Restoring the Link Trainer Telegon Oscillator

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Caution:

The Telegon oscillator contains dangerously high AC and DC voltages that could cause severe injury and possibly death.

Distribution

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Restoring the Link Trainer Telegon Oscillator

The Telegon oscillator is the device that provides excitation energy for use in the Link Trainer Telegon remote instrument indicator system. The Telegon system consists of both sensors (transmitters) and indicators (instruments). The three types of instruments that this system supports are:

1. Airspeed

2. Vertical Speed

3. Altitude

The appropriate instrument, one type mounted on the trainer's panel and a duplicate mounted at the instructor's desk, are slaved to one of three different transmitters that are mounted in the trainer behind the student's seat.

The Telegon system utilizes devices that are commonly known as synchros, sometimes also referred to as selsysns. These are small devices that resemble an electric motor and work in a master/slave relationship where by the master is the transmitting unit and the slave is the indicating unit. When two or more such devices are electrically linked together with their rotor windings driven by a common AC power source, the movement of the transmitting device's shaft will cause a like movement in the receiving devices shaft, the latter typically connected to a pointer in an indicating instrument.

Various Link Trainer manuals provide an extensive discussion of the Telegon system including the oscillator which is used to excite the system. This article will focus on the Telegon oscillator from the perspective of restoration, test, and operation.

Overview

The Telegon oscillator is housed in a vented black metal enclosure that is mounted in the base of the trainer. It receives 115 VAC at 60 Hz and generates 85 VAC rms at a frequency between 700 to 800 Hz. The output of the Telegon oscillator is connected to rotor windings of each Telegon system device that consists of both transmitters and indicators. The Telegon oscillator consists of three major sections that include:

(1) The Power Supply

(2) The low level signal Oscillator

(3) The Power output amplifier

There is actually a fourth component to the Telegon Oscillator system that is required for proper operation and that is electrical connection to the nine Telegon synchros associated with the trainer and the instructor's desk. This fourth element of the system provides the proper inductance and loading that allows the Telegon's oscillator resonant output circuit to function properly. The Telegon system inductance is placed in parallel with a 1 uF capacitor that is part of the Telegon Oscillator final output forming a LC tuned circuit that resonates in the 700 to 800 Hz range. This is reason why all of the Link Trainer maintenance documentation states that the Telegon oscillator output level adjustment must be performed with the Telegon oscillator attached to the Link trainer Telegon system.

A schematic of the Telegon Oscillator, extracted from a Link Trainer Technical Manual, is shown in the Figure 1 below. You will note that it is a relatively simple design that consists of four vacuum tubes, three transformers and a small number of resistors and capacitors.

Power Supply

The Power supply portion consists of a power transformer and a type 83V full wave rectifier tube. The 83V tube contains Mercury and should be handled with care and disposed of properly if it is not functional. The 83V acts as a full wave rectifier with voltages supplied by a high voltage center tapped power transformer that also provides the filament voltages to the Oscillator's vacuum tubes. The filament voltage to the 83V rectifier tube is approximately 5 volts. This vacuum tube is equivalent to two separate diodes and provides full wave rectification of the center tapped 690 VAC, resulting in approximately 355 volts DC. Filter capacitor C5 filters the high voltage which is applied to the resistive biasing network of R4 and R5 (used to bias the grids of the three 6L6G vacuum tubes into the active region). The 355 volts DC is also provides power to the two 6L6G push pull power amplifier tubes via the center tap of the output transformer T2.

700 – 800 Hz signal oscillator

The signal Oscillator consists of a single 6L6G vacuum tube, positive feedback circuit and, an output transformer, T1 that generates the complimentary drive needed for the push pull output amplifier. The frequency of oscillation is tuned through adjustment of the value of capacitor C3. C3 is nominally 0.05 uF in value. Increasing the value of C3 lowers the frequency of oscillation, likewise, a decrease in value will increase the oscillator's frequency.

