TRIOPAR Lab Experiment

Physics 398 EMI/Physics 498POM

The Physics of Electronic Music/Musical Instruments

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Professor Steven Errede

Dept. of Physics

University of Illinois at Urbana-Champaign

VACUUM TUBE OPERATION

The first vacuum tube device created was the vacuum tube diode. It contained only two elements, the cathode and the anode – the latter is also known as the plate (Fig 1).
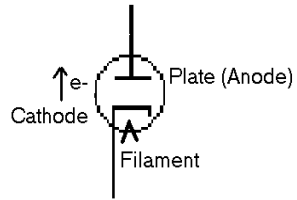

FIG 1. The Vacuum Tube Diode

The unidirectional/rectifying current of electrons flowing in a vacuum tube diode arises from thermionic emission of electrons from the cathode. The filament, also known as the heater, which is usually electrically isolated from the cathode, indirectly heats the cathode (via black body radiation of photons) until the free electrons in the cathode acquire enough kinetic energy and boil off the surface of the cathode, forming a space charge. Note that thermionic emission of electrons from a metal at finite temperature is intimately related to another phenomenon – that of black body radiation of massless photons from a material at finite temperature. The cathode of a vacuum tube is typically made out of tungsten, or an oxide of tungsten. When the anode/plate is held at a positive potential with respect to the cathode, then a current of electrons will flow from the cathode to the plate (and not vice-versa – why?). Many consider the discovery of this effect to have sparked the birth of modern electronics. The vacuum diode thus provides a means for rectification of an AC signal. The vacuum diode's ability to block negative voltages, and conduct only in the presence of positive voltage provides a way to rectify alternating (i.e. AC) voltages.

Although the vacuum diode was a major scientific breakthrough, a third element was required in order to amplify a signal. In a vacuum tube diode, there is no way of controlling the amount of current flow in the tube, except by varying the potential difference from plate to cathode. It is essentially either conducting, or not conducting. In 1907 Lee Deforest added a grid to the vacuum tube diode, creating a vacuum tube with three elements, thus it is known as the triode (Fig 2).
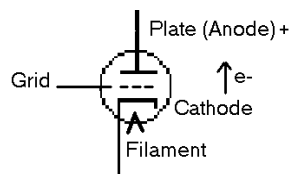

Fig. 2 The Vacuum Tube Triode

If the grid is held negative with respect to the cathode, then this limits the flow of thermionic emitted electrons from the cathode to the plate. The grid acts as a valve that reduces electron current as the grid becomes more negative with respect to the cathode potential. A sufficient negative grid voltage will put the triode in its so-called cutoff

condition, where no current will flow. Maximum current will flow when the grid is at 0 volts potential difference with respect to the cathode.

If a resistance is placed between the plate and a positive high voltage supply, a varying anode current will produce a proportional varying voltage drop across the resistance. Just a small change in grid voltage will produce a large variation at the plate. Thus, the triode effectively amplifies the grid voltage. The amount of voltage gain (amplification) is then determined by the change in plate voltage for a given change in grid voltage.

The triode will voltage-amplify an AC signal on the grid without any change in frequency. However, phase shift can/does occur. In fact, knowing the phase shift between the input and output of a triode as a function of frequency is important in understanding the triode's behavior and response to different input frequencies.

TRIOPAR, (short for Triode Parameters) can be used for studying tube parameters with static DC input. One can obtain online plots of the results and compare to previously published values.

Two main graphs have traditionally been included as part of a triode's data sheet published by the manufacture. The first is a graph of Plate Current vs. Grid Voltage. This graph is obtained when the plate voltage is set to a constant high voltage (50 -300 V), and the plate current is measured for different grid voltages (–5 V - 0V). A family of these grid curves is obtained by repeating the test for different plate potentials (0- 300 V).

The second graph is of Plate Current vs. Plate Voltage. This graph is obtained when the grid voltage is set to a constant (-.5 - -3.0 V), and the plate current is measured for different plate voltages (0 – 300 V). A family of these plate curves is obtained by repeating the test for different grid potentials (-.5 - -3.0V).

