VACUTRACE

Vacuum Tube Curve Tracer

Made in USA

Copyrights & Trademarks

© Copyright Hagerman Audio Labs 2008. All rights reserved. No part of this document may be photocopied, reproduced, or translated to another language without the prior written consent.

Disclaimer

The information contained in this document is subject to change without notice. Hagerman Audio Labs shall not be liable for errors contained herein or for consequential damages in connection with the furnishing, performance, or use of this material.

Warranty

Hagerman Audio Labs warrants this product free of defects in materials and workmanship for a period of 10 years (90 days on tubes). If you discover a defect, Hagerman Audio Labs will, at its option, repair or replace the product at no charge to you provided you return it during the warranty period, transportation charges prepaid to Hagerman Audio Labs. This warranty does not apply if the product has been damaged by negligence, accident, abuse or misuse or misapplication, has been damaged because it has been improperly connected to other equipment or has been modified without the express written permission of Hagerman Audio Labs. This warranty is limited to the replacement or repair of this product and not to damage to equipment of other manufacturers. Any applicable implied warranties, including warranty of merchantability, are limited in duration to a period of the express warranty as provided herein beginning with the original date of purchase and no warranties, whether express or implied shall apply to the product thereafter. Under no circumstances shall Hagerman Audio Labs be liable for any loss, direct, indirect, incidental, special, or consequential damage arising out of or in connection with the use of this product.

Hagerman Audio Labs
PO Box 26437
Honolulu, HI 96825
808-383-2704 (voice)
808-394-6076 (fax)
www.haglabs.com

Description

The VacuTrace is a unique piece of laboratory test equipment that converts your analog oscilloscope into a full-features vaccum tube curve tracer. This powerful and flexible combination accurately sweeps the characteristic curves of diodes, triode, tetrodes, and pentodes in real-time. A special A/B comparison mode allows perfect tube matching by overlapping both sets of curves. A digital readout displays plate and grid bias voltages, cathode current, transconductance gain, and output conductance (1/rp).

Package Contents

- VacuTrace
- Power cord
- Four Adapter card in case
- Three BNC cables

Specifications

Item	Specification
Plate Voltage	0V to 380V @200mA
Cathode Current	0mA to 100mA (200mA in 2A mode)
Grid Step Sizes	0.5V, 1V, 2V, 5V, 10V (8 steps) @5mA
Plate Power	20W peak
Screen Voltage	100V to 300V @25mA
Transconductance	0.1mA/V to 20.0mA/V
Output Conductance	0.001mA/V to 2.000mA/V (1000k to 500 ohm)
Basic Accuracy	2% voltage and current, 5% conductance
Output Signal Gains	Plate/Screen: 10mA/V Grid: -50mV/V Cathode: 40mV/mA
Intensity Modulation	5V TTL levels, low on, high off
Heater Supplies	6.3V @5 amp 5.0V @3 amp
Socket Adapter Cards	Dual Triodes: 8 and 9 pin Pentodes: 8 pin (A and B) Power: 5V Diodes and 2A3/300B Blank: (wire up you own socket)
Input Voltage	120Vac or 240Vac, 50W
Fuse	1 amp 5x20 slo-blo

Socket Adapter Cards

Socket adapter cards are employed to accommodate various tube pinouts. These cards plug onto the connector at the top of VacuTrace and are held in place by four wing nuts. They are built to be rugged and quickly swapped with one another. A socket adapter card must be installed before a vacuum tube can be tested. Standard cards included with VacuTrace are:

- Dual 8 and 9 pin triodes (12AX7A/6DJ8, 6SN7)
- Octal pentode power tubes (6L6GC, KT88)
- Power triodes and diodes (2A3/300B, 5Y3)
- Blank (for customization, see Chapter 6)

Connections

Connecting a VacuTrace is simple. Use the BNC cables provided to connect the *X, Y* and *Z* outputs to your oscilloscope. Note, not all oscilloscopes have intensity modulation. This is ok, but makes it more difficult to determine which curve belongs to which tube in *A/B* comparison mode.

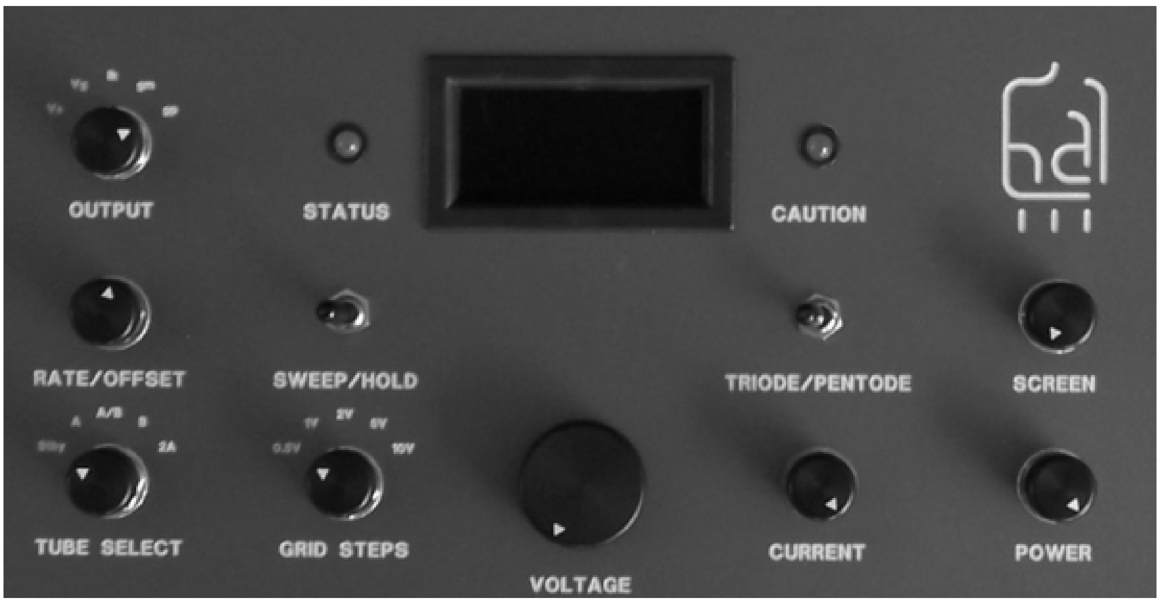
1. Connect *X* to channel 2 (horizontal) on your oscilloscope.
2. Connect *Y* to channel 1 (vertical).
3. Connect *Z* to the intensity modulation input, usually located on the rear.
4. Connect the ac power cord.

That's it, install a socket adapter card and you are ready to go. Be sure to set your oscilloscope to XY mode. Also, initially set both channel attenuators to 0.5V/division.

Operation

Front Panel

The controls have been laid out and spaced for easy and intuitive operation. Be sure to select standby mode before changing tubes or socket adapter cards.



Control / Indicator	Description
Tube Select	Sets the operating mode and chooses which tube to sweep. There are two tube circuits, *A* and *B*, which define the sections within a dual tube (or left and right sockets on the octal power pentode adapter). *Stby* mode shuts down all signals to the sockets, including heater supplies. Selecting *A* or *B* tests just that tube. *A/B* mode alternately tests both tubes resulting in overlapped curves and is ideal for matching tubes. *2A* mode doubles current and power capability by shunting the cathode current sense resistors together.
Grid Steps	Selects the step size (gain) for the grid amplifiers. There are always eight steps starting at 0V.
Voltage	This is the main limit control and sets the maximum value of plate voltage for sweeping. When the limit is reached, the plate voltage ramps back down to 0V initiating another cycle.
Current	Sets the maximum value of cathode current for a sweep.