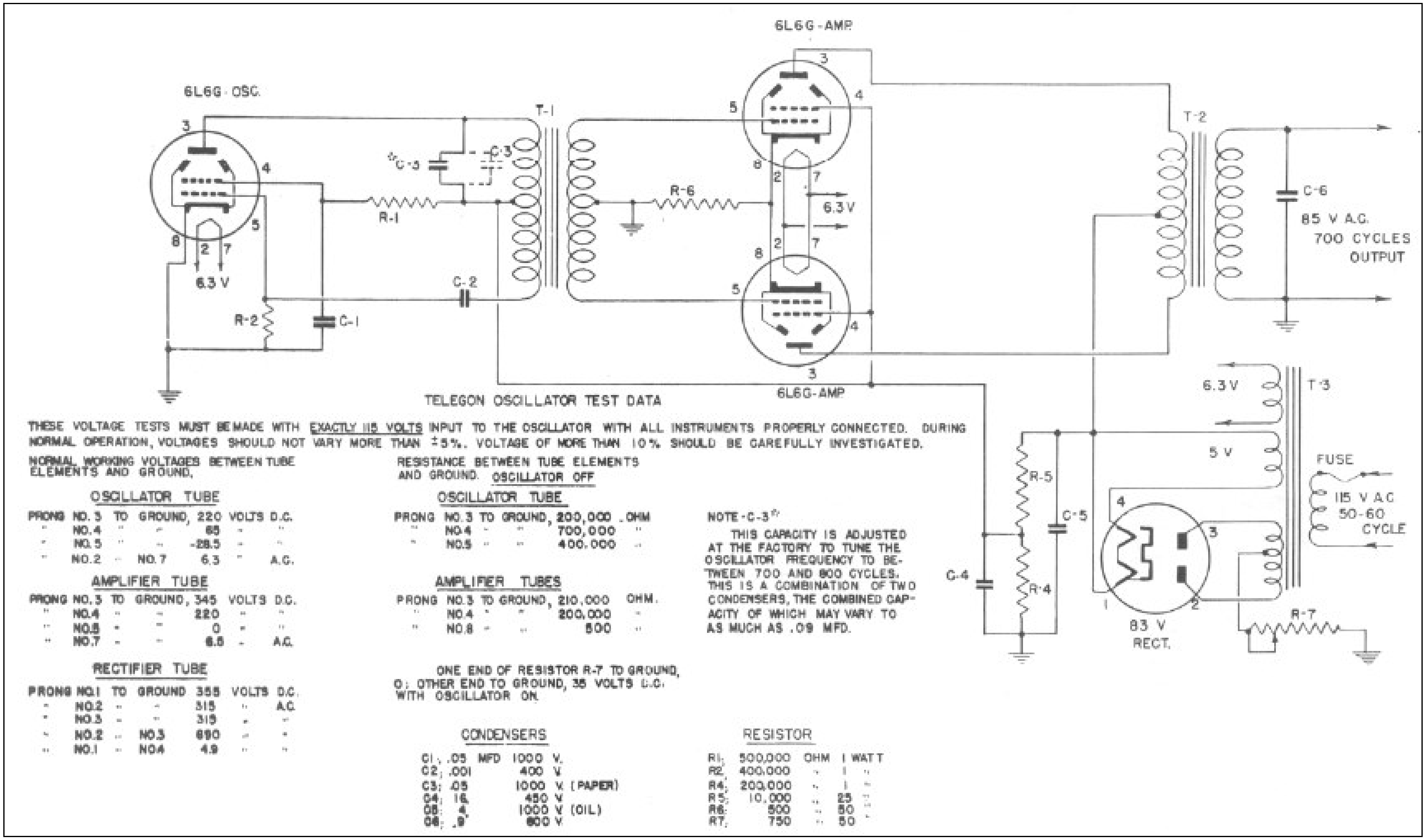

Figure 1 Schematic of the Telegon Oscillator extracted from the Link Technical manual

Power output amplifier

The power amplifier consists of two 6L6G vacuum tubes that operate in a push pull class B arrangement and drive transformer T2. The center tapped primary of T2 is supplied with 355 volts, the secondary of T2 is the output to the system with a 1uF capacitor in parallel to form a LC circuit which, when connected to the trainer's Telegon system of nine Synchros in parallel, results in a resonant system near 750 Hz. This is why the Link Trainer maintenance manual warns that the output voltage adjustments must be made with the Telegon oscillator electrically connected to the trainer's Telegon system as the inductive loading of the nine synchros shift the total inductance downward to about 44mH. At the resonant frequency in the 700 to 800 Hz range the output waveform is nearly sinusoidal and the amplitude will easily peak to the required 80 to 85VAC rms. When operated without connection to the trainer the resonant frequency shifts to about 96Hz which results in a non sinusoidal waveform of much lower amplitude.

Restoring the Telegon Oscillator

The Telegon Oscillator utilizes technology available in the late 1930s and is a relatively simple unit. High voltage vacuum tubes and capacitors are used throughout the design and three different transformers are utilized. A small number of resistors are also incorporated into the design, three of these are wire wound power types and one, R7, is adjustable via a sliding contact so as to set the output voltage amplitude of the 700 to 800 Hz signal.

If the Telegon Oscillator to be restored has not been operated for many years and has not received any replacement parts such as new capacitors it is recommended that the unit not be immediately powered, instead perform the following steps:

1. Carefully disconnect the input and output cables and remove the Telegon Oscillator chassis from the housing in the base of the trainer.

2. Mark the vacuum tubes so that they may be installed into their original positions (three of them should be identical 6L6G types), inspect the tubes during removal for damage such as cracked glass, bases, etc and set them aside in a safe location. Be aware that the 83V rectifier tube contains mercury. Any missing tubes will need to be replaced with the exception of the 83V for which a solid state replacement may be made – more details regarding this will be disclosed later.

3. Set the Telegon oscillator on a work bench and inspect the top and under chassis for any signs of damage such as over heated components, tar/wax/oil (which may drain out of a transformer that over heated or failed capacitor), broken wires, etc. Signs of a melted transformer may require the transformer to be replaced and or rewound.

4. Identify the resistor and capacitor components and note their marked values – compare those against the schematic. According to the Link manual capacitor C3 may consist of more that one capacitor in parallel or be a different value than the .05 uF shown on the schematic. C3 is used to adjust the frequency of oscillation.

5. Make a shopping list and order the necessary replacement components before removing any of the soldered parts.

Provided that no major damage exists most of the restoration work will consist of removing and replacing the capacitors, resistors and the input power wiring along with cleaning and painting. Try to minimize moving the existing wires as any movement may cause the insulation to crack and fall away from the wires.