The purpose of the TRIOPAR lab setup is to obtain the grid and plate family graphs for various triodes, e.g. new old stock (NOS) RCA, GE, Sylvania, Mullard, Telefunken and/or currently-made Sovtek, Tesla-JJ, Chinese, etc. 12AX7, 12AT7, 12AY7, 12AU7 that are commonly used in many new and vintage tube amplifiers and to compare them to existing plate/grid family graphs from these companies. From these two graphs, one can decide whether the tube is appropriate for the design of a particular application in a tube amplifier, and decide what range of operating parameters should be/can be used.

Traditionally, the current flowing through the tube (plate current) is obtained by measuring the voltage drop across a resistor tied to the plate. However, the cathode current is equal to plate current (as long as no electron current flows from cathode to grid). Because it is safer to measure the voltage at the cathode, in this experiment, we place no resistance between the plate and the +HV supply. Instead, a 1 Ohm resistor is placed in series with the cathode to ground (Fig. 3). Throughout the experiment an ADC monitors the voltage across the 1 ohm resistor. Since V = IR, the voltage reading in mV thus corresponds to the cathode current in mA.

For the TRIOPAR setup, DAC 0 controls the Bertan HV power supply that provides the voltage to the plate of the triode vacuum tube under test. DAC 1 on the LabPC+ card controls both grid voltages, and ADC's 2 and 3 digitize the voltage across both cathode resistors for obtaining cathode 1 and 2 currents. A block diagram can be seen in figure 4.
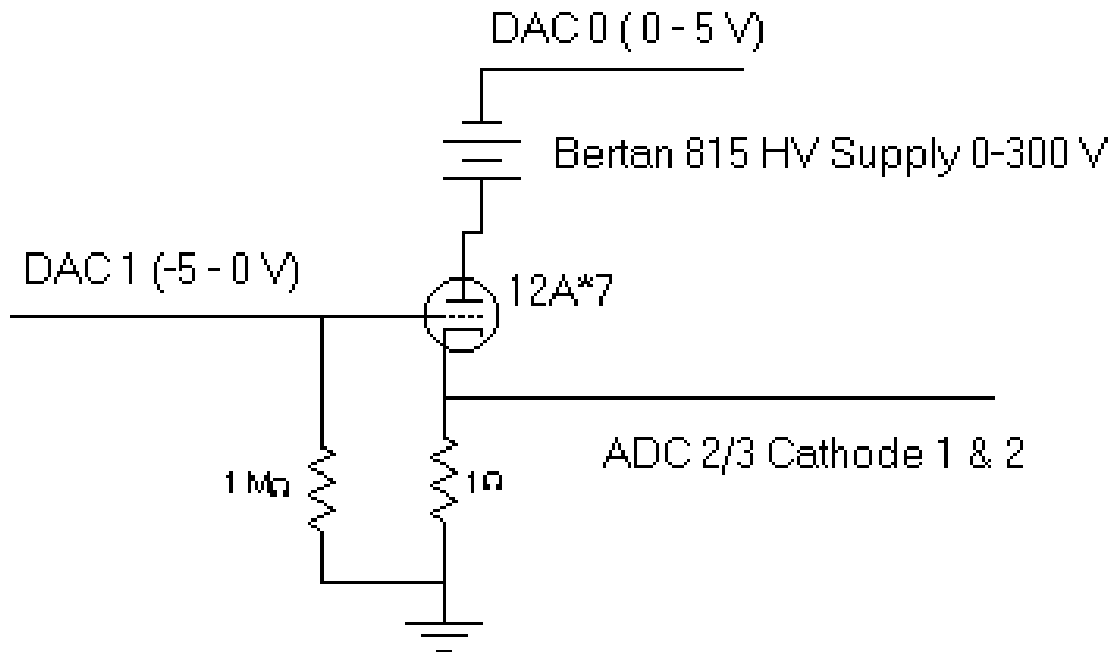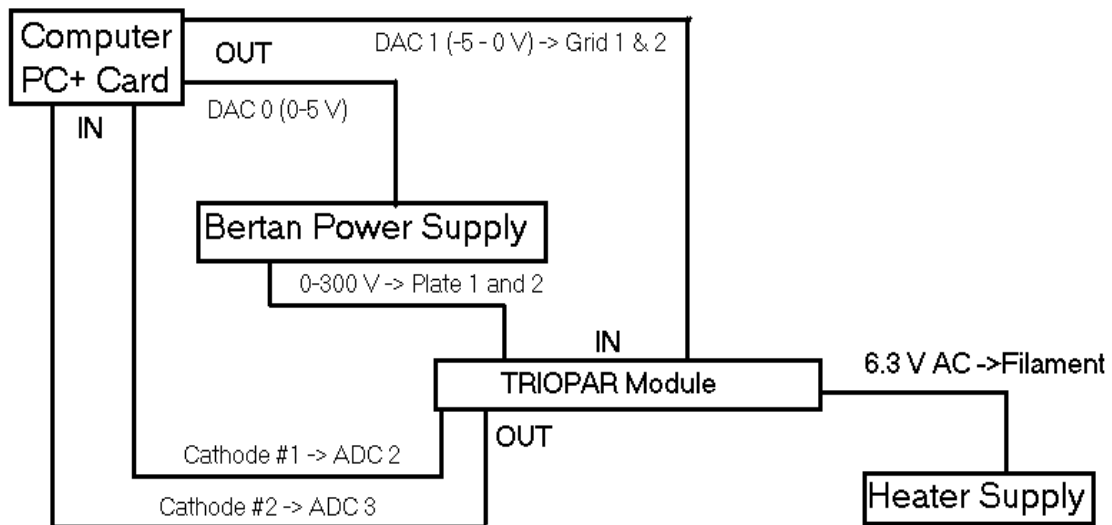