Power	Sets the maximum peak power dissipated by the tube's plate during a sweep.
Rate/Offset	This is a dual function control. While sweeping it acts as sort of a sweep rate adjustment. It offers a compromise between accuracy and visual flicker. In *Hold* mode this becomes an offset adjustment for the grid bias voltage.
Sweep/Hold	Sets the operating mode between sweeping curves and taking measurements. In *Hold* mode the 3½ digit LED display is turned on and reads the value of the measurement selected by the *Output* control.
Output	Selects the measurement to be read in the display. Normally, tube curves are swept in the *gp* mode, but the *gm* mode can also provide useful information.
Triode/Pentode	Operates the tube as either a triode or pentode. The screen is tied directly to the plate in triode mode.
Screen	Adjusts the screen voltage when in pentode mode.
Status	LED indicates the present operating mode or condition. When in standby it is red. During normal operation it is green. If flashing yellow, then VacuTrace is experiencing an overload condition.
Caution	LED lights up yellow when a voltage greater than 70V is present on the output connector.

Rear Panel

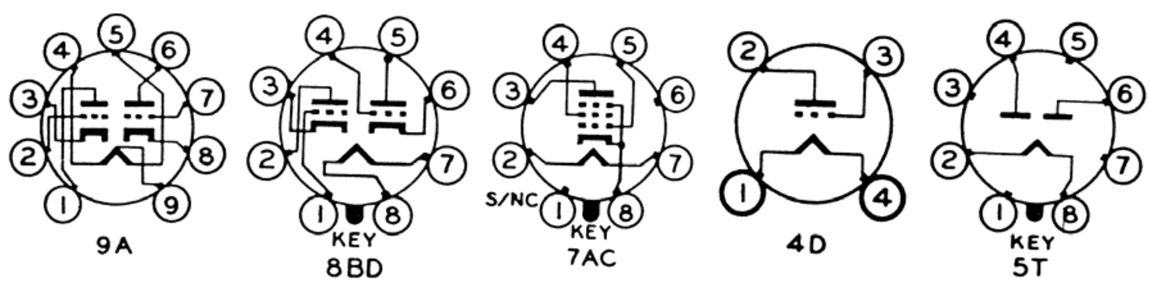
The rear panel holds the ac mains input/fuse holder connector, on/off power switch, and three output signal BNC connectors. The outputs are labeled *X*, *Y* and *Z* and connect to your oscilloscope by the BNC cables provided. See Chapter 1 for correct wiring.

Socket Adapter Cards

Some of the socket adapter cards contain switches. These are for heater voltage selection or, in the case of a diode, to choose which plate is operating (pin 4 or pin 6). The heaters of a 12AX7 type tube are run in parallel at 6.3V (set switch to 12.6V). All heaters are ac. The wing nuts are connected to chassis ground. There are two tube circuits, *A* and *B*, which allows for tube matching. The output connector has the following pinout:

Pin #	Signal	Description
1	PLATE	Plate (common to A and B)
2		
3	IKA	Cathode (A)
4	GRIDA	Grid (A)
5	+6H	Switched 6.3V heater power
6	5CT	5V heater center tap, connected to cathode
7	+5H	Switched 5V heater power
8	SCREEN	Screen (can be switched to plate, common to A and B)
9		
10	IKB	Cathode (B)
11	GRIDB	Grid (B)
12	-6H	6.3V heater return
13	GND	
14	-5H	5V heater return

On the *Duals* card, both sockets use *A* and *B* circuits (use only one tube at a time). On the *Pentodes* card, the left socket uses *A*, right *B*. Both sockets on the *Power* card use the *A* circuit.



Generating Curves

Setup

The most common use of VacuTrace is to sweep the characteristic curves of a vacuum tube. There are two ways to display curves, cathode current vs. grid voltage, and cathode current vs. plate voltage. Most users are familiar with published operating curves as shown below (which were actually generated using a VacuTrace).

While in standby mode, install your tube. Set the *Voltage* limit to minimum, the *Sweep/Hold* switch to sweep, and *Output* to *gp*. Adjust the *Current* and *Power* limits to appropriate levels. Set the attenuator controls on your oscilloscope to the desired gain levels as given in the following table.

Output	Oscilloscope	Actual
Plate/Screen	1V/div 0.5V/div	100V/div 50V/div
Cathode	0.5V/div 0.2V/div 0.1V/div	12.5mA/div 5mA/div 2.5mA/div
Grid	1V/div 0.5V/div 0.2V/div	20V/div 10V/div 4V/div

Make sure the oscilloscope is set to XY mode and the spot is positioned in the lower left corner (you may need to use the horizontal position control instead of the channel 2 offset). This point is defined as 0mA and 0V. Now turn the *Tube Select* to *A* and wait 10 to 30 seconds for the heater to warm up. Slowly increase the *Voltage* limit and you will see curves starting to form. Adjust the *Grid Steps* and other controls as necessary until you have a full set of curves and the tube is running safely within its ratings.

Limits

Three sweep limit controls are provided to prevent tube damage and allow you to adjust the way you want the curves presented. The triode curves shown above are power and voltage limited. The A/B mode curves shown below are both current and voltage limited. Sometimes you will want to combine all three.

Modes

Tube matching is accomplished using the *A/B* mode. VacuTrace automatically alternates sweeps between tube *A* and tube *B* displaying both sets of curves simultaneously. Differences in tubes are readily apparent and it becomes obvious that single point matching (such as current at a given bias) is insufficient. The *Z*-axis intensity control modulates the *B* tube so that its curves appear dotted.

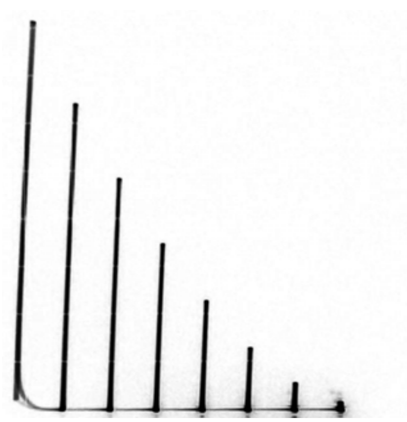
Switching to *2A* mode connects both cathode sense resistors together thereby doubling the current capability to 200mA. Note that while in *A* or *2A* mode, the *B* tube is cutoff by applying –70V to its grid. And, of course, vice versa.

Sweep rate is adjusted by the *Rate/Offset* control. Use this to reduce flicker in the display. Setting the *Triode/Pentode* control to pentode enables the *Screen* control. It is best to start at 100V and work your way up.

You may switch modes at any time and set controls to any position in any combination without causing damage to VacuTrace.

Transfer Function

By switching the *Output* to *gm* the oscilloscope display changes to current vs. grid voltage. You will probably have to readjust the attenuator on the X-axis to get a better aspect ratio. This unusual set of curves defines the transfer function for a given plate voltage. However, you must insure that neither the *Current* nor *Power* limit controls are involved. Drawing imaginary lines connecting each peak yields the input-to-output transconductance transfer function. Linearity of the tube is demonstrated by the spacing from peak to peak.



Measurements

Hold Mode

Tube measurements are taken by switching to *Hold* mode. By doing so, the plate voltage goes to the *Voltage* limit setting and the grid voltage goes to the *Grid Steps* setting plus the offset from the *Rate/Offset* control. This determines the bias point to operate the tube. You will also notice the 3½ digit LED display is enabled.

Setting the *Output* control to *Vs* reads the present screen voltage, or if set to triode mode, plate voltage. Changing to *Vg* reads grid voltage. Use the combination of *Grid Steps* and *Rate/Offset* controls to obtain any grid voltage from –0.5V to –70V. Once the desired operating point is dialed in, switch *Output* to *Ik* to read the resulting cathode current in milliamps.