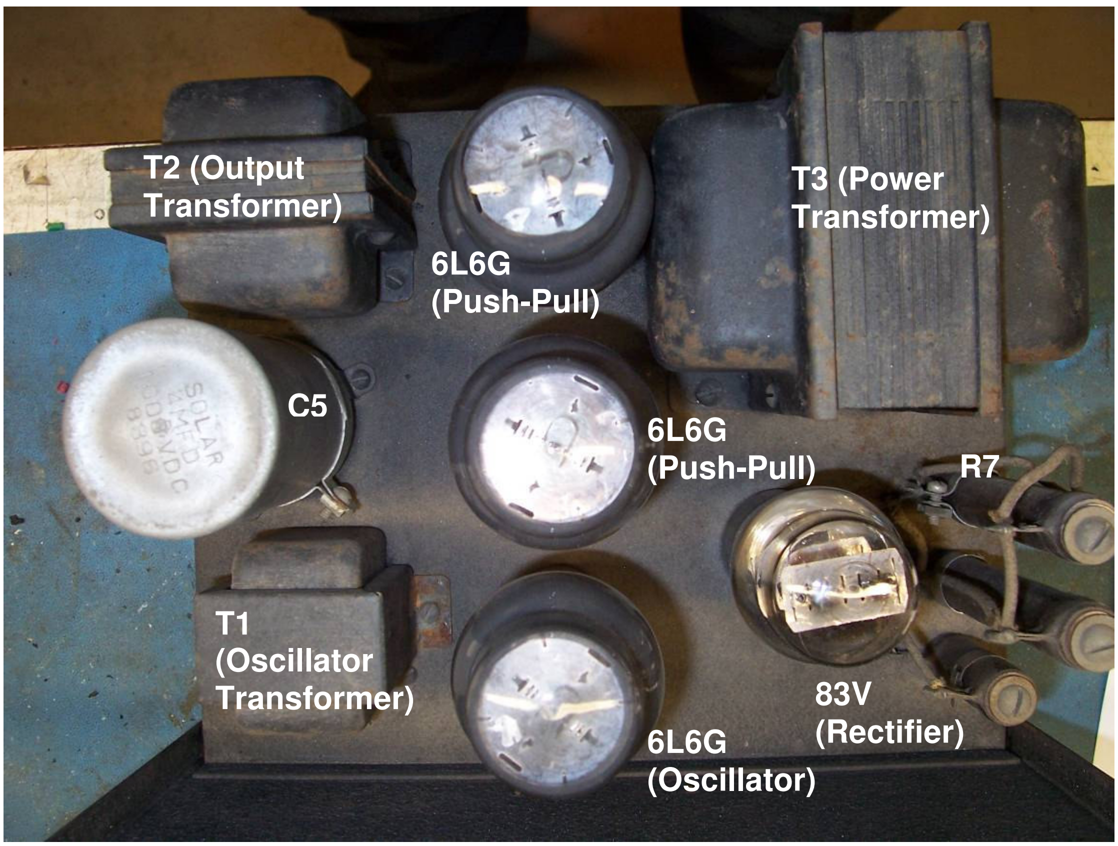

Figure 2 Telegon Oscillator Top Chassis View with major components identified

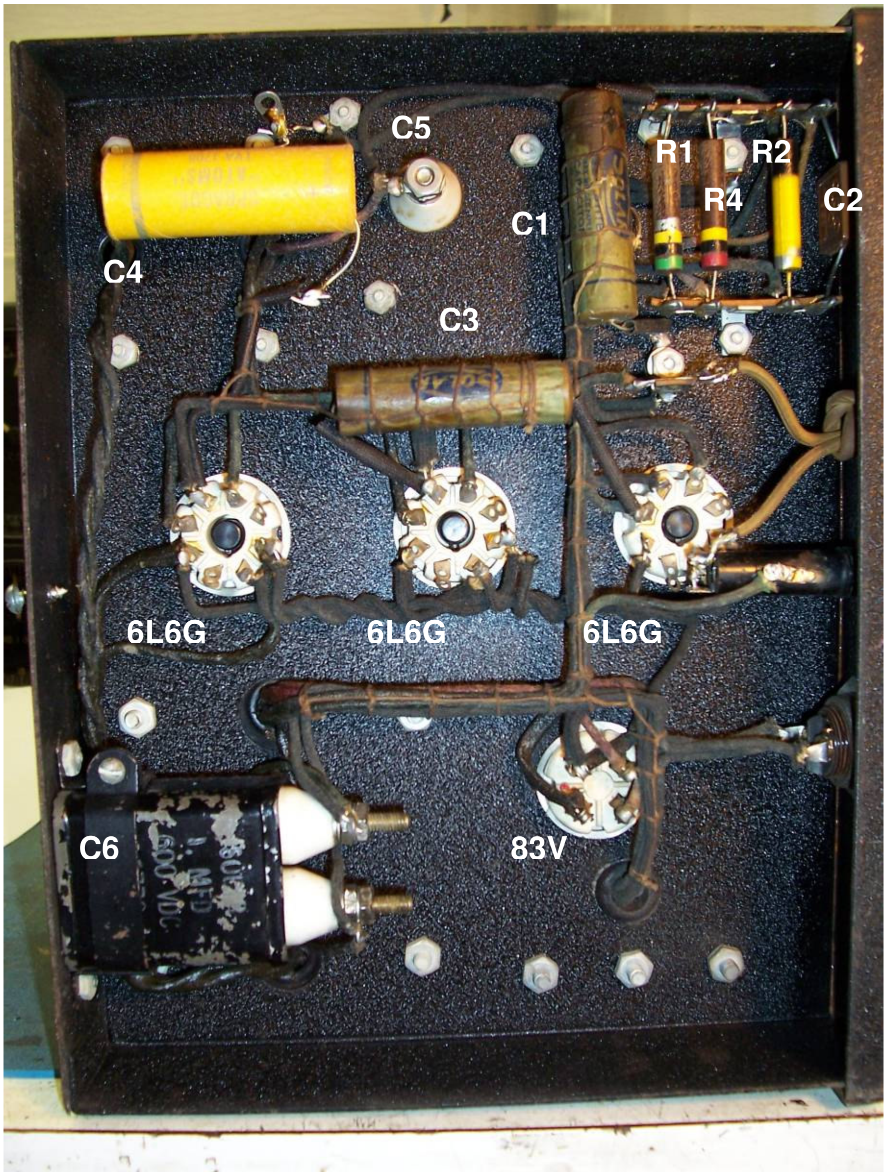

Figure 3 Telegon Oscillator Under Chassis View, original – note that C4 was replaced at some point in the past and is not the original component.

