Kliegl Bros. P-73
Light Dimmer Module

2 kW and 5 kW

Operation and Service Information

Kliegl P-73 Dimmer Operation and Service

Revision 1, February 27, 2011

This operation and service information is based on reverse engineering of the P-73 2kW and 5 kW dimmer modules. It is believed to be correct, but has not been independently verified at the time of this publication. It is provided as a convenience to assist those who may need to service or use this dimmer. There are no warranties expressed or implied. This information contained in this document may not be incorporated into other documents or otherwise modified without the express written consent of the author. Permission is given to copy this document in PDF or printed format in it's entirety without modification and without charge. Please submit any corrections or improvement suggestions to kfilardo@aol.com.

WARNING

This unit contains lethal voltage and currents, service personal shall be qualified technicians and experienced in working with line voltage electronics. This manual is intended to be used only by qualified technicians due to safety hazards, and is not appropriate for use by less experienced personnel. Anyone who is not qualified should never touch or probe the internal components of this unit when it is connected to power.

CAUTION

This unit contains semiconductor devices that may be damaged by electro static discharge. While the devices used in this dimmer are less sensitive than modern computer circuits, it is strongly recommended to use ESD procedures when handling the circuit board to insure reliable performance after servicing.

Dimmer Module Operation

The P-73 dimmer is a electronic dimmer that functions by varying the duty cycle of the AC line voltage. The control circuitry is fully transformer isolated and is controlled by a 0 to 10 volt DC voltage source. Since the control circuitry has no connection to ground, the external control voltage must be tied to ground. Either positive or negative control voltages may be used, however normally a positive control voltage is used and the negative control input tied to the control system common ground. The input impedance of the control input is 10k ohms, the controlling voltage source should be able to drive this impedance with limited loading effects to minimize altering the dimmer brightness vs. control voltage characteristics.

The design of the module connector allows for hot insertion and removal of the dimmer module. The control circuit power and control voltage pins make last and break first, insuring that the Triac is in the off condition when the line and load contacts make or break.

Theory of Operation

The dimmer circuitry is composed of variable current source controlled by the applied control voltage, a voltage ramp generator driven by the variable current source, a triac gate driver, and power supply.

The power supply uses a center tapped transformer to produce a full wave rectified positive and negative output. The Positive output is filtered by R13 and C1 to produce approximately 25 volts. Zener D13 provides a regulated voltage 5.1 volts below the 25 volt supply that is the reference for the ramp current source. The voltage divider made up of R10, D8, and D9 provides a 0.6 volt and 1.2 volt bias source. The negative supply is not filtered, as it is used for zero crossing detection to control the timing of the triac trigger pulse.

The input control voltage is applied through R16 and 15 the emitter of Q8 which translates the control voltage into a current that is independent of the collector voltage of Q8. The voltage divider R15 R16 at the input control voltage causes the dimmer common to be floated at 1/2 the control voltage to minimize interference. The network of R18, R19, Q1 compose a non-linear resistive load that converts the control current from Q8 into a voltage that drives the Q3 current source, The circuit of Q1 and Q2 affect the Q3 emitter impedance, and the Q3 collector current is equal to Q3 base voltage divided by the effective impedance of the Q3 emitter circuit. This complex network is used to shape the brightness response, and there are likely multiple configurations of this shaping circuit as Kliegl offered three different control voltage response characteristics. Available responses were Square Law, Linear Light, and Linear Voltage. The P-73 control board information in this document is based on modules that produce the square law voltage response. Since power is proportional to voltage squared, the control voltage response produces a linear power output, 1V = 10% power, 2V = 20% power, 9V=90% power.

The dimmer response characteristics below were published in the Kleigl Bros. P-82 manual.

Control	IES Square Law		Linear Light		Linear Voltage	
Voltage	% Lumens	VAC	% Lumens	VAC	% Lumens	VAC
0	0	0	0	0	0	0
1	1	35	10	70	0.07	16
2	4	51	20	76	2	27.5
3	9	63	30	84	4	39
4	16	72	40	91	6	50
5	25	80	50	97	18	61.5
6	36	88	60	101	27	73
7	49	96	70	107	34	84.5
8	64	104	80	111	50	97
9	81	112	90	115	72	107.5
10	98	117	98	117	98	117

The voltage ramp generator consists of C5, which with the applied current will charge positively at a rate controlled by the current source. When the AC voltage goes through zero crossing, the negative supply is 0 volts, allowing R1 to turn on Q9, discharging C5 to zero volts. Note that Q4 and Q6 also are controlled by the zero crossing to turn off the current source Q3 during the zero crossing event.

The triac gate signal is generated by Q5, a silicon unilateral switch that is high impedance until the applied voltage reaches 8 volts, then it turns on, dumping the stored charge of C5 into Q10, which turns on and drives transformer T2, applying a pulse into the triac gate.

The 2 kW and 5 kW dimmers are similar in operation and construction, with the same control board used in both dimmers. The chassis of the 5 kW dimmer uses a 45 amp circuit breaker instead of a 20 amp fuse, and incorporates a higher current triac and filter choke.