Ratios

VacuTrace provides dynamic ratio measurements of great value to circuit designers, namely transconductance gain and output conductance.

Transconductance (*gm*) mode measures the ratio of output Ik divided by input Vg given in mA/V. The modulation of signals and division is all accomplished with analog circuitry. You can see the modulation on the oscilloscope, centered about the chosen operating point.

Similarly, *gp* measures the output conductance (1/rp) of the tube. It is the ratio of output Ik divided by input Vp given in mA/V. Again, the modulation, or portion of the curve being measured is visible in the display. VacuTrace always provides a clear picture of what is being measured.

Other standard tube parameters are calculated by:

$$r_p = \frac{1}{g_p}$$

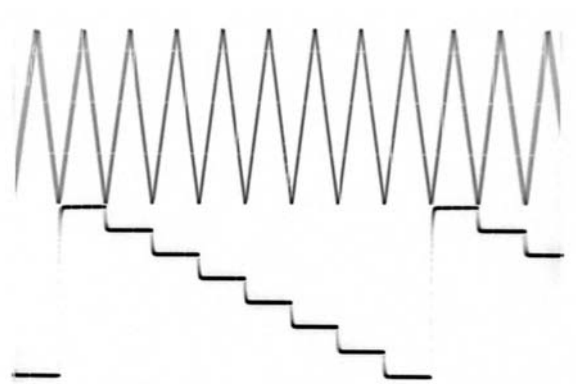
$$\mu = \frac{g_m}{g_p}$$

Technology

Generating Curves

VacuTrace sweeps the characteristic curves of a vacuum tube by applying plate, screen and grid bias voltages and measuring the resulting cathode current. A low value resistor shunts the cathode to ground converting the current into a voltage that is then amplified and sent to the Y channel of the oscilloscope. The plate voltage is ramped up and down and (an attenuated copy) is sent to the X channel, thereby “drawing” a curve on the oscilloscope’s display. The update rate determines image flicker and if fast enough, the curves will appear continuous.

A set of curves is formed because the grid voltage changes to a new value every time the plate reaches 0V. The grid is stepped to eight different levels starting at 0V. The oscilloscope photo below shows the relationship between plate and grid voltages.



The peak plate voltage is determined by any of the three limit controls. When one of these limits is reached the ramp is reversed back towards 0V. Normally the voltage limit control sets the peak voltage. But often you may want to limit either peak current or peak plate power, both of which can occur prior to the voltage limit. This capability is to prevent tube damage.

The current sense resistor causes a bit of degeneration or negative feedback that introduces small errors in the swept curves. This is because the actual effective grid-to-cathode voltage changes as a function of cathode current. VacuTrace subtracts out this error internally for the *Vg* and *gm* measurements, but curves on the oscilloscope remain affected. The 20 ohm sense resistor causes a 1V grid error at 50mA current.

Taking Measurements

Both static and dynamic measurements are done in *Hold* mode. Switching to *Hold* mode turns off the sweep and sets the plate voltage to the present limit setting (regardless of current and power limits).

Static voltages and current are measured using a standard analog-to-digital converter (DMM) IC.

In *gm* (transconductance) mode, a 625Hz modulation is added to the grid output. The dynamic peak-to-peak grid voltage is used as the reference for the LED analog-to-digital converter and the resulting cathode current modulation (just the ac component) is used as the input. This creates an analog divider circuit to calculate $\partial Ik/\partial Vg$, which is transconductance gain. Similarly, in *gp* mode, the plate voltage is modulated and dynamic cathode current measured to determine output conductance.

Miscellaneous

Tube Life

Always set the plate voltage limit to minimum before coming out of standby. Do not turn up the plate voltage until the heaters have warmed up, otherwise you could cause cathode-stripping damage.

Be careful not to exceed any of the tube's maximum operating specifications. VacuTrace can deliver a lot of voltage, current and power to a tube. Small signal types such as a 12AX7 are vulnerable to such overdrive.

It is not necessary to turn off VacuTrace when swapping tubes or socket adapter cards. That is what standby mode is for. All signals to the output connector are shut off in standby and it is safe to change tubes.

Accommodating Other Tubes

The socket adapter cards that come standard with VacuTrace only cover the most popular tubes in use today. There are thousands of tubes that do not plug into these sockets. However, all is not lost. Included is a blank socket adapter card (additional ones can be purchased separately). You can customize this card for virtually any tube. Sockets can be mounted on standoffs or, if octal or noval, soldered directly on the card. Just add wire.

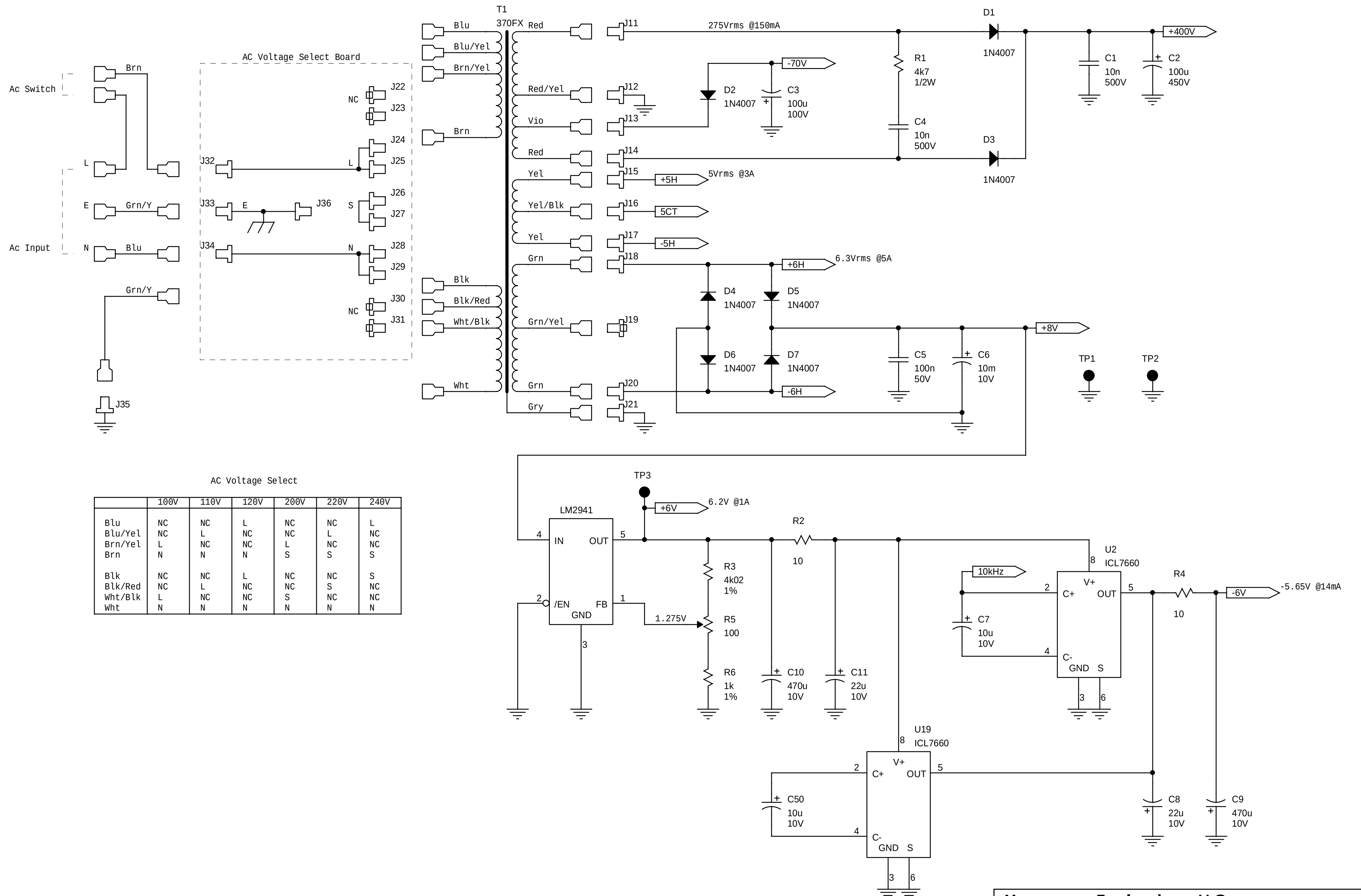
Below is an example which connects an EL84 to the *A* circuit and an EF86 to the *B* circuit. This lets you run both tubes simultaneously. For power tubes it is best to use the *A* circuit as it can operate in *2A* mode for up to 200mA of current. You could actually wire up all four sockets for different tubes, but make sure to operate only one at a time. It is preferable to run the wiring on the underside of the card, but is shown topside here for clarity.