The under chassis view of Figure 3 shows both twisted and straight wiring. Most of the twisted wires carry the low voltage AC to the tube filaments while the straight wires primarily carry DC voltages. The unit should only be worked on with the power removed **and** the high voltage capacitors discharged but beware, when the chassis is powered some of the low voltage AC filament wires associated with the 83V tube are energized with high DC voltages – this a consequence of Vacuum tube design where the cathodes of the rectifier tubes are at potentials greater than 300 volts.

Table 1 lists the components used for the restoration documented herein. As may be see in Table 1, most of the replacement parts obtained were very close in value to the original with the exception of C4 a 16 uF 450 VDC electrolytic capacitor. This capacitor serves as a filter capacitor for the 6L6G grid bias network formed by R4 and R5. The value of C4 is not critical and a 33uF capacitor of identical voltage rating was conveniently available.

Original	Replacement	Ref	Size old/new	Mouser PN	Qty	Cost
.05 uF 1kV paper NP	.047 uF 2kV	C1, C3	.58 X 2.17/ .59 X 1.4	5984-940C20S47K-F	2	$3.43
16uF 450V elct	33 uF 450V	C4	.8 X 2.3/ .63 X 1.65	140-XAL450V33-RC	1	$2.94
1uF 1kV	1uF 660VAC	C6	1 X 1.75 X 2.2 1.3 X 2.2 X 1.6	598-SFA66S1K156B-F	1	$8.53
4uF 1kV elec oil	4.7uF 1.5kV non-pol	C5	2.0 X 4.1 1.37 X 2.11	598-UNL15W4P7K-F	1	$27.48
500K 1W	510K 3W 350V metal oxide	R1	Orig .22 X .63	283-510K-RC	1	$0.39
200K 1W	200K 3W 350V metal oxide	R2	Orig .22 X .63	283-200K-RC	1	$0.39
400K 1W	390K 2W 350V metal oxide	R4	Orig .2 X .5	282-390K-RC	1	$0.19

Table 1 List of Original and replacement parts used

One capacitor, C2, is not found in the above table. C2 is a mica type capacitor and these types rarely degrade and as such it was left undisturbed.

Capacitor C5

The most expensive and complex capacitor to replace is the large chassis mounted oil filled 4 uF1000 Volt DC electrolytic capacitor. While high voltage capacitors are still available, most are no longer constructed in the same physical manner that C5 is. Modern capacitors are of smaller size for the same or higher capacitance and voltage ratings as compared to their 1930s and 40s counterparts. It is desirable, however, to maintain the appearance that C5 presents and so it was decided to remove the electrode and the internal contents of C5 and install within its interior a modern capacitor.

C5's capacitor casing appears to be made from mu metal as it is non-ferrous and soft yet it is easily soldered if well cleaned (mu metal is an alloy of 75% nickel, 15 % iron, and molybdenum). Once the capacitor is removed from the chassis the band clamp should be removed. The band clamp was tack soldered in two locations to the case and was unsoldered using a large 200W electric soldering iron.

The removal of the electrode and interior is a messy operation and the oil filled contents are probably hazardous so wear gloves and dispose of the internals properly. The attempt to remove C5's base using a large 200W "American Beauty" soldering Iron worked but effectively destroyed the base. An alternative suggested by others is to cut off the bottom of the capacitor in a metal lathe. Either way it is a messy process so be prepared to strike oil. After the bottom is removed the roll of foil and insulation, along with the oil, is removed and the interior cleaned out using paper towels. The cleaning process was completed by bead blasting the casing. Figure 4 shows the housing of C5 after the electrode and contents were removed and the case bead blasted.

A new base was fabricated from galvanized steel sheet metal and an appropriate size hole punched to allow for remounting of the positive ceramic electrode. It is important to isolate the center electrode from the case otherwise a direct short will exist which could cause a catastrophic failure of the rectifier tube and or power transformer. Use an ohm meter to verify that the electrode is isolated.

Figure 4 Capacitor C5 housing with contents removed

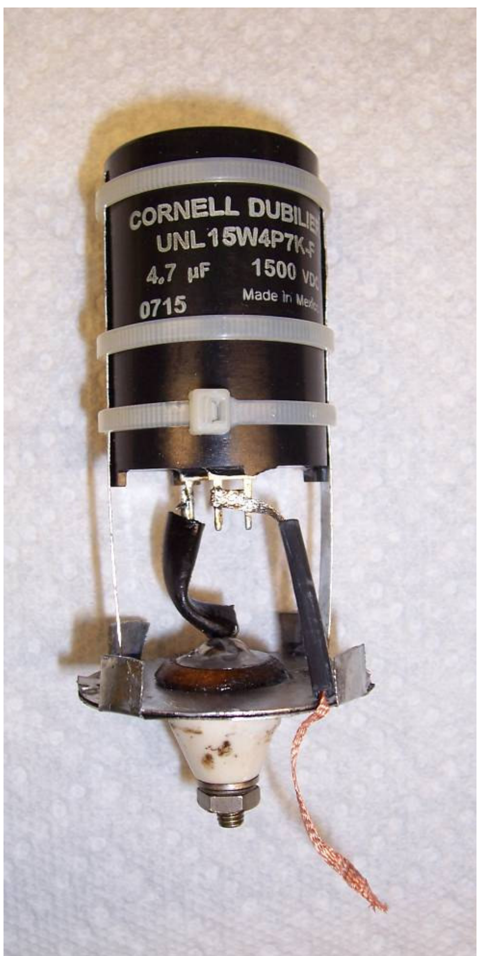

Figure 5 The new electrode mounting plate and new capacitor to be installed within the original C5 case

Figure 5 shows the replacement capacitor, a 4.7 uF 1500 volt DC non-polarized capacitor, ready for installation back into the original C5 housing. Unlike the original capacitor this particular capacitor is non-polarized and there is no defined preference for connection of the center (positive) or case (negative) positions. Both lead wires are fitted with insulation and the negative or case terminal is connected to the case via braided copper wire that is soldered to the base and housing when the new bottom plate is soldered to the original C5 housing. Figure 6 shows the assembly of the updated C5 capacitor prior to solder attachment of the new bottom.

