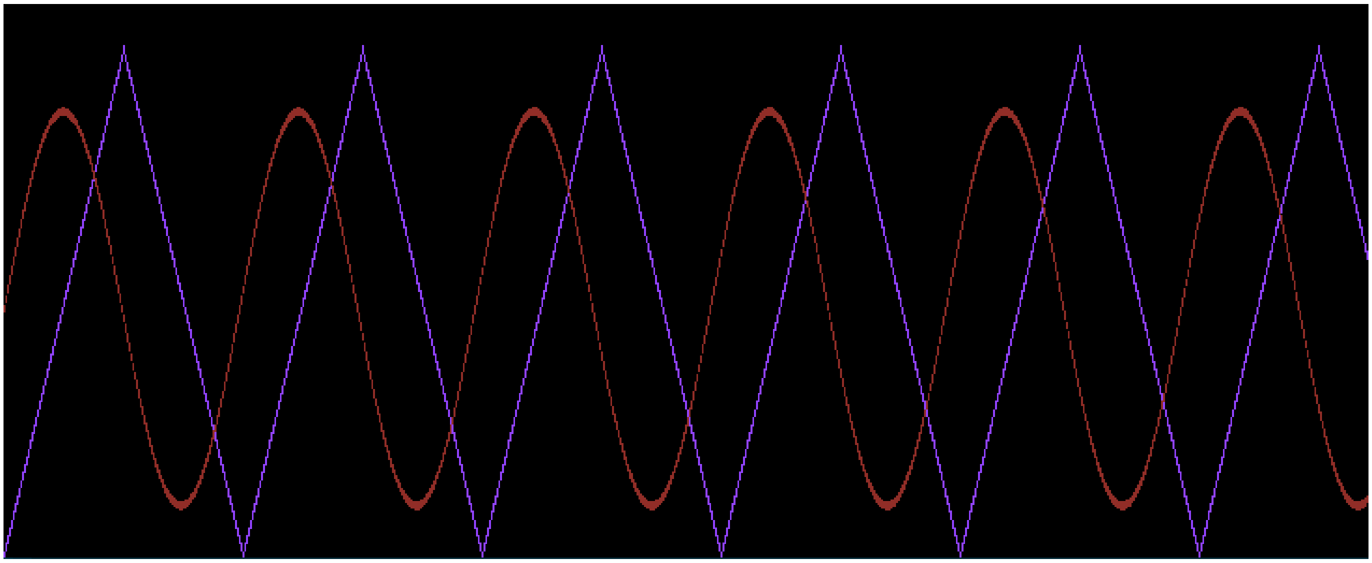
(can look at waverforms)



```
================Dual_Scope_Processing_Code========================
import                  processing.serial.*;
PrintWriter            output;                                      // output file
Serial                 myPort;                                      // The serial port
int                    xPos = 1;                                    // hor position graph

  void                 setup ()
{ size(                800, 300);                                   // set the window size:
  println(             Serial.list());                              // List serial ports
  myPort =             new Serial(this, Serial.list()[0], 9600 );   // initialize to 9600 baud
  myPort.bufferUntil('\n');                                         // serialEvent()newline ch
  background(          0);                                          // set inital background:
  println(             "Click on image and hit s to start");        // will start serial data
  println(             "Hit w to write to file");                   // dump to file ad stop
  output =             createWriter("TheDataFile.txt");             //  Sketch->Show_Sketch_fie
}                       // end

  void                 draw ()
{ if(                  keyPressed)
{ if                   (key == 's' || key == 'S')
{ myPort.write(         "H");
}                      //if (key == 's' || key == 'S')
  if                    (key == 'w' || key == 'W')
{ output.flush();      // Writes the remaining data to the file
  output.close();      // Finishes the file
  exit();              // Stops the program
}                      // if (key == 'w' || key == 'W')
}                      // if( keyPressed)
}                      // draw ()

  void                 serialEvent (Serial myPort)
{ String inString =    myPort.readStringUntil('\n');                   // get the ASCII string:
  if                   (inString != null)
{ inString =           trim(inString);                                 // trim whitespace:
  int[] vv =           int(split(inString, ' '));
  // println(           inString );
  output.println(      inString );
  float val0 =         float(vv[0]);
  float val1 =         float(vv[1]);
  val0 =                map(val0, 0, 1023, 0, height*.95);
  val1 =                map(val1, 0, 1023, 0, height*.95);
  stroke(              127,34,255);                                     // set color draw
  line(                 xPos, height - val0-6, xPos, height - val0-3);  // draw line:
  stroke(              127,34,32);                                      // set color draw
  line(                xPos, height - val1-6, xPos, height - val1-3);   // draw line:
  if                  (xPos >= width)
{ xPos =               0;                                               // if edge go back
  background(          0);
}                      // if (xPos >= width)
  else
{ xPos=                xPos+1;                                          // increment hor
}                      // else
}                      // if (inString != null)
}                      // serialEvent (Serial myPort)
```

===

It is possible to generate any kind of waveform at the "analog" output ports as well.



===============Sine_Generator_Arduino_Code========================

```
  int                 incomingByte;                           // read incoming serial data
  int                 slope = 4 ;
  float               x;
  void                setup()
{ Serial.begin(       9600);                                  // set baud
} //                  setup() end
  int j =             0;
  void                loop()
{ if                  (Serial.available() > 0)                 // see if incoming serial
{ incomingByte =      Serial.read();                          // read oldest byte in serial
} //                  if  (Serial.available() > 0)
  if                  (incomingByte == 'H')                    // if H (ASCII 72), printoutput
{ delay(              1000);
  for                 (int i=0; i <= 2550; i++)
{ Serial.print(       4*j);
  Serial.print(       " ");
  x =                 3.14*i/63;
  Serial.println(     int(400*sin(x))+500);
  delay(              50);                                        //  stabilize adc:
  j =                 j+slope;
  if                  (j > 254) slope = -4 ;
  if                  (j < 1)   slope =  4 ;
} //                  for   (int i=0; i <= 2550; i++)
} //                  if  (incomingByte == 'H')
} //                  loop()
```

Conclusion...

The analog input/output ports of the Arduino, together with some support hardware, and free online software, makes it easy to build an automated analog test interface with a laptop.

10.14.11_1.18PM
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