Troubleshooting and Repair of the Dimmer

Recommended Equipment:

- Digital Multimeter, with diode test function
- True RMS Voltmeter, or Wattmeter / power factor meter
- Oscilloscope with probes may be required for difficult problems
- 0 to 10 volt isolated power supply, or 9 volt alkaline battery & 10 k ohm pot
- Test cable for interconnecting line voltage and lamp load to dimmer connector
- Line cord for testing control PC board

Fault Isolation:

The most likely failure mechanism for a dimmer is a blown fuse or triac failure due to a shorted load. If the indicator light on the front of the dimmer is not lit, the fuse is likely blown (assuming the light is working). If the dimmer operates at full brightness at all times, the triac is likely shorted. With the dimmer disconnected from power, an ohmmeter can be used to check the fuse and triac. If the triac is shorted on any terminal, it must be replaced. Note that the resistance of the triac gate can be fairly low (measured across the yellow and brown wires connected to the triac), with the 5 kW triac gate resistance typically 3 to 10 ohms.

If the dimmer has power, the the front panel indicator is lit, but will not turn on a load with an applied control voltage, it is likely the problem is likely in the control board. If a known good control board is available, it may be substituted to confirm the control board failure.

Testing of the Control Board:

The control board can be removed and operated separately from the dimmer chassis to facilitate repair. After removal, the board should be given a visual inspection for damaged or missing components, and fractured solder joints, Pay particular attention to the two transformers, as these relatively large and heavy components are only supported by the solder connections. The P-73 utilizes a robust design and quality components, after 30 or more years in service fatigued solder connections may be more likely to occur than tired components. Initial troubleshooting can be done using a DMV diode test function check the transistors in circuit, replacing any transistors that indicate a shorted condition. Resistance measurements of the transformers and electrolytic capacitors are as follows:

T1 primary (connector pin 14 to pin 11) is about 700 ohms
T1 secondary D1 cathode to C1 negative is about 100 ohms
T1 secondary D3 cathode to C1 negative is about 100 ohms
T1 secondary D1 cathode to D3 cathode is about 200 ohms
T2 primary D10 cathode to D10 anode is about 1.0 ohms
T2 secondary D15 cathode to connector pin 7 is about 0.5 ohms
Across C1 – greater than 200k ohms
Across C2 – approximately 18 k ohms
Across C3 – approximately 3.7 k ohms
Across C4 – approximately 66 k ohms

If the problem cannot be resolve by visual inspection and ohmmeter checks, it will be necessary to test the control board while powered.

WARNING
Lethal voltages are present on the PCB in the area of the power transformer. Appropriate caution must be taken, it is recommended to cover the top and bottom of the board with a temporary shield or electrical tape in the area of the transformer primary (where the white and black power cord was attached).

To operate the board, a three wire power cord can be temporarily soldered to the power transformer terminals on the back side of the PCB, neutral (white) connected to the trace routing to pin 11, line (black) connecting to the trace routing to pin 14, and ground (green) connecting to the transformer secondary center tap (trace connecting to C1 - lead). By connecting the floating common to ground during testing, voltage and oscilloscope measurements may be easily made. Since the control inputs are no longer floating, an isolated dc power supply is required to provide the 0-10 volts. If a power supply is not available, a nine volt battery and 10 k ohm pot may be used to control the dimmer PCB during testing.

To observe operation of the dimmer control, attach an oscilloscope probe to D10 anode, the probe ground to C1 negative, set the scope for 5 volts per division, 5 ms per division, and line trigger. If the board is operating properly, adjustment of the 0-10 volt control voltage will shift the trigger signal observed on the scope over a range of about 5 ms in time. If you connect a second scope channel) to D1 cathode, you can observe the trigger point (rapid negative edge of waveform) move from about 20% to 80% of the distance between the AC voltage zero crossings. It is normal to see the trigger pulse quit below about 0.5 volts control voltage. If an oscilloscope is not available, the operation of the Q10 pulse driver can be verified by observing the voltage across R21. When the control voltage is zero, there will be no pulse and no voltage drop across R21. Once the control voltage is increased above 1 volt, pulse presence will be indicated by about a 2 volt drop across R21.

If the dimmer does not operate normally with the above oscilloscope test, the DC voltages below should be checked. The voltages in the chart below are referenced to the control circuit common, connect the negative voltmeter lead to C1 negative, Voltages shown are approximate, it is more important that the voltage track with varying control voltage. Note that Kliegl offered options to support different brightness response curves, so your voltages may be different in mid-range than shown.

Measured Point	Control Voltage = 0	1V	5V	10V
C1 + (25 V supply)	26V	25.5V .	25V	24.5V
D13 Cathode (20 V supply)	21V	20.5V	20V	19.5V
C2 negative	25.5V	23.5V	18V	14V
C3 negative	26V	25V	19V	15.5
Q8 collector	25.5	23V	17V	13V

Replacement Components

Most components used on the control board are available at the time of this writing (2011). The electrolytic capacitor C1 may fail with age and should be checked, replace if significant AC ripple appears across C1. The other capacitors should have a longer lifetime, currently available electrolytic capacitors are acceptable replacements. The 2N2222A NPN and 2N2907A PNP transistors are general purpose 40V audio or switching transistors, the plastic case versions of these devices (PN2222A and PN2907A) are excellent replacement choices. Any general purpose switching transistor (of correct NPN or PNP type) will likely work if these devices become hard to find in the future. The 2N4990 transistor is an 8 volt silicon unilateral switch that is becoming hard to find, a silicon bilateral switch, diac, or other similar device with an 8 volt nominal turn on should also work. An electrically equivalent power transformer is easy to find, however finding an exact mounting replacement is unlikely and it may be necessary to drill new lead holes in the board to facilitate replacement. The pulse transformer will be difficult to obtain, but is unlikely to fail or be damaged.