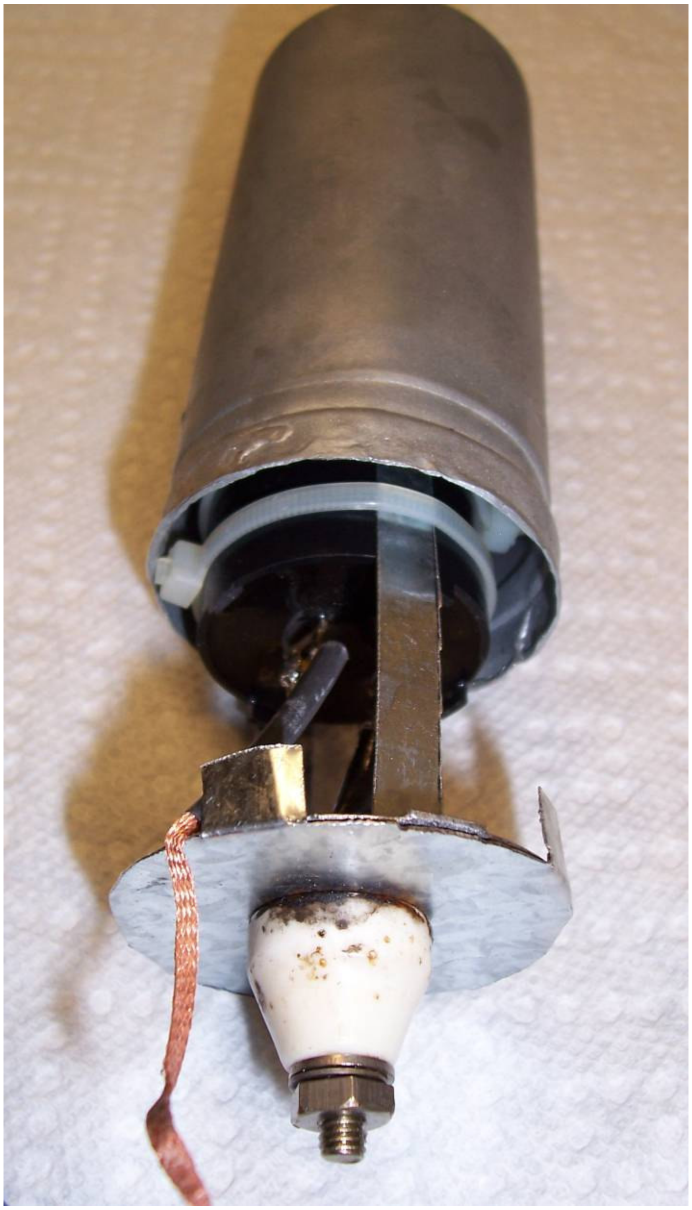

Figure 6 The C5 Assembly Process

Figure 7 The finished C5 upgrade – note that solder is absent in one small area to allow for venting.

Replacing the components

Once all of the replacement parts have been obtained it is time to begin the restoration process by replacing each component **one at a time**. Since all of the soldered components to be replaced are on the under chassis side set the chassis on its side with the under chassis oriented as shown in Figure 3. It will be necessary to cut and replace the lacing cord that was used to secure the original components. When reinstalling you may use waxed dental floss as a substitute if you don't have any lacing cord.

Start with the capacitors. Since C5 will have been restored and ready for replacement reinstall it to the chassis via the mounting clamp and connect the lug to the ceramic electrode – carefully tighten the nut against the lug, and nut under the lug that secures the electrode to the bottom of C5.

C6 is a 1uF high voltage AC type capacitor and is DC rated to 600 volts. It mounts to the chassis with a clamp around its base. The capacitor selected to replace this is 1uF with a 660 VAC rating. AC voltage rating are typically lower than the allowable DC values and the specific specifications relate to applied current, ESR, frequency and dissipation factor. In terms of a pure AC/DC comparison the ACV rating X 1.414 is a relatively conservative means of predicting the DC equivalent, thus 660VAC X 1.414 = 933 volts DC which exceeds the original 600 VDC rating. The original capacitor used insulated ceramic stud terminals however, the new capacitor utilizes push on spade type terminals, thus, the lugs were removed from the wires and push on terminals were soldered to the wires. Mounting of the new C6 capacitor required the fabrication of a custom clamping plate that was designed to reuse the original chassis screw holes. The clamp was secured to hold the capacitor to the chassis using two, 2 inch long brass 6-32 flat head screws.

Figure 8 The new C6 on the left, original on the right

Figure 9 The new C6 with custom clamping plate fabricated from flat aluminum bar stock 1/8 in. thick.

Continue by replacing the other capacitors one at a time. C4 is polarized and it is necessary to ensure that proper polarization is maintained. The negative side of C4 should connect to chassis ground. If possible you can reuse the sleeve material use on the leads of the original capacitors, however, if this is not possible use small diameter heat shrink tubing cut to length and then shrunk over the lead. If possible use lead based solder to restore all of the connections. The capacitors should be laced in a manner similar to that shown in Figure 10.

Carbon Composition Resistors

The Telegon oscillator makes use of three carbon composition resistors. These are identified as R1, R2 and R4. Each are rated at a 1 watt power dissipation. Carbon composition resistors can change value significantly over time and this was found to be true. Table 2 displays the carbon composition resistors, their measured values and replacement values. The replacement resistors are all 5% tolerance (versus 10% for the originals) metal oxide types with power ratings two to three times that of the originals (even though they are physically smaller than the original ones). Examination showed that some had increased in value by over 50%. Deviation from the original values was done for R1 (510k vs original 500k) and R4 (390k vs original 400k) but due to the better 5% tolerance this is an acceptable practice. As with the capacitors, each resistor should be replaced one at a time. Be sure to check the color codes of the original resistors to ensure their value matches the original schematic.