Some tubes will be difficult, if not impossible to operate. For example, the SV-572 is a directly heated power triode – but runs at 6.3V. VacuTrace does not support directly heated cathodes except for the 5V variety. It is possible to add an external heater supply transformer with the center tap connected to IKA, but these big tubes barely get turned on at 400V so it is not worth the effort.

Pin #	EL84 / 6BQ5	EF86 / 6267
1		SCRN
2	GRIDA	
3	IKA	IKB
4	+6H	+6H
5	-6H	-6H
6		PLATE
7	PLATE	
8		IKB
9	SCRN	GRIDB

Troubleshooting

Problem	Possible Causes / Solutions
Does not turn on.	Power cord not plugged in or fuse blown. Power switch on rear panel must be turned on.
Tries to turn on but does not operate correctly.	AC input voltage selection on wrong setting.
LED display does not work.	VacuTrace must be in *Hold* mode.
Curves not generated.	Faulty tube. Oscilloscope not in XY mode or set up improperly. Heater not warmed up yet. VacuTrace in *Stby* or *Hold* modes.
Oscilloscope display is backwards.	XY cables are reversed.
Curves keep disappearing.	VacuTrace is in an overload condition, lower the plate or screen voltage or remove fault.



AC Voltage Select

	100V	110V	120V	200V	220V	240V
Blu	NC	NC	L	NC	NC	L
Blu/Yel	NC	L	NC	NC	L	NC
Brn/Yel	L	NC	NC	L	NC	NC
Brn	N	N	N	S	S	S
Blk	NC	NC	L	NC	NC	S
Blk/Red	NC	L	NC	NC	S	NC
Wht/Blk	L	NC	NC	S	NC	NC
Wht	N	N	N	N	N	N

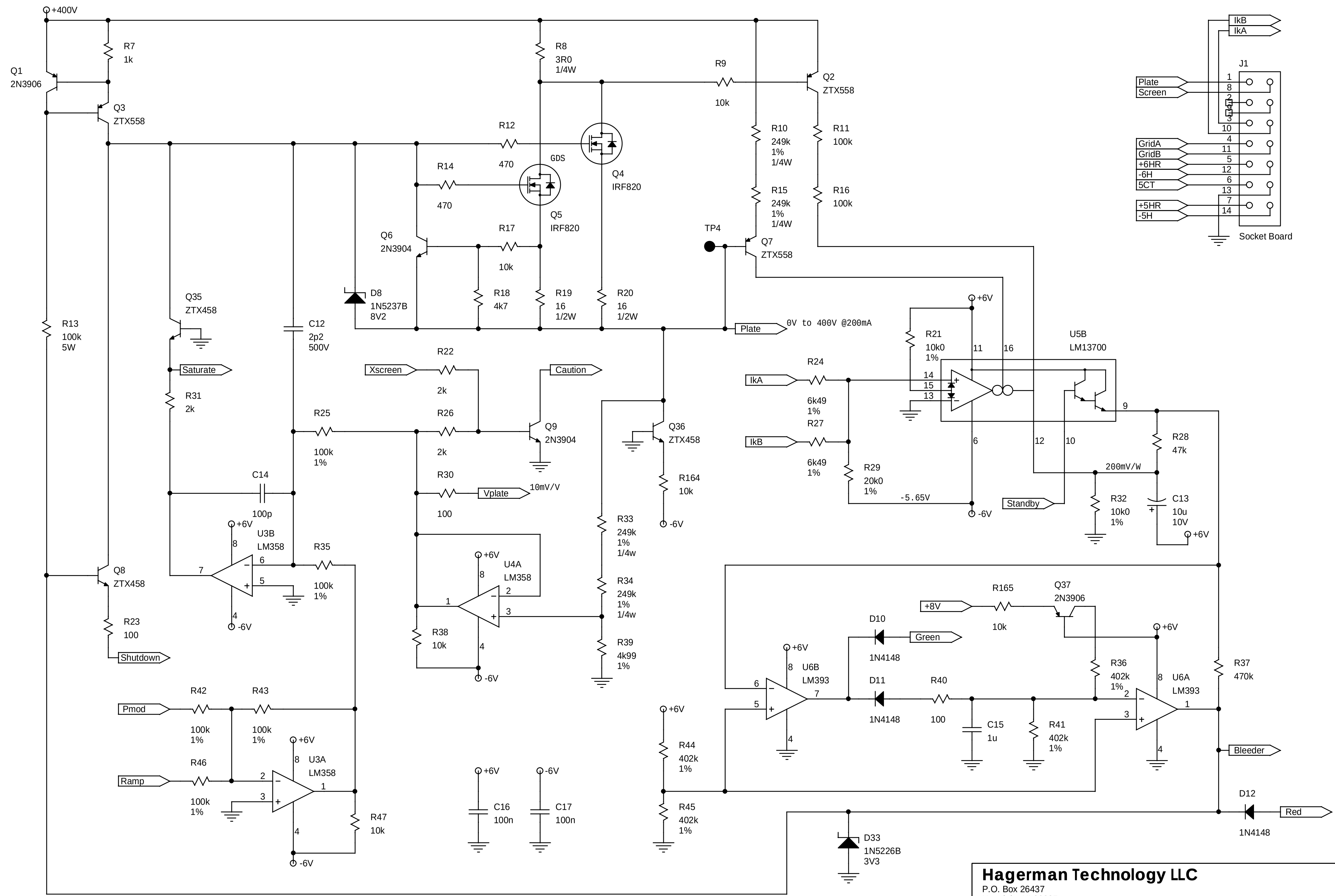
This document contains proprietary information and except with written permission of Hagerman Technology LLC such information shall not be published, or disclosed to others, or used for any purpose, and the document shall not be copied in whole or in part. Copyright Hagerman Technology LLC 2000. All rights reserved.