The stud mount triacs used in these dimmers are becoming difficult to obtain, but any general purpose triac with sufficient current and voltage rating will likely work acceptably. The 2 kW dimmer uses a 40 amp 200 volt triac and provides a conservative margin. 40 amp 800 volt plastic packaged triacs are available at reasonable cost ($5) and can be used, it will be necessary to drill and tap a smaller mounting hole in the heat sink for it's mounting hole. Be sure to use heat sink compound, do not use an insulator since the heat sink is mounted on insulated brackets. Triacs over 40 amp are not common and are likely to be expensive, if necessary a 40 amp plastic triac can be used to repair the 5 kW dimmer if it is not be be used over 3.6 kW / 30A maximum loading. Note that because of the conservative triac rating used, dimmer capacity is limited by the filter inductor current rating and the rated 2 or 5 kW should not be exceeded regardless of the replacement triac rating.

Preventive Maintenance

While the dimmer does not normally need regular maintenance, after 30 years of service several common failure modes have been observed and can be addressed when the dimmer is repaired or calibrated to improve reliability. The following recommendations were based on inspection and repair of 30 dimmer modules.

1 The front panel indicator lamp is neon and has a finite lifetime, and should be replaced if it flickers or is not working.

2 The dimmer circuit card is not mechanically protected when the dimmer module is removed from the dimmer rack, if it has not been handled with care there may be mechanical damage and a careful visual inspection should be performed. Check transistor alignment, T1 transformer damage, C1 damage, and solder joints.

3 The T1 transformer is held only by solder joints, about 1/3 of units observed showed broken or fatigue in the transformer solder joints. It is recommended to re-solder T1 even if the solder joints look OK.

4 The pins of the chassis PCB connector may have lost tension, typically from an impact that causes sufficient chassis flex for the PC board to disconnect and bend the connector pins. This damage is much more likely on the 5 kW dimmer chassis. Pins with insufficient grip will be indicated by no output or intermittent output with board movement, the contacts should be inspected and adjusted as needed. Use a small screwdriver and carefully bend the contact forks slightly inward to reduce the spacing between the forks.

Dimmer Calibration

WARNING – LEATHAL VOLTAGES ARE PRESENT DURING CALIBRATION

The Kliegl Bros. P-82 dimmer manual recommends calibrating the dimmer output to control voltage relationship by observing the output voltage. Because of the partial duty cycle of the dimmer output, a true RMS AC voltmeter must be used with this adjustment method. An alternative measurement method is to use a wattmeter to observe the input power drawn by the dimmer and load using a low cost consumer type watt / power factor monitoring meter, which incorporate true RMS measurement techniques. As the power consumption of the dimmer module without a load is approximately one watt, the input power may be monitored and assumed to be the same as the load wattage as the module power can be neglected. The wattmeter method works well with the square law dimmer curve, as the wattage indicated will increase linearly with a control voltage increase.

This calibration procedure assumes that R18 and R19 had been previously adjusted. If is possible that the dimmer may not work at all, or preform strangely in response to the control voltage if the initial pot settings are significantly wrong. If adjustment difficulty is encountered, the pots may be reset to an approximate initial condition by removing the power from the assembly, then setting the measured in-circuit resistance reading across R19 to 10.7k and R18 to 18.8 k.

A 0 to 10 Volt control voltage source is also required, a 9 volt alkaline battery and a 10k pot are acceptable. A 100 watt light bulb can be used to load the dimmer, when the dimmer is calibrated properly the 0 to 10 volts applied to the control input will approximately match the 0 to 100 watts observed on the wattmeter. Before connecting the dimmer, connect the lamp to the wattmeter and observe the full line voltage wattage of the lamp. The lamp wattage is not critical, 100 watts is sufficient and a convenient value.

A test fixture can be assembled as follows: Connect a line cord to the dimmer, connecting the white wire to the small dimmer pin with the white wire, the green wire to the small dimmer pin with the green wire, and the black wire to the large male dimmer pin that connects to the fuse or breaker. Connect one lead of the lamp used as the dimmer load to the large female dimmer pin that connects to the triac, and the other lamp lead to the line cord white wire. Connect the 0 to 10 volt source negative to the small dimmer pin with the black wire, and the positive to the small dimmer pin with the red wire. Be sure all connections are insulated and secure before applying power. Do not touch any part of the dimmer when connected to line power.

Apply line power, with the control voltage set to zero, the lamp should be off and the dimmer chassis power consumption should read under 1 watt. Set the control voltage to 1 volt and observe the wattmeter reading. Set the control voltage to 2 volts and observe the wattage. Using an insulated screwdriver, adjust R18 to obtain the best fit of 1 volt equals 10% of lamp wattage, and 2 volts equals 20% of lamp wattage. Adjust the control voltage to 9 volts, and adjust R19 to obtain a wattmeter reading of 90% of lamp wattage. Repeat the adjustments several times as the two control adjustments interact – until the best tracking is obtained. Set the control voltage to 5 volts, the wattmeter should ideally read 50% of lamp wattage, but will typically read 55 to 60 %. Other settings can be checked, ideally the dimmer should produce within 10% of total lamp wattage of the ideal setting. It is more important that the 90% point and turn on point (about 0.6 volts) be correct than perfect square law linearity. The dimmer linearity specification is 5% of line voltage, which would be 10% of full voltage lamp power.