Fig.3 TRIOPAR Circuit

Fig. 4 TRIOPAR Block Diagram

Grid Voltage vs. Cathode Current:
Obtaining The Grid Family of Curves

Under computer control, the plate voltage is initially set at +50 V. The grid voltage is initially set at –5 volts (for 12AX7 type dual triode tubes). The PC then steps the grid voltage from –5.0 V to –0.5 V in 0.01 V increments. At each point, the National Instruments' LabPC+ ADCs (2 & 3) take 1000 samples of the voltage across the 1 Ohm resistors across each cathode, and averages of the ADC voltage readings are computed on-line. When this task is completed, the PC increases the plate voltage on both plates by +50 V, and runs the test again. This happens a total of six times (+50, +100, +150, +200, +250, and +300 V plate potentials).

The TRIOPAR program includes some protective code that prevents the maximum plate power dissipation from being exceeded. At each data point, we calculate the plate power dissipation (Plate Voltage x Cathode Current). If the power dissipation rating is exceeded from the manufacturer's specifications then the software ends that plate voltage run. For this reason, each curve in the grid family will end at different grid voltages. This can be seen in sample graph of the Grid Voltage vs. Cathode Current for a Groove Tubes 12AT7 Dual Triode (Fig 5). The data was obtained using the new TRIOPAR experiment. The graph was created in Microsoft Excel, using the dat file generated by the TRIOPAR software.

Plate Voltage vs. Cathode Current:
Obtaining The Plate Family of Curves

The TRIOPAR program initially sets the grid voltage at –3.0 V. The plate voltage is set at 0 volts. The plate voltage is then stepped from 0 to +300 V in 0.75 V increments. At each point, the LabPC+ ADC's take 1000 samples of the voltage across the 1 Ohm cathode resistors and again and average of the ADC voltage readings are computed. When this is completed, the TRIOPAR program increases grid voltage by +0.5 V, and runs the test again. This happens a total of six times (-3.0, -2.5, -2.0, -1.5, -1.0, -0.5 V grid potentials). A sample plate family graph of a Groove Tubes 12AT7 can be seen in figure 6.

TRIOPAR Software Interface Definitions (Fig. 7)

INIT DAQ button - Initializes the LabPC+ card, clears all inputs and outputs, sets the Bertan HV power supply to 0 volts, and LabPC+ DAC 1 to –5.0 V.

STOP button - Stops the data taking. Sets the Bertan power supply to 0 Volts and LabPC+ DAC 1 to -5 V.

RUN GRIDFAM button - Starts the data-taking for Grid Family Curves.

RUN PLATEFAM button - Starts the data-taking for Plate Family Curves.

TUBE TYPE port - Displays the tube type being tested based on user input.

Max Plate (W) port - Displays the maximum plate power dissipation in watts. Determined by user input of tube type.