Hagerman Technology LLC
P.O. Box 26437
Honolulu, HI 96825

Title
VacuTrace: Power Supply

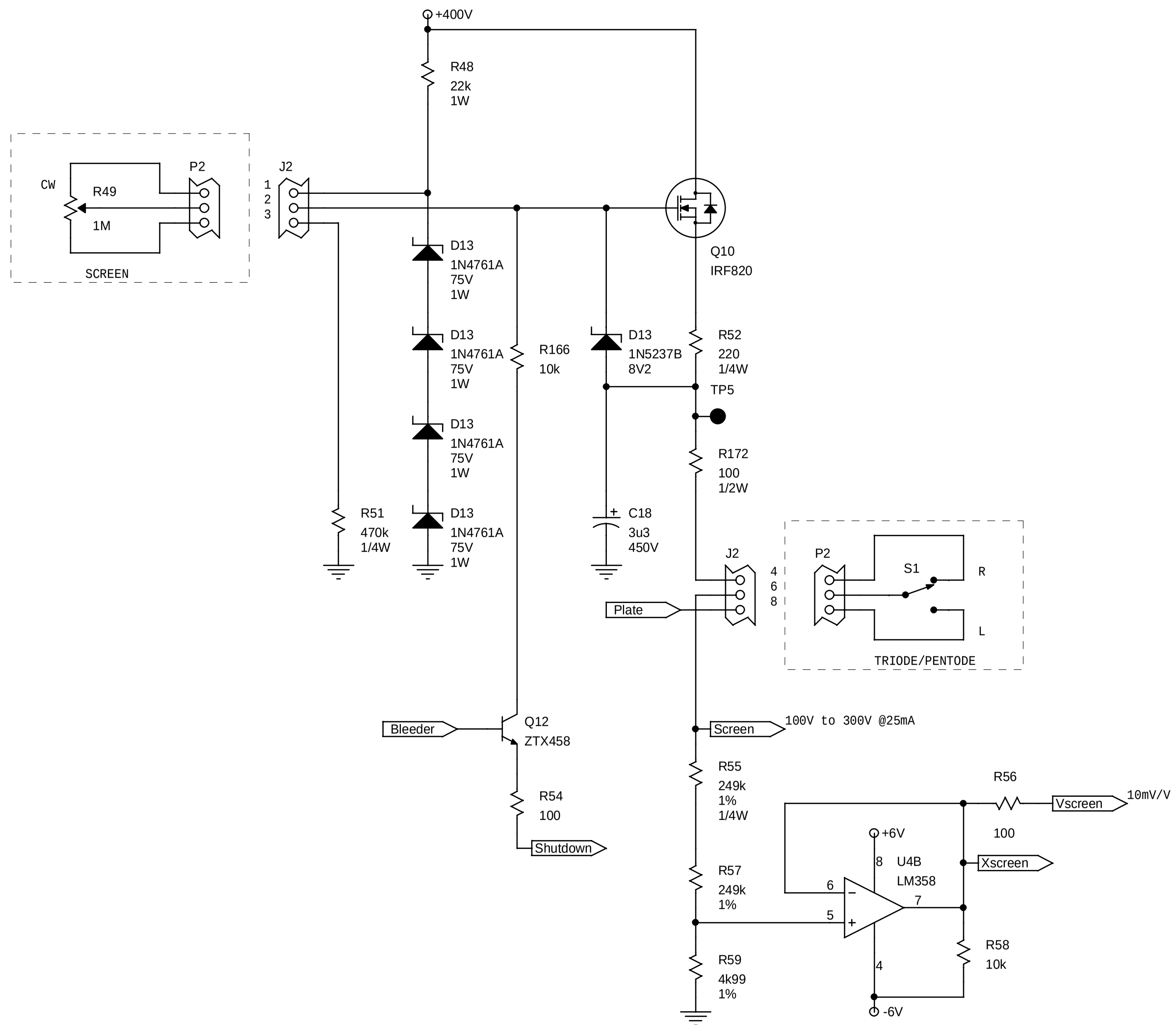
Size	Document Number	Rev
	n/a	A

Date: Tuesday, August 22, 2000 Sheet 1 of 8



Hagerman Technology LLC
P.O. Box 26437
Honolulu, HI 96825

Title	VacuTrace: Plate Amp		
Size	Document Number: n/a		Rev: A
Date:	Tuesday, November 14, 2000	Sheet 2	of 8