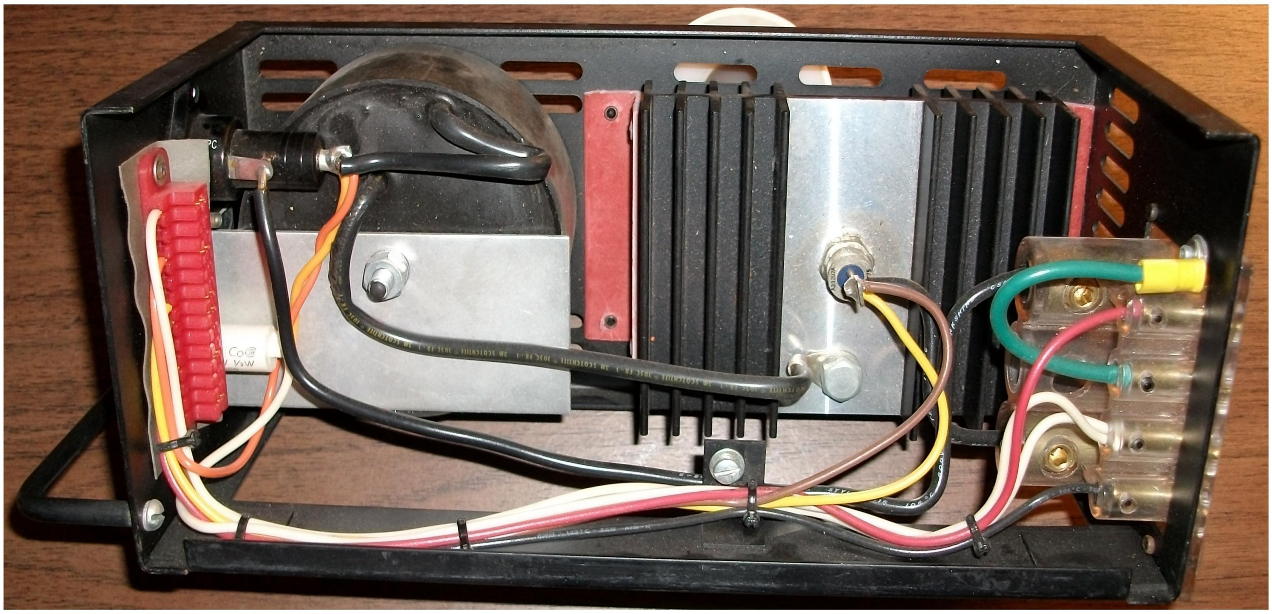


Figure 1 2 kW Dimmer Chassis View with control board removed.