Plate 1 W port - Displays the current Plate #1 power dissipation. (Cathode #1 Current x Plate Voltage).

Plate 2 W port - Displays the current Plate #2 power dissipation. (Cathode #2 Current x Plate Voltage).

Cathode #1:

Raw <ADC 2> port - displays the raw <ADC 2> reading across 1 ohm cathode resistor.

<PED 2> port - displays the avg. offset voltage on ADC 2. (obtained at the start of each data run).

<ADC 2> port - displays the raw <ADC 2> - <PED 2>

I 0 (mA) port - displays the < ADC 2> x 1000 = Cathode #1 Current in mA

Cathode #2:

Raw <ADC 3> port – displays the raw <ADC 3> reading across 1 ohm cathode resistor.

<PED 3> port - displays the avg. offset voltage on ADC 3 (obtained at the start of each data run).

<ADC 3> port - displays the raw <ADC 3> - <PED 3>

I 1(mA) port - displays the < ADC3> x 1000 = Cathode #2 Current in mA

DAC0 Plate Voltage:

V Plate (V) port - displays the Command Plate Voltage

V DAC0 port - displays the Actual Voltage on DAC 0

DAC0 Plate Vstep port - displays the Step Size for DAC 0

DAC1 Grid Voltage:

V Grid (V) port - displays the Command Grid Voltage

V DAC1 port displays the Actual Voltage on DAC 1

DAC1 Grid Vstep port - displays the Step Size for DAC 1

Bertan 815 HV Power Supply:

ON/OFF port - indicates whether power supply is enabled or disabled

PS STABILIZING port - indicates the power supply needs time to stabilize to 0 volts after being set at high voltage.

Constant Voltage/ Constant Current port - indicates whether power supply is operating as voltage source or current source.

Raw <ADC 0 > port - displays the raw ADC 0 reading for VOut Monitor.

<PED 0> port - displays the offset voltage on ADC 0 (obtained at the start of each data run).

<ADC 0> port - displays the raw <ADC 0> - <PED 0>

V Monitor(V) port - displays the <ADC 0> x 100 = Actual Voltage Output of Bertan HV Power Supply

Raw <ADC 1 > port - displays the raw ADC 1 reading for IOut Monitor.

<PED 1> port - displays the offset voltage on ADC 1 (obtained at the start of each data run).

<ADC 1> port - displays the raw <ADC 1> - <PED 1>

I Monitor(mA) - <ADC 1> x 40 = Actual Current Output of Bertan Power Supply

PRINT button - Prints main panel

QUIT button - Exits program.

TRIOPAR Lab experiment

Equipment

Bertan 815 HV Power Supply
12A*7 Triode Tube Parameters (TRIOPAR) PC-based DAQ Program
6.3 Vac (rms) Unregulated Filament Power Supply & Variac
White/Black 5/15 V DC Power Supply
50-pin Green Connector Board

Initial Lab Setup

1. At the start of each TRIOPAR experiment, the Bertan HV Power Supply 3-pin power cable should be removed, the 5V DC power supply should be off, and the Filament Power Supply should be off.

2. Plug the 50 Pin cable into the green connector board. Make sure that red triangles in the right corners align with each other.

3. Ensure All SMB cables are connected correctly to TRIOPAR Module. The Labels on the Cable Ends must correspond to the labels on the module.

4. Plug the 3 pin Molex connector (Blue, Black and Green) into the Filament Power Supply.

5. Plug the 6 pin Molex connector (Blue, Black, Green, & Red, Green, Black) into the 6.3 V AC input on the TRIOPAR module.

6. Place a dual triode vacuum tube in the tube socket, place the tube shield on the tube.

7. Turn on the filament power supply, let the tube warm up for 5 minutes.

8. Close all programs on the computer.

9. Run Labwindows/CVI by clicking on the shortcut on the desktop.

10. Go to File -> Open -> Project -> open TrioPar2.prj located in c:\cvi\P398\DAQ Prog\TrioPar2.prj

11. Turn the 5V power supply on. (the red LED above the +5 will light)

12. Plug the 3 pin power cable into the bertan power supply.

13. Go to Run -> Run Project. The TRIOPAR software will load.

Running the TRIOPAR experiment

1. Click on the INIT DAQ button to initialize the PC+ card. This clears all inputs and outputs and sets the power supply to 0 Volts, and DAC 1 to -5 Volts.