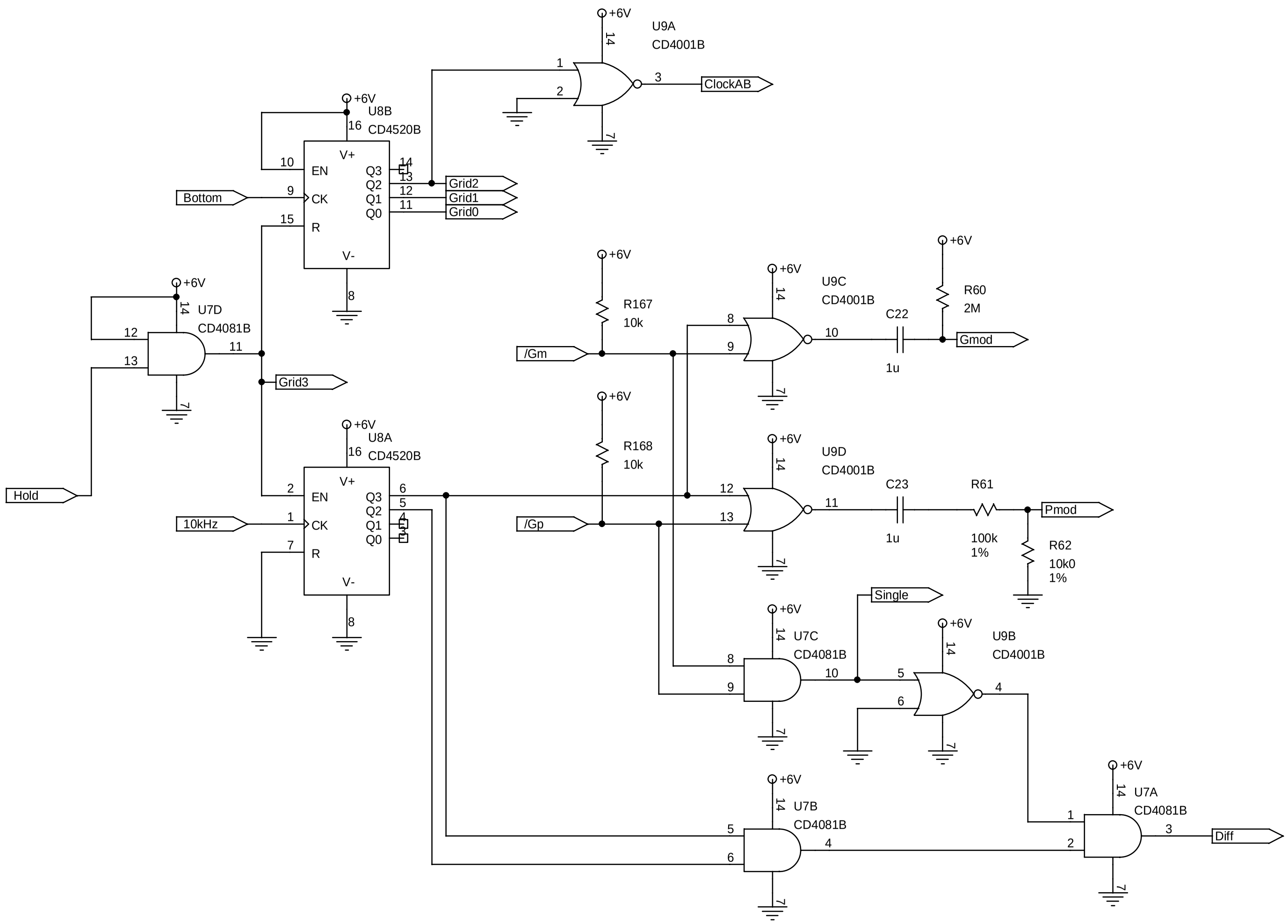


Hagerman Technology LLC
P.O. Box 26437
Honolulu, HI 96825

Title
VacuTrace: Screen Amp

Size	Document Number	Rev
Custom	n/a	A

Date: Friday, December 22, 2000 | Sheet 3 of 8

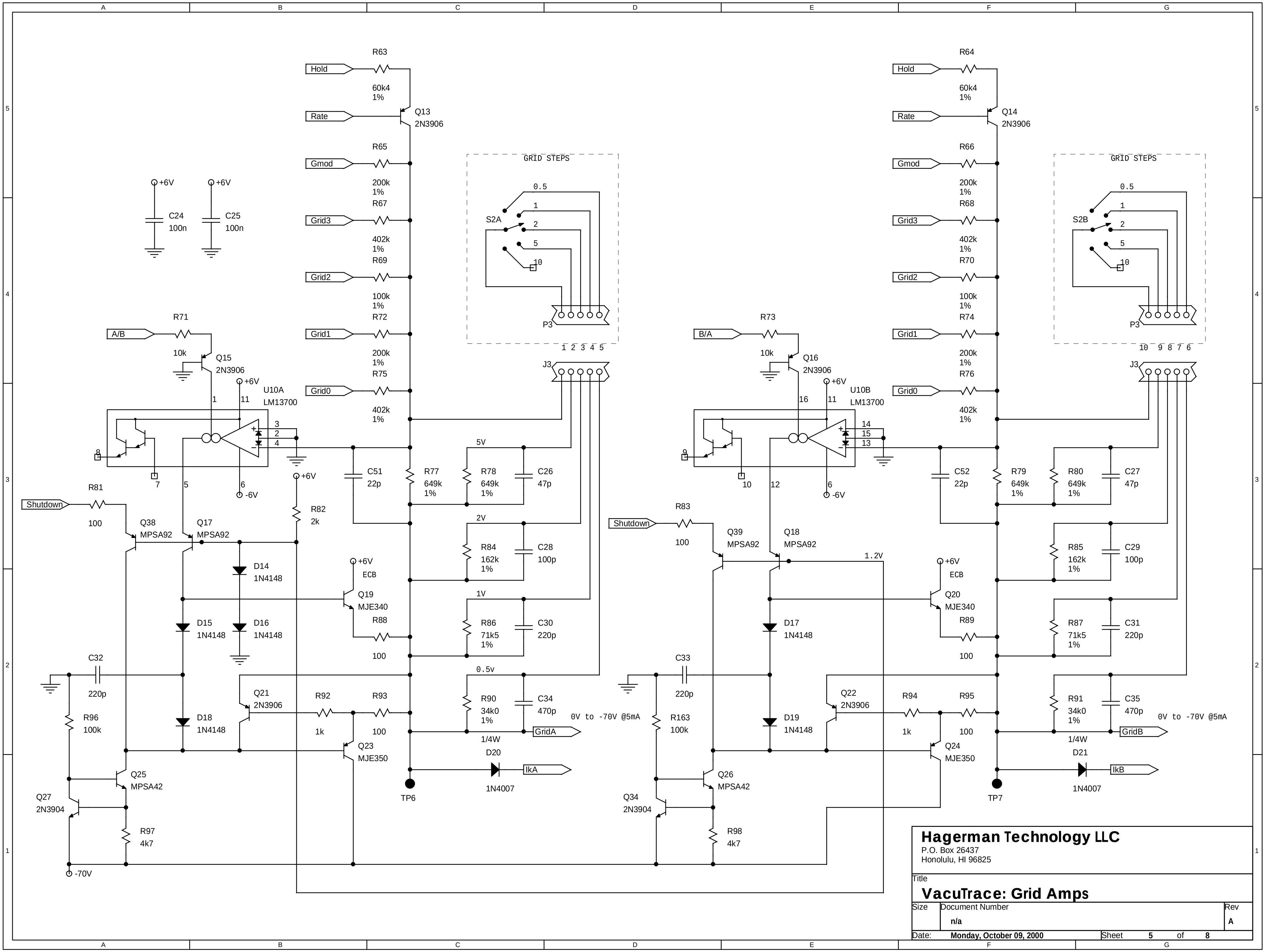


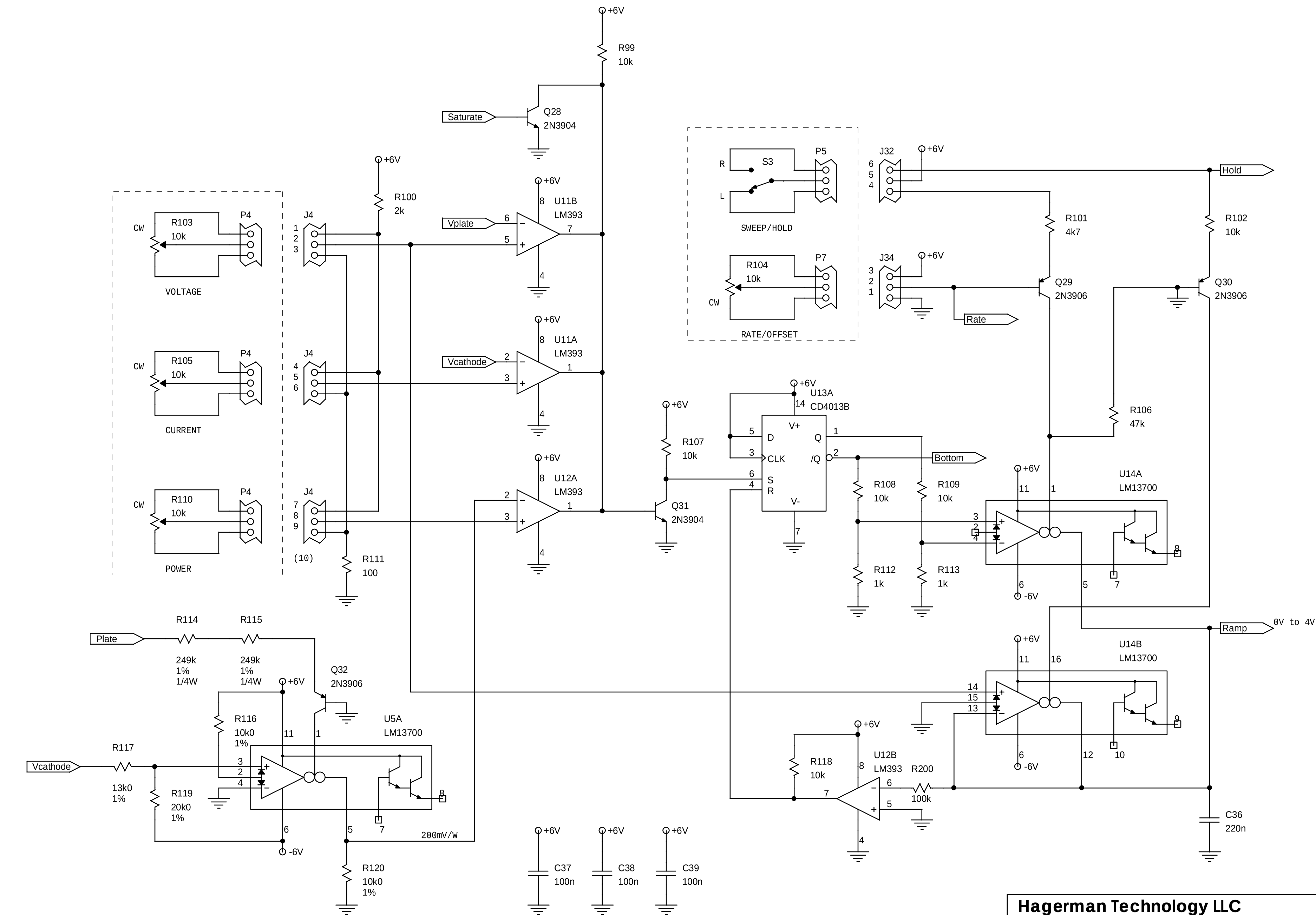
Hagerman Technology LLC
P.O. Box 26437
Honolulu, HI 96825