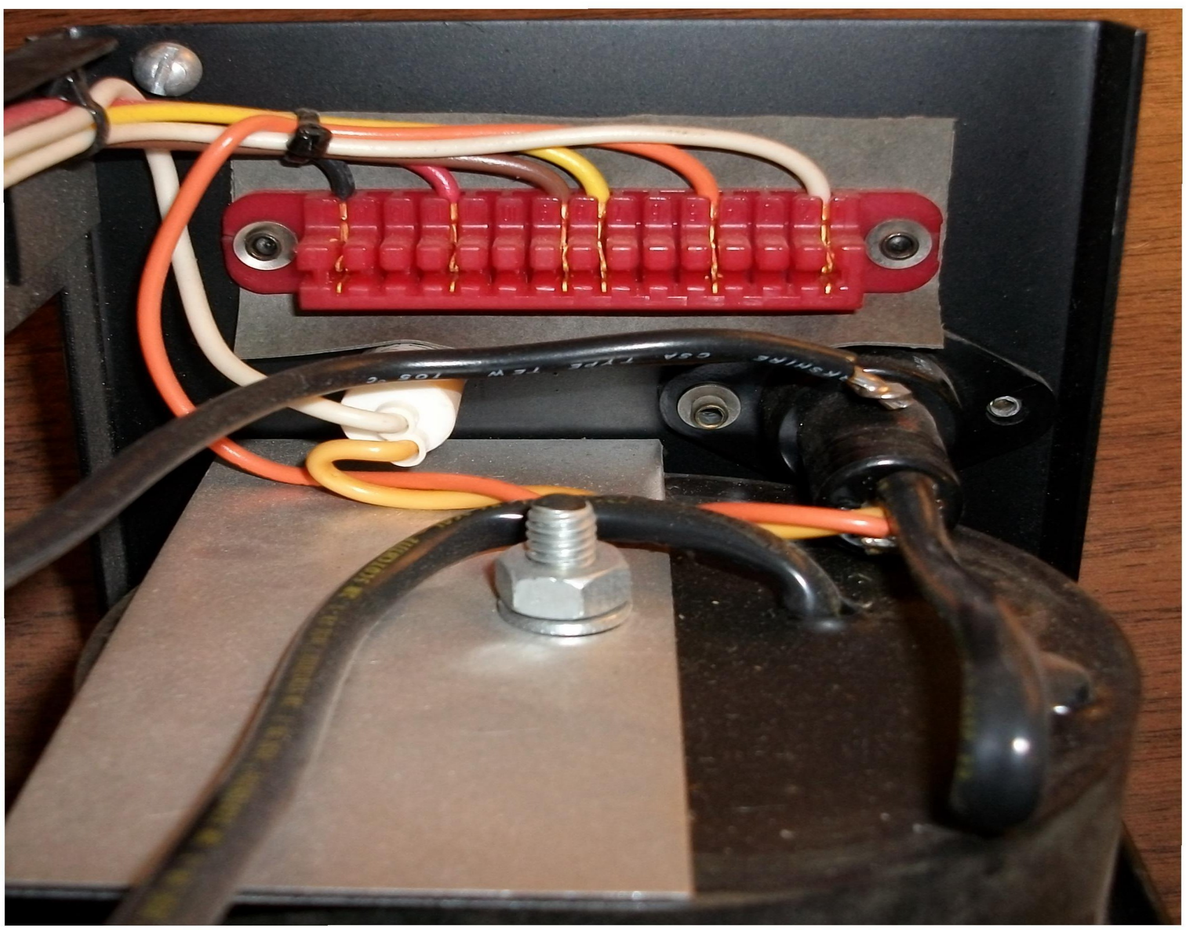


Figure 2 Chassis View Front

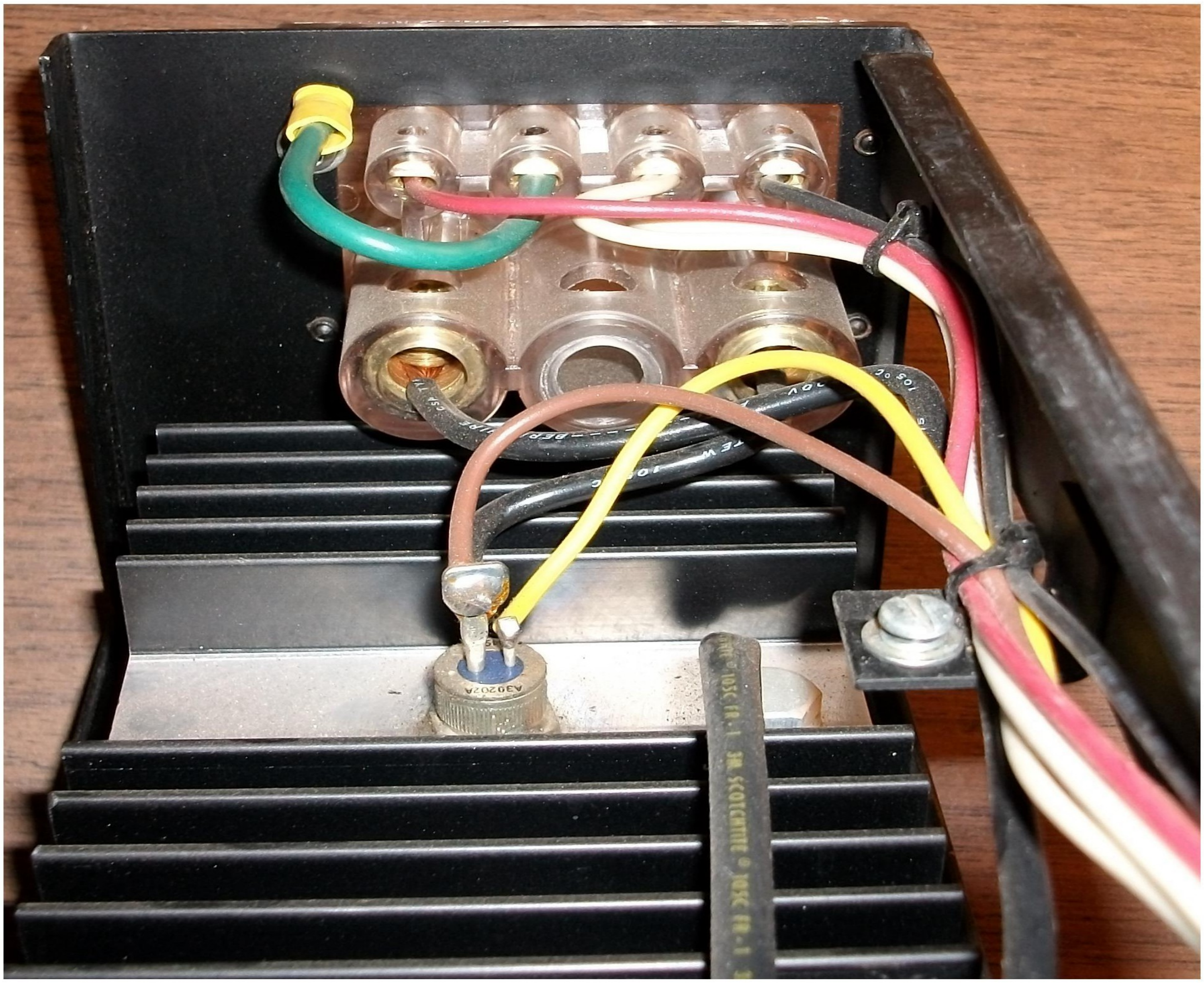


Figure 3 Chassis View Rear

Figure 4 Dimmer Module Connections