2. Click the RUN GRIDFAM button to run the Grid Family Curves.

3. Click the RUN PLATEFAM button to run the Plate Family Curves.

4. To stop the program and disable the +HV, hit the stop button anytime during the program. Hitting the stop button will not "pause" the run, the run will end completley.

5. To view plots, click on PLOTS at the top bar and select a graph to view.

6. Label the Plots in the TUBE INFO text box.

7. Click on SAVE at the top bar to save the data in a dat file to be used in Excel.

8. Click Quit to Exit the TRIOPAR program.

9. Unplug the 3 pin power cord from the Bertan Power Supply, Turn off the 5V power supply, Turn off the the Filament Power Supply.

10. Let the tubes cool before removing from TRIOPAR Module.

To Exit the TRIOPAR program, click on File -> Exit.
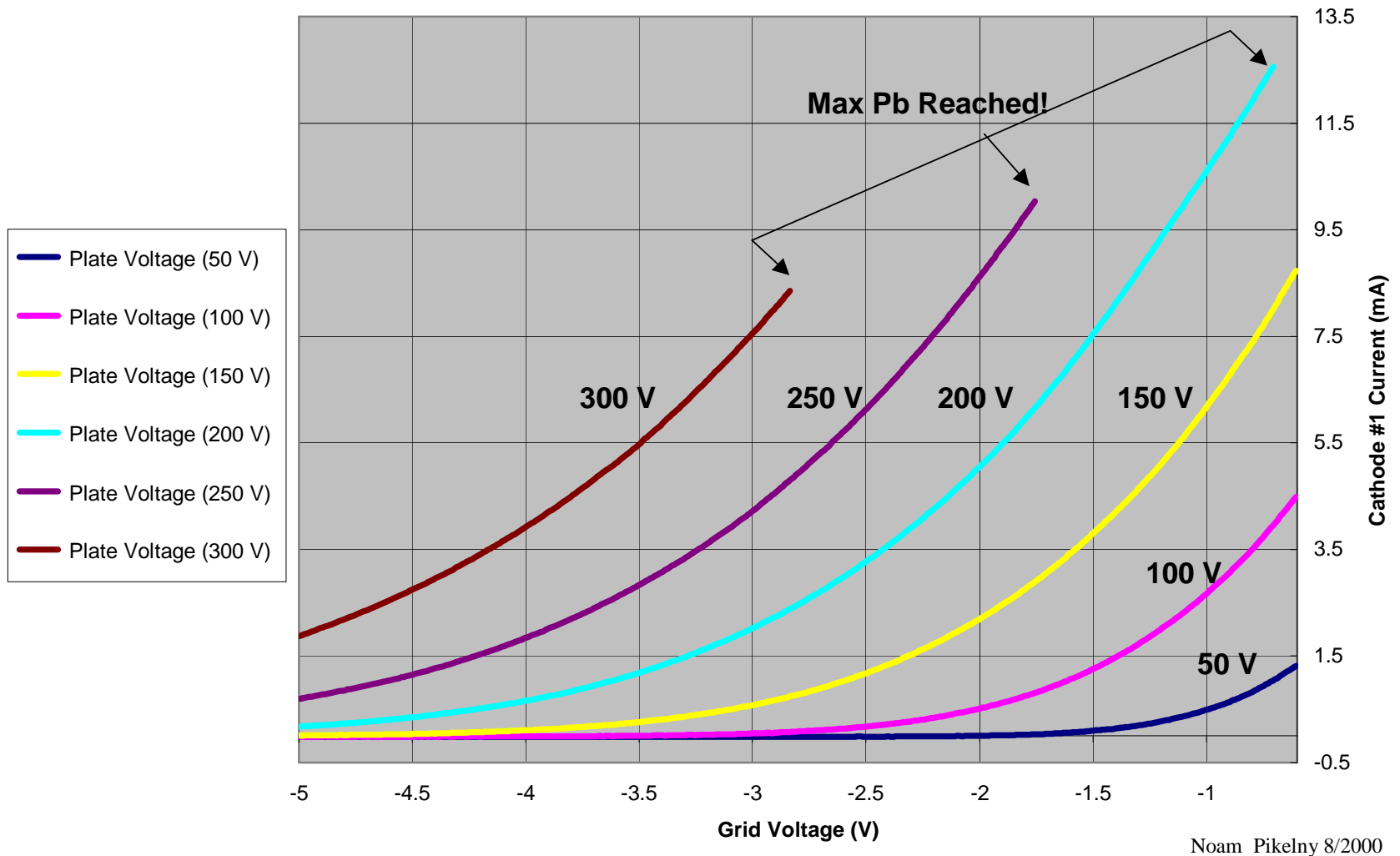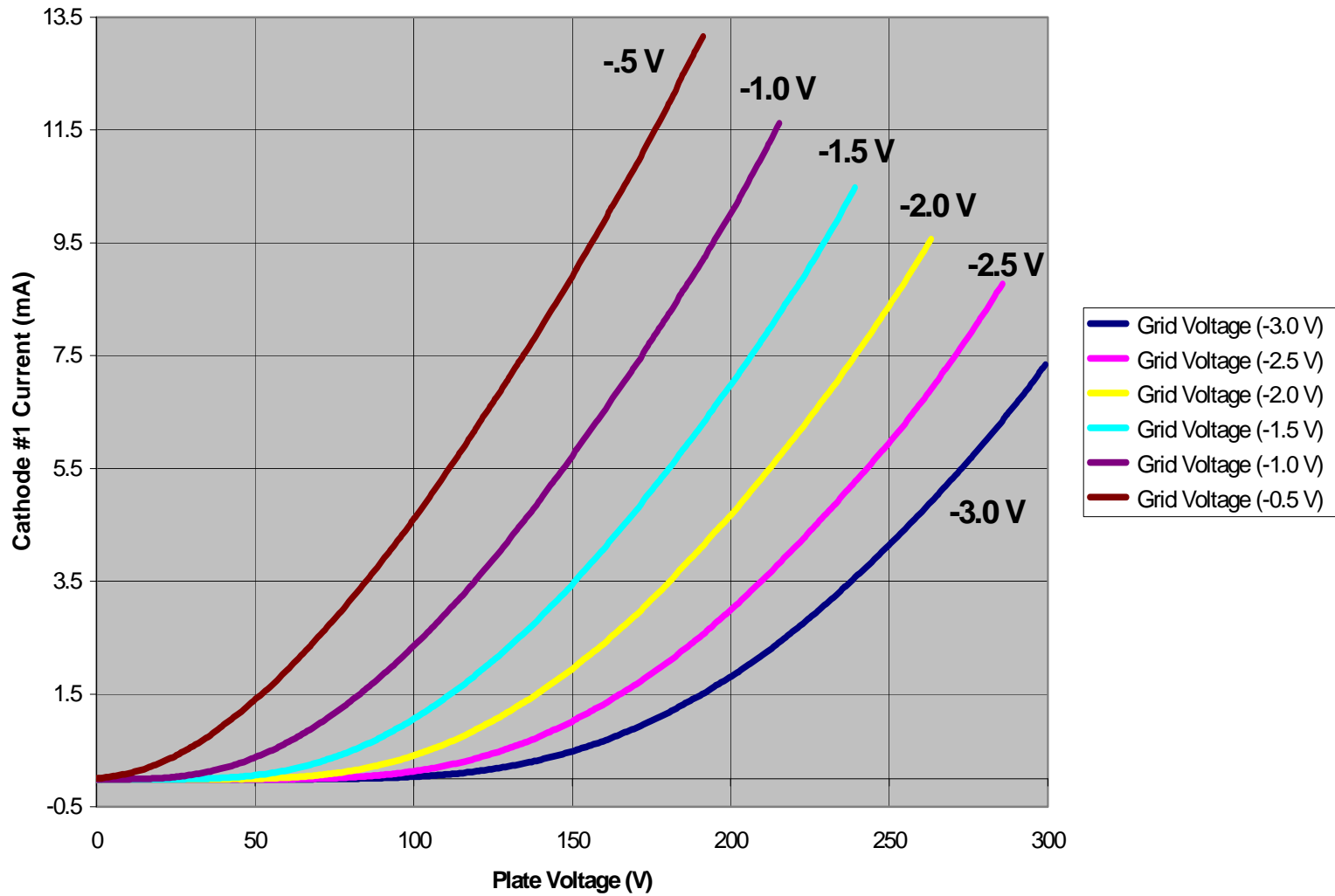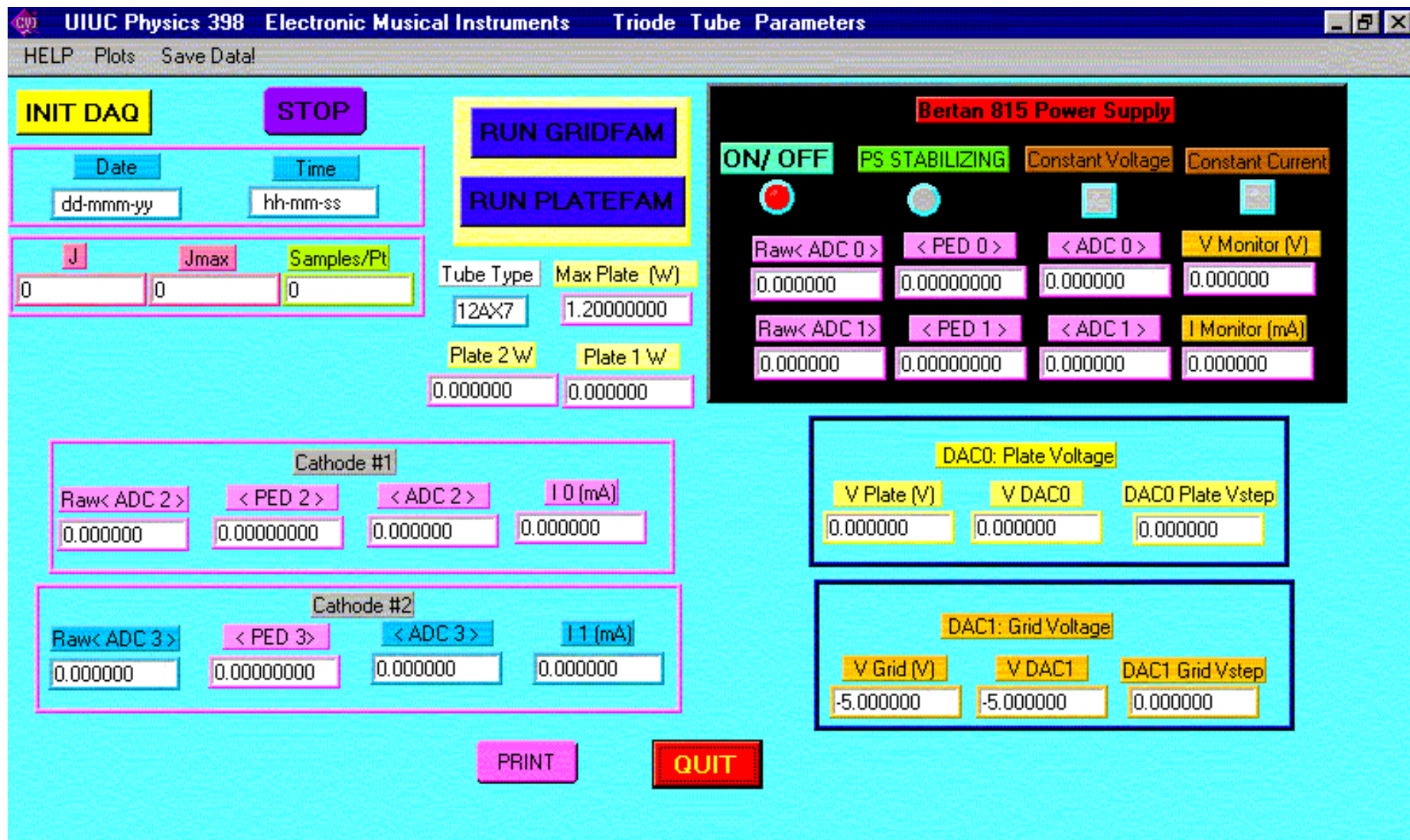
Fig. 5 GT12AT7 Grid Family

Fig. 6 GT12AT7 Plate Family

Fig. 7 TRIOPAR Software Interface