Title
VacuTrace: Grid Control, Modulation

Size	Document Number	Rev
	n/a	A

Date: Friday, August 18, 2000 | Sheet 4 of 8


Hold
Rate
Gmod
Grid3
Grid2
Grid1
Grid0
R63
60k4
1%
Q13
2N3906
R65
200k
1%
R67
402k
1%
R69
100k
1%
R72
200k
1%
R75
402k
1%
R64
60k4
1%
Q14
2N3906
R66
200k
1%
R68
402k
1%
R70
100k
1%
R74
200k
1%
R76
402k
1%
GRID STEPS
0.5
1
2
5
10
S2A
S2B
P3
1 2 3 4 5
10 9 8 7 6
J3
C24
100n
C25
100n
+6V
-6V
A/B
B/A
R71
10k
Q15
2N3906
R73
10k
Q16
2N3906
U10A
LM13700
U10B
LM13700
C51
22p
C52
22p
R77
649k
1%
R79
649k
1%
5V
2V
1V
0.5v
R78
649k
1%
C26
47p
R84
162k
1%
C28
100p
R86
71k5
1%
C30
220p
R90
34k0
1%
C34
470p
1/4W
R80
649k
1%
C27
47p
R85
162k
1%
C29
100p
R87
71k5
1%
C31
220p
R91
34k0
1%
C35
470p
0V to -70V @5mA
GridA
GridB
D20
D21
1N4007
IkA
IkB
TP6
TP7
Shutdown
R81
100
R83
100
Q38
MPSA92
Q17
MPSA92
Q39
MPSA92
Q18
MPSA92
1.2V
R82
2k
D14
1N4148
D15
1N4148
D16
1N4148
D18
1N4148
D17
1N4148
D19
1N4148
Q19
MJE340
Q20
MJE340
ECB
R88
100
R89
100
C32
220p
C33
220p
R96
100k
R163
100k
Q21
2N3906
Q22
2N3906
R92
1k
R93
100
R94
1k
R95
100
Q23
MJE350
Q24
MJE350
Q25
MPSA42
Q26
MPSA42
Q27
2N3904
Q34
2N3904
R97
4k7
R98
4k7
-70V
Hagerman Technology LLC
P.O. Box 26437
Honolulu, HI 96825
Title
VacuTrace: Grid Amps
Size
Document Number
n/a
Rev
A
Date:
Monday, October 09, 2000
Sheet
5
of
8