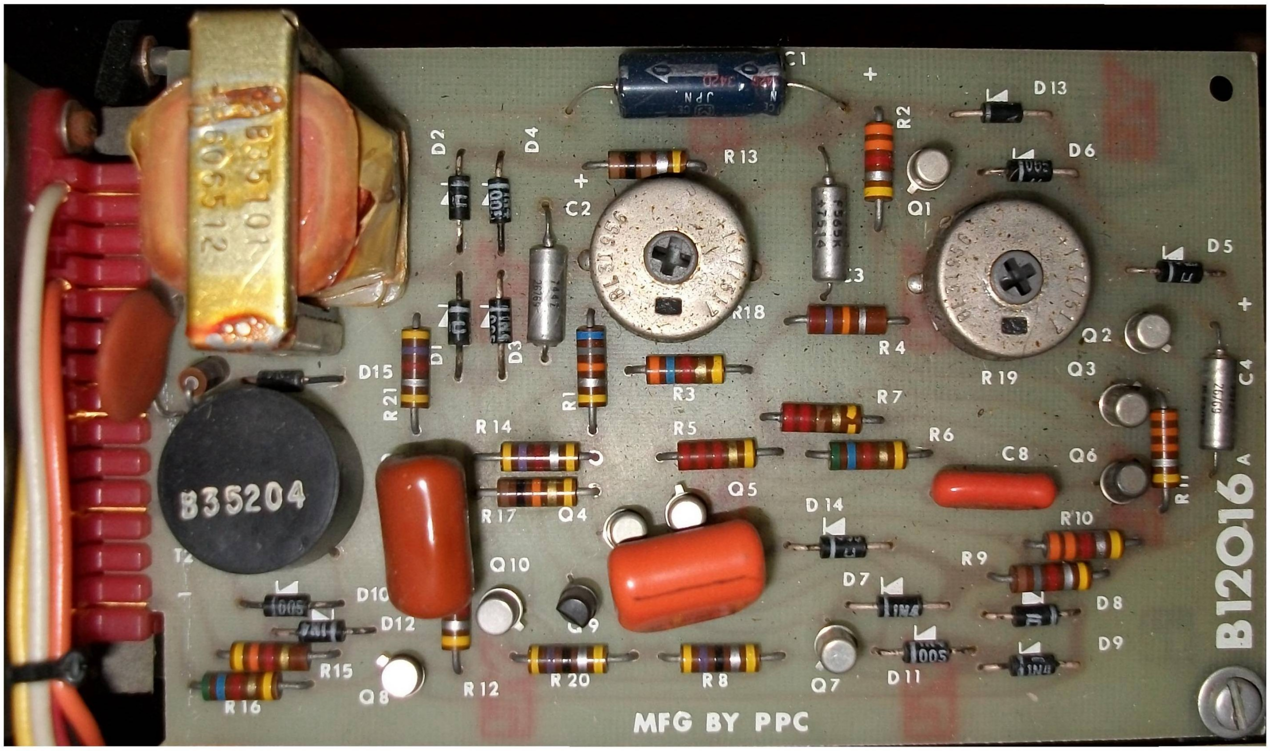


Figure 5 Control Board Component Side

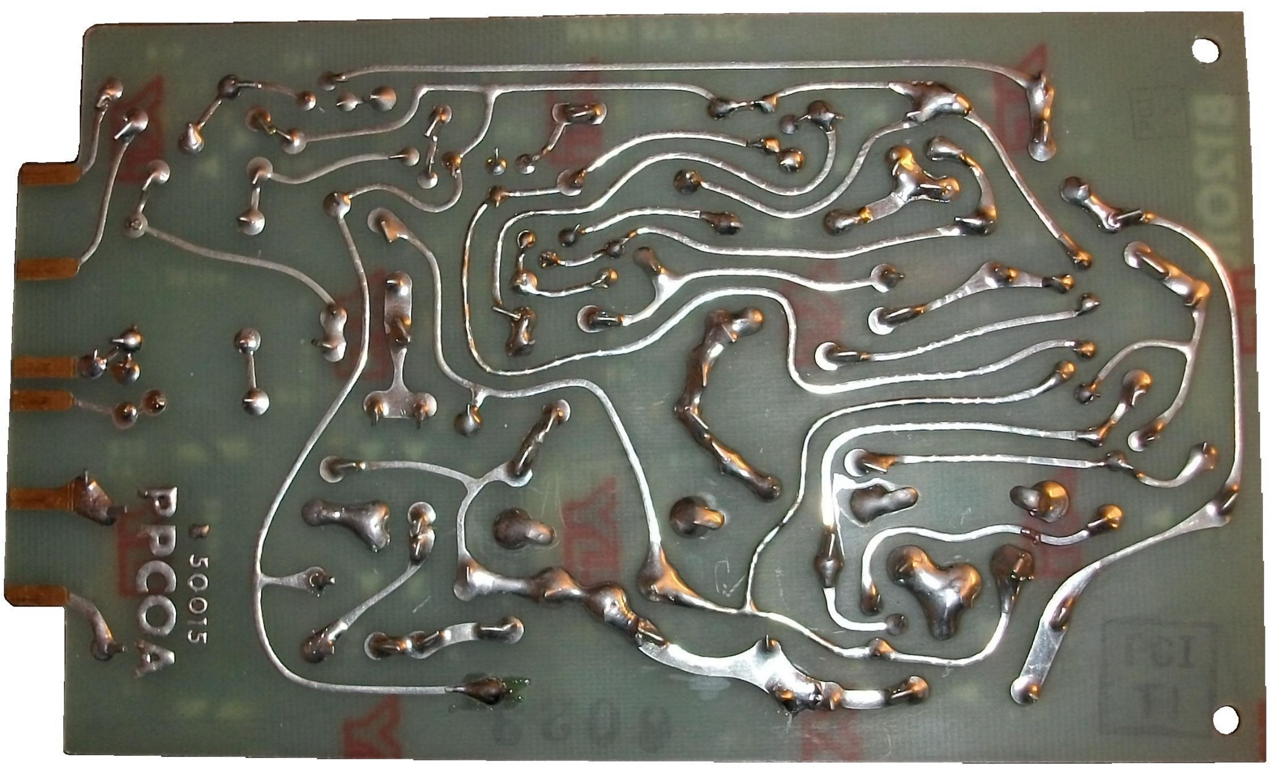


Figure 6 Control Board Back Side

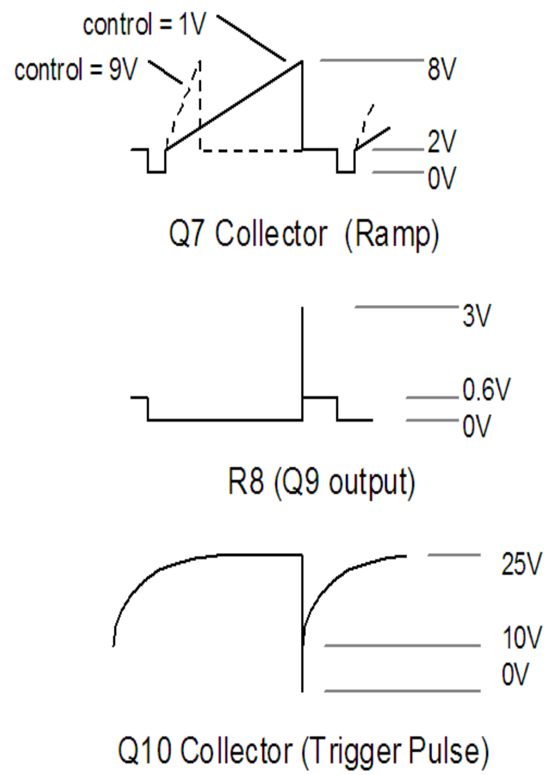