Table 2

Original	Replacement	Ref	Orig Value Ω	Repl Value Ω
500K 1W Carbon Comp 10%	510K 3W 350V metal oxide 5%	R1	622k measured	510k
200K 1W Carbon Comp 10%	200K 3W 350V metal oxide 5%	R2	325k measued	200k
400K 1W Carbon Comp 10%	390K 2W 350V metal oxide 5%	R4	485k measured	390k

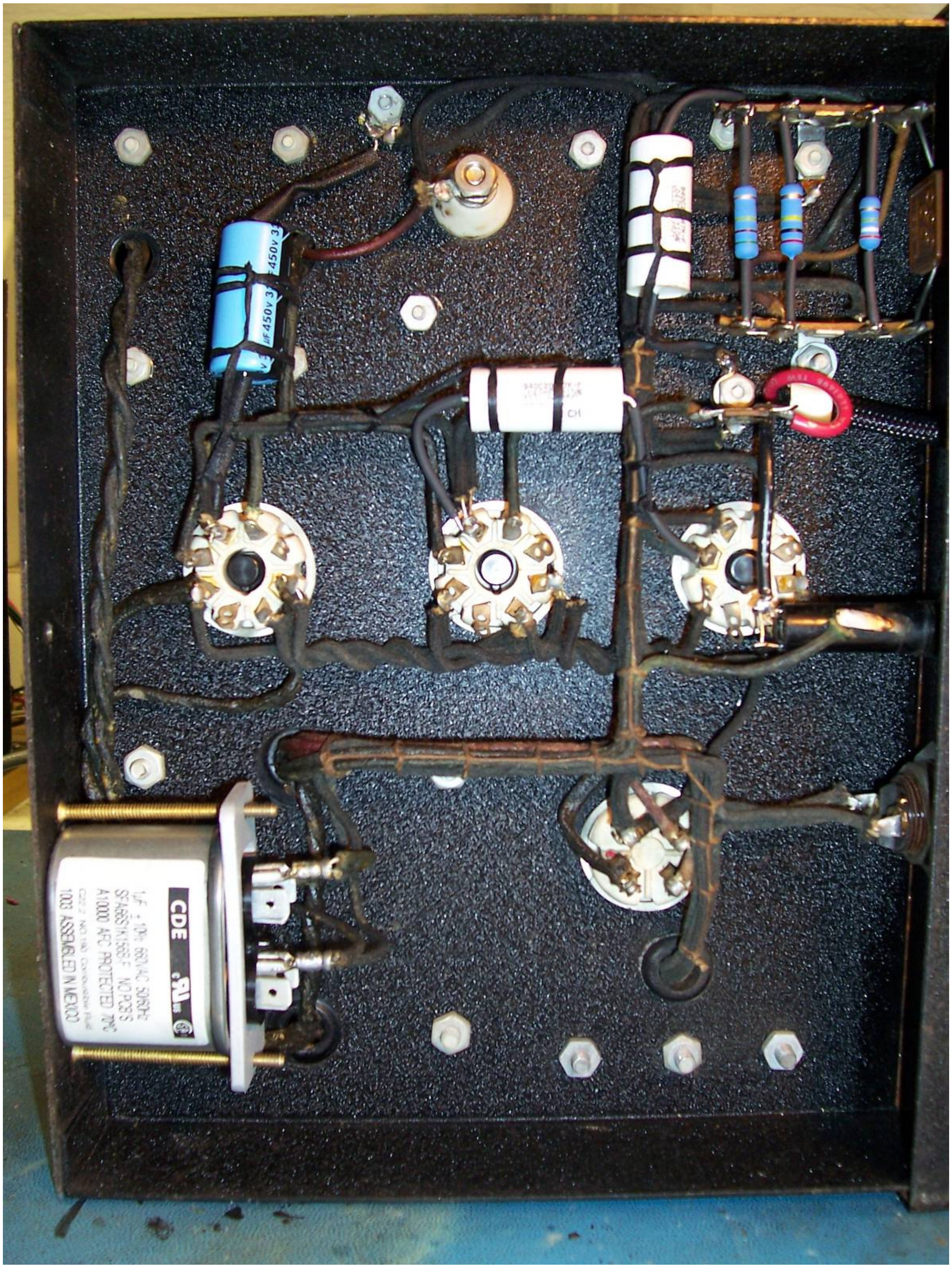

Figure 10 The completed under chassis

The 83V rectifier tube

As previously mentioned the 83V rectifier tube was found to be faulty and it was decided to build a solid state replacement in lieu of finding a replacement rectifier vacuum tube. Replacing the 83V with a solid state rectifier provides a number of advantages as noted below:

1. The elimination of the filament reduces the total operating power and lowers the power dissipation of the primary power transformer.

2. The cost to fabricate a solid state version is at most no more or perhaps less than a new old stock (NOS) 83V.

3. The solid state version will be much more reliable.

It should be noted that the start-up voltage of the solid state rectifier will be slightly higher due to the instantaneous rectification capability (i.e. no warm-up since there is no filament) and the lower forward voltage drop prior to the delayed loading of the 6L6G tube (filament warm-up latency). Table 3 displays the maximum voltage and time observed for a tube based 80 rectifier and the solid state. The solid state rectifier yielded a maximum voltage 16 volts higher for a duration of 10 versus 6 seconds for the 80 vacuum tube. However, the higher voltage is well within the rating of the filter capacitor and 6L6G tubes. A plot of the high voltage start is shown in Figure 11 – note that the vertical scale value is actually 100 volts/division due to the use of an external voltage divider.