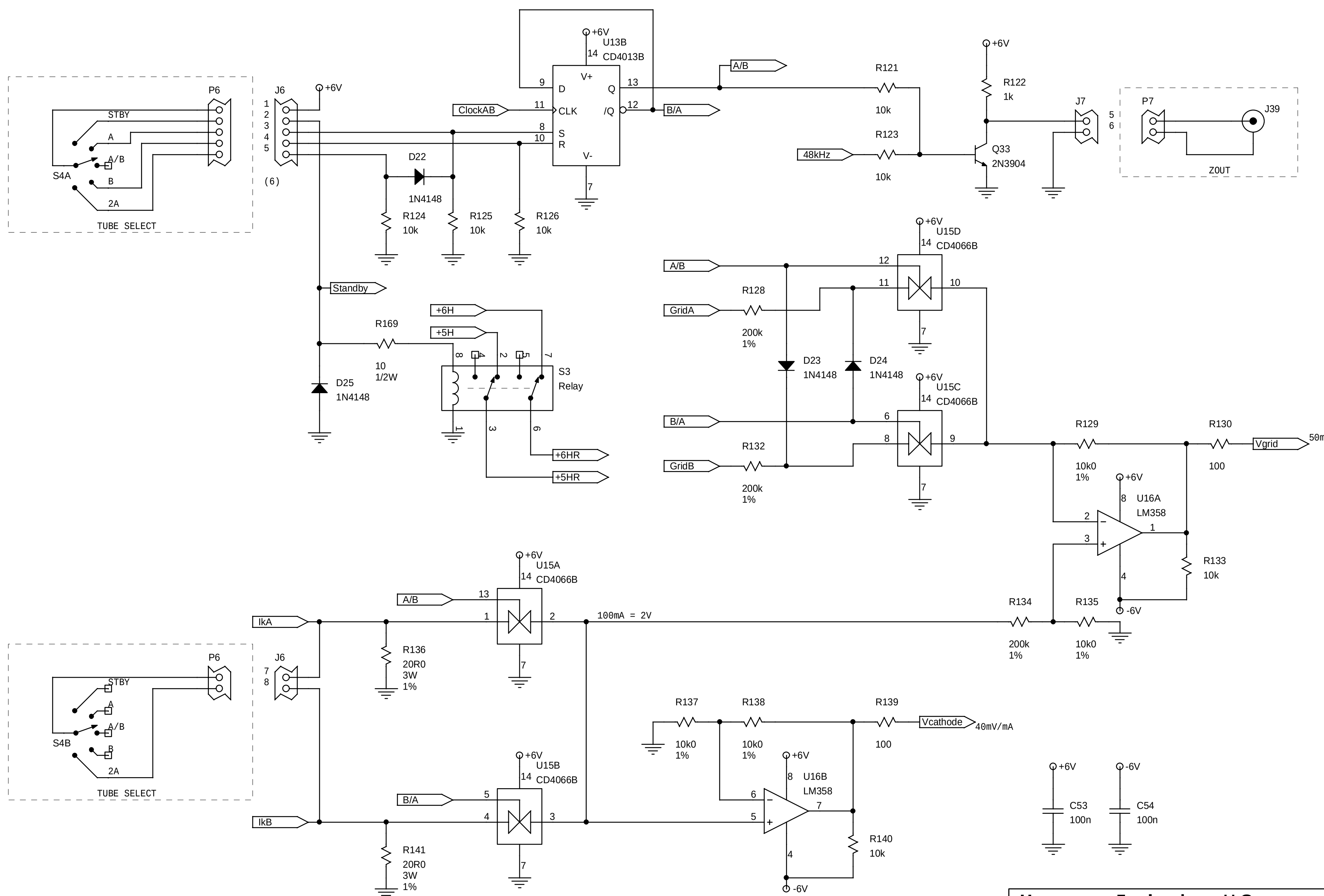


Hagerman Technology LLC
P.O. Box 26437
Honolulu, HI 96825

Title
VacuTrace: Limits, Oscillator

Size	Document Number	Rev
	n/a	A

Date: Wednesday, September 20, 2000 | Sheet 6 of 8

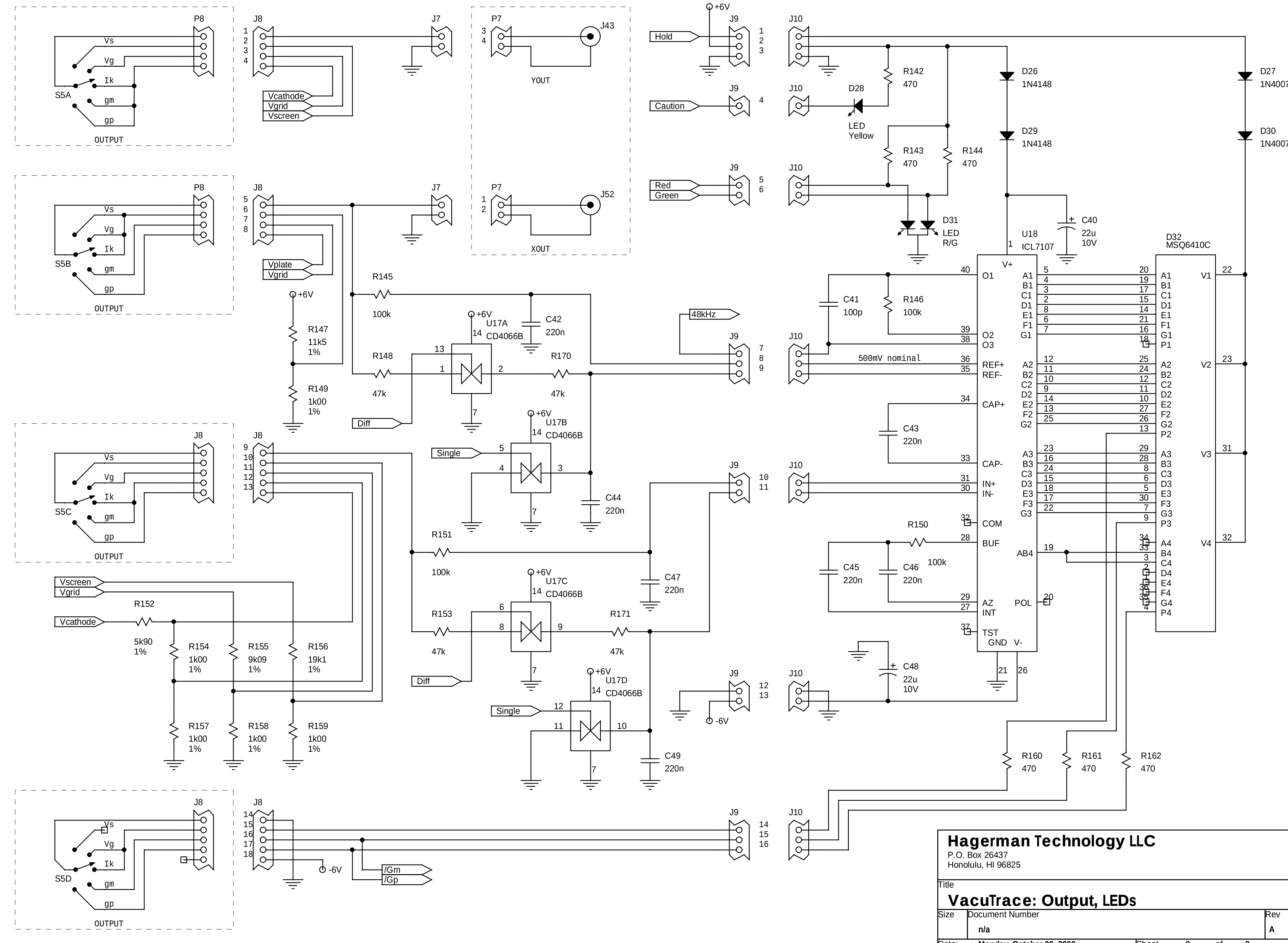


Hagerman Technology LLC
P.O. Box 26437
Honolulu, HI 96825

Title
VacuTrace: A/B, Cathodes

Size	Document Number	Rev
	n/a	A

Date: Wednesday, September 20, 2000 | Sheet 7 of 8

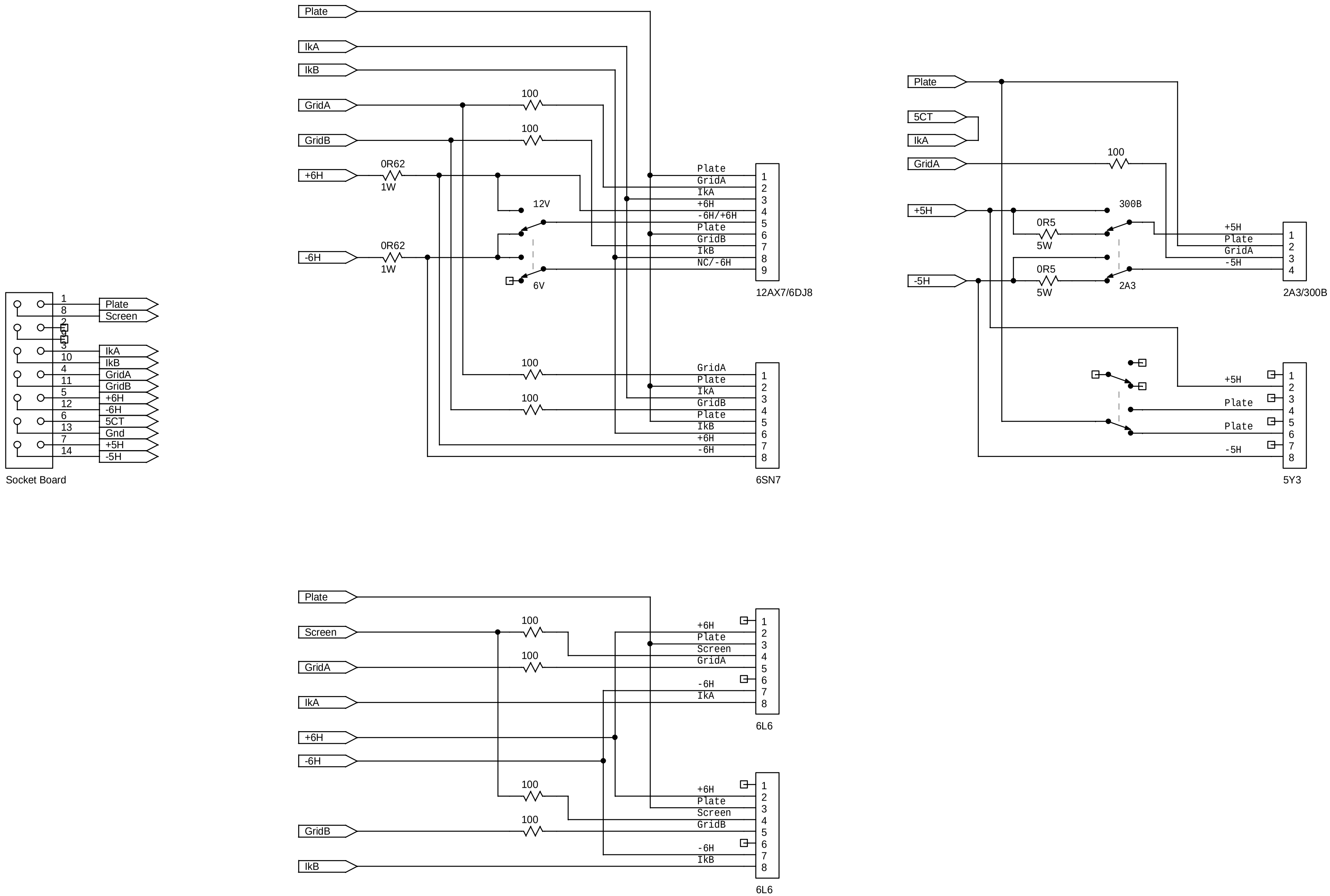


Hagerman Technology LLC
P.O. Box 26437
Honolulu, HI 96825

Title: **VacuTrace: Output, LEDs**

Size	Document Number	Rev
	n/a	A

Date: Monday, October 09, 2000 | Sheet 8 of 8



Hagerman Technology LLC
P.O. Box 26437
Honolulu, HI 96825

Title
VacuTrace Adapter: Duals, Octals, Power

Size	Document Number	Rev
	n/a	A

Date: Friday, August 18, 2000 | Sheet 9 of 9