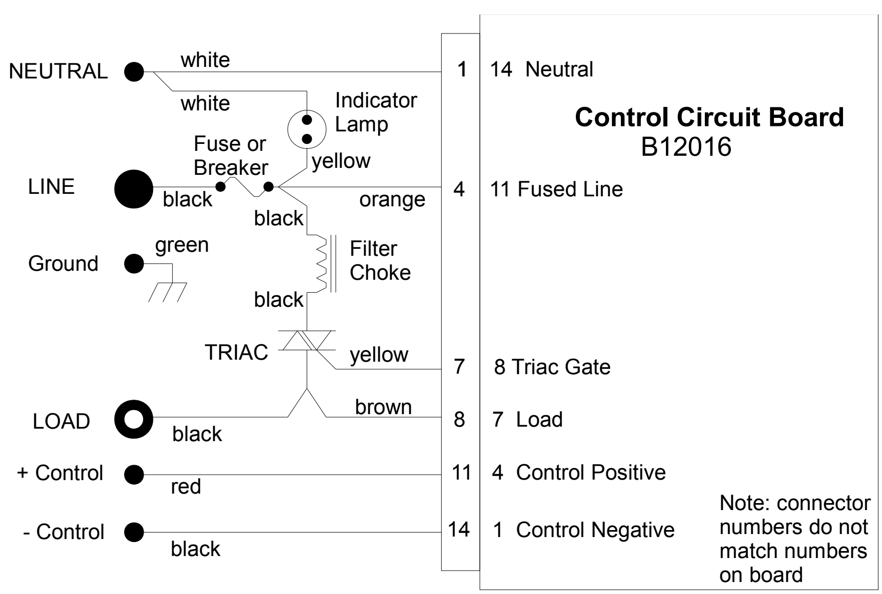


Figure 7 Oscilloscope Waveforms



Kliegl P-73 Dimmer Chassis Schematic

Chassis components	2 kW	5 kW
Fuse	20 amp	45 amp circuit breaker
Triac	2N5444 or A30202A	IR 61AC20