Table 3

Rectifier type	Max voltage	Steady state voltage	Time to reach steady state
80*	468 for 6 s	296	15 seconds
Solid State	484 for 10 s	340	15 seconds

*The original is an 83V but none was available for this test so an 80 type was substituted. It is possible that the 83V would have resulted in a higher maximum and steady state voltage as the 83V has a lower forward voltage drop (15 volts @ 300mA) than that of the 80 (50 volts @ 150 mA).

There is much information available from the antique radio community regarding the replacement of vacuum tube rectifiers with sold state versions. For originality it is suggested that the solid state rectifier be compatible with the original vacuum tube socket as opposed to making the modification permanent as could be done by direct wiring in the under chassis. Appendix A provides information related to the construction of the solid state rectifier replacement for the 83V.

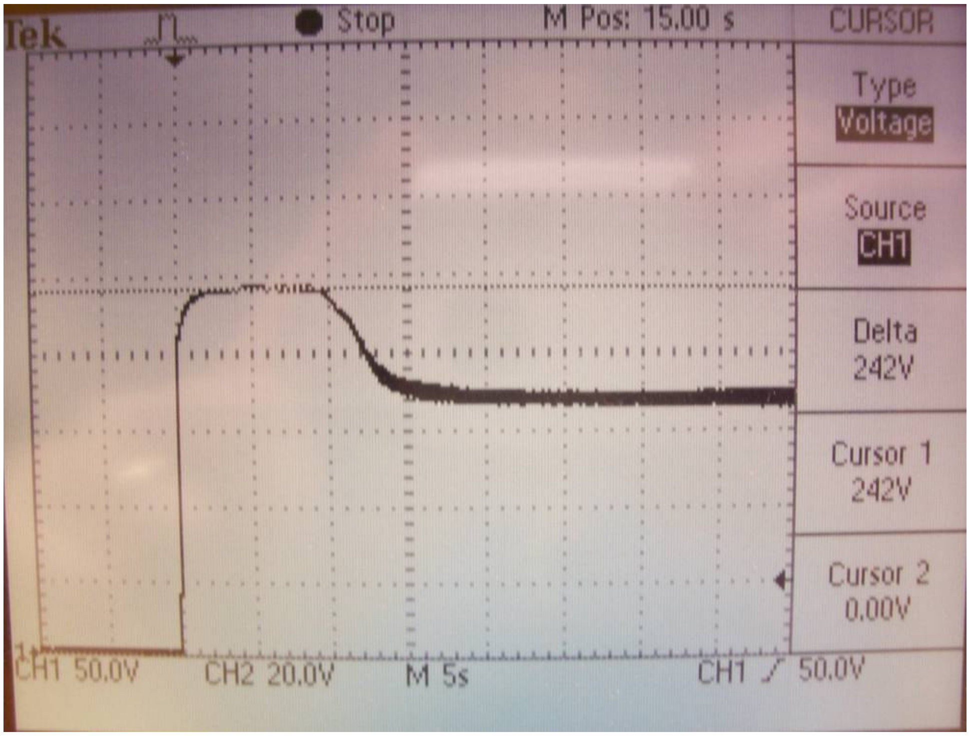

Figure 11 High voltage power up characteristic with the solid state rectifier – note that the voltage scale is actually 100 volts/division due to the use of an external voltage divider to prevent the vertical scale from being exceeded.

Cleaning the chassis

The chassis was originally painted with a crinkle finish black paint. The texture of this paint makes it ideal for trapping dust and dirt. Years of accumulated dust and dirt may be removed using a mild dishwashing detergent such a "Dawn". Mix a small about of water and detergent into a bowl and use a toothbrush to scrub and lift out the accumulated dirt – wipe the surface clean with a paper towel and clean small areas at any given time. After the surface is clean it can be repainted using a semi-gloss black paint applied using an artists paint brush. By applying a light coat of paint and working it into the original finish the texture is retained and a nice semi-gloss finish returns. Water based Rustoleum brand paints are a good choice for this application.

Checking operation – measuring voltages and waveforms

The Telegon oscillator schematic of Figure 1 lists the voltages that may be observed while the input is set to "exactly" to 115VAC and the output is connected to the complete Telegon system. Since line voltage may be different than 115VAC a Variac can be used adjust the supply voltage to 115VAC. These voltages are one means to determine if the oscillator is operating properly. One comment about measuring voltages, the volt-ohm meters of the 1940's were not of the same input impedance that one finds in a contemporary volt meter of today that is typically 10 Million (Meg) ohms. A typical 1940's volt meter would exhibit a meter sensitivity ranging form 2000 ohms/volt to 20,000 ohms/volt. The lower the sensitivity and measurement scale, the greater the volt meter loads the circuit under measurement. Usually, a schematic would not only list typical operating voltages but it would also report the sensitivity of the volt meter used to make the measurements, however, the Telegon Oscillator schematic does not include this information. The table below provides a comparison of voltage measurements made using a 2000 ohms/volt meter and a 10Meg ohm input impedance meter. You will note that for some of the voltages shown in **BOLD** that the sensitivity of the volt meter makes a difference in measurement.