Figure 8 Chassis Schematic and Configurable Parts

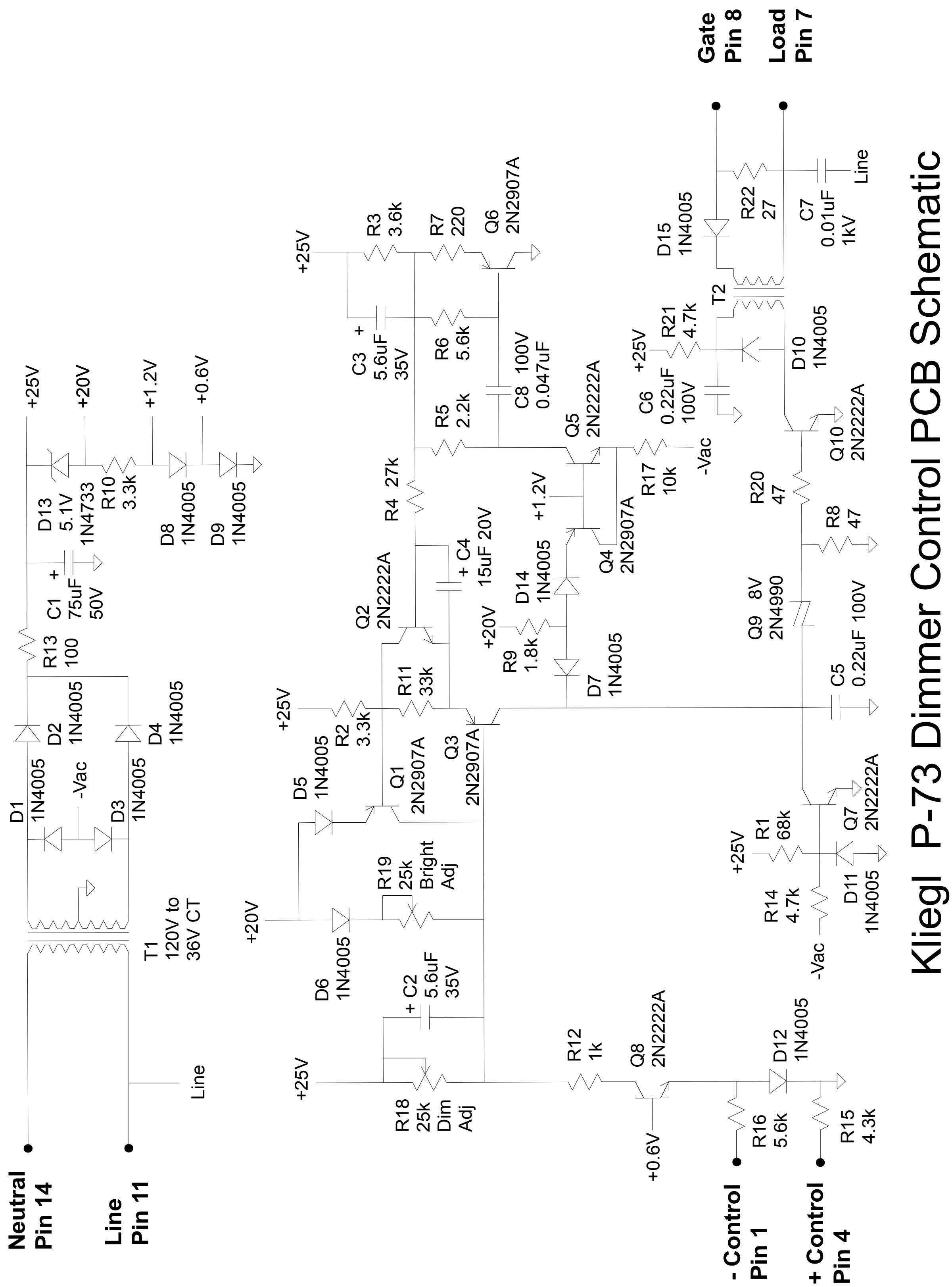


Figure 9 Control Board Schematic

Circuit Board Bill of Materials

Component	Part Number	Description
Q1	2N2907A	PNP general purpose
Q2	2N2222A	NPN general purpose
Q3	2N2907A	PNP general purpose
Q4	2N2907A	PNP general purpose
Q5	2N2222A	NPN general purpose
Q6	2N2907A	PNP general purpose
Q7	2N2222A	NPN general purpose
Q8	2N2222A	NPN general purpose
Q9	2N4990	Silicon Bilateral Switch 8V
Q10	2N2222A	NPN general purpose
D1	1N4005	Rectifier 400V general purpose
D2	1N4005	Rectifier 400V general purpose
D3	1N4005	Rectifier 400V general purpose
D4	1N4005	Rectifier 400V general purpose
D5	1N4005	Rectifier 400V general purpose
D6	1N4005	Rectifier 400V general purpose
D7	1N4005	Rectifier 400V general purpose
D8	1N4005	Rectifier 400V general purpose
D9	1N4005	Rectifier 400V general purpose
D10	1N4005	Rectifier 400V general purpose
D11	1N4005	Rectifier 400V general purpose
D12	1N4005	Rectifier 400V general purpose
D13	1N4733	Zener, 5.1 V
D14	1N4005	Rectifier 400V general purpose
D15	1N4005	Rectifier 400V general purpose
C1	75uF 50V	Electrolytic
C2	5.6uF 35V	Electrolytic
C3	5.6uF 35V	Electrolytic
C4	15uF 20V	Electrolytic
C5	0.22uF 100V	film
C6	0.22uF 100V	film
C7	0.01uF 1kV	ceramic disk
C8	0.047uF 100V	film
R1	68 k	
R2	3.3 k	
R3	3.6 k	
R4	27 k	
R5	2.2 k	
R6	5.6 k	
R7	220 ohm	
R8	47 ohm	
R9	1.8 k	
R10	3.3 k	
R11	33 k	

R12	1 k	
R13	100 ohm	
R14	4.7 k	
R15	4.3 k	
R16	5.6 k	
R17	10 k	
R18	25 k	trim pot, dim adjust
R19	25 k	trim pot, bright adjust
R20	47 ohm	
R21	4.7 k	
R22	27 ohm	
T1	36 Vac CT	power transformer
T2		pulse transformer

Chassis Components	**2 kW Dimmer**	**5 kW Dimmer**
Indicator Lamp		
Fuse	20 Amp fuse KTK-20	45 Amp Breaker
Filter Inductor		
Triac	2N5444 (RCA) 40 amp 200 V or A30202A	61AC20 (IR)