Table 4

Oscillator Tube		Volt meter sensitivity	
Pins	Schematic	2kΩ/volt	10Meg
3 to Chassis	220 VDC	199 VDC	200 VDC
4 to Chassis	65 VDC	66 VDC	**72 VDC**
5 to Chassis	-28.5 VDC	-26.0 VDC	**-40 VDC**
20 to 7	6.3 VAC	6.2 VAC	6.2 VAC
Amplifier Tube		Volt meter sensitivity	
Pins	Schematic	2kΩ/volt	10Meg
3 to Chassis	345 VDC	348 VDC	348 VDC
4 to Chassis	220 VDC	201 VDC	201 VDC
5 to Chassis	0 VDC	0	-94mV
7 to Chassis	6.5 VAC	4.9 (6.7*) VAC	**63.3 VAC**
5 to 5 **	110 VAC	106.5 VAC	108.5 VAC
Rectifier Tube		Volt meter sensitivity	
Pins	Schematic	2kΩ/volt	10Meg
1 to Chassis	355 VDC	357 VDC	357 VAC
2 to Chassis	315 VAC	370 VAC	370 VAC
3 to Chassis	315 VAC	376 VAC	376 VAC
2 to 3	690 VAC	741 VAC	742 VAC
1 to 4	4.9 VAC	5.2 VAC	5.2 VAC

Voltages with 115 VAC input and Telegon system load applied
* Voltage with simulated 20kΩ/volt loading
** From pin 5 of one 6L6G amplifier tube to another – stated in a Telegon schematic from a1939 Link manual for a model E special.

If a Variac is available it is recommended that the first application of supply voltage to the Telegon oscillator be applied gradually while monitoring the high voltage output of the rectifier as well as the oscillator signal at the output of capacitor C6. If the Telegon oscillator is not connected to the trainer's Telegon system the waveform shape will not resemble a sine wave and the amplitude will be low. Since it is much more convenient to operate and test the oscillator on the bench a simulated load was constructed that closely matched that of the Telegon system attached to the trainer. The characteristics of the Link trainer's Telegon system with the Telegon Oscillator **NOT** attached, are as follows:

Total measured inductance: 45mH
Total measured DC resistance: 48 ohms

The author was able to find a solenoid that exhibited an inductance very close to 45mH (with the solenoid armature fully inserted) and a 13 ohm DC resistance. The lower resistance was adjusted upward to 33 ohms by adding two 10 ohm 5 watt power resistors in series with the solenoid winding. While the total resistance was about 15 ohms less that that of the trainer the emulated load was found to result a comparable waveform when compared to the actual trainer's Telegon load. This emulated load, shown in Figure 12 was used to allow for testing of the Telegon Oscillator on the bench, however, due to thermal heating of the solenoid, operating times had to be kept to less than 5 minutes followed by a 10 minute cool down.

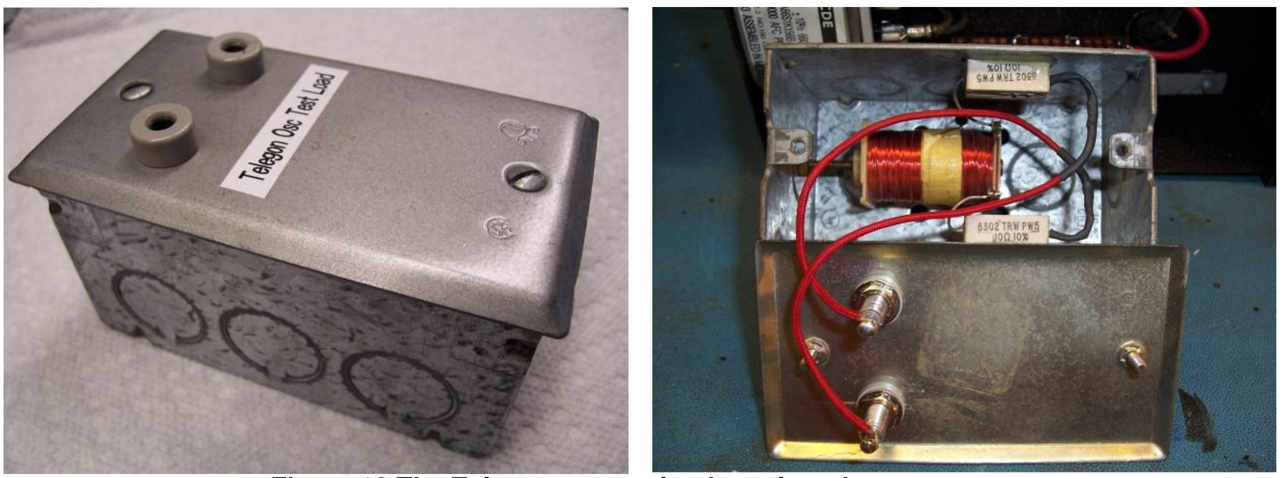

Figure 12 The Telegon system load emulator box

Telegon Oscillator Waveforms

The original Link Trainer service documentation did not include any oscilloscope waveforms of the various points in the circuit so the author though that the following observations might be of interest. Oscilloscope waveforms for various points throughout the Telegon Oscillator may be found in Appendix B.

Other observations

While testing the Telegon Oscillator it was noted that the output waveform was varying slightly in amplitude. This amplitude variation was correlated to the ripple voltage present on the high voltage output. The high voltage full wave rectifier output ripple is filtered by the 4uF filter capacitor C5. During the restoration, this capacitor was replaced with a 4.7 uF non-electrolytic type. While some variation in amplitude will most likely be acceptable the author felt that some additional filtering of the high voltage would be beneficial and constructed the capacitor bank shown in Figure 13. This bank was constructed from three 47 uF 350 volt electrolytic capacitors placed in series with a 220k ohm resistor across each capacitor to form a voltage equalizing network. Thus the completed capacitor bank resulted in a 16 uF capacitor with a DC rating of 1050 Volts. This capacitor bank was placed in parallel with C5 to form a total of about 20 uF. The reduction in ripple voltage was significant as noted in the Table 5 and displayed Figure 27 and Figure 28 found in Appendix B.

Table 5

Filter Capacitance	Ripple	Comments
4.7 uF	100 Vptp	Replacement C5 alone
20 uF	24 Vptp	Replacement C5 plus 16uF capacitor bank

It should be noted that the total filter capacitance in the high voltage section should not exceed 8 uF if the 83V rectifier tube is used so as not to exceed the maximum rated plate supply impedance of 65 ohms per plate for the 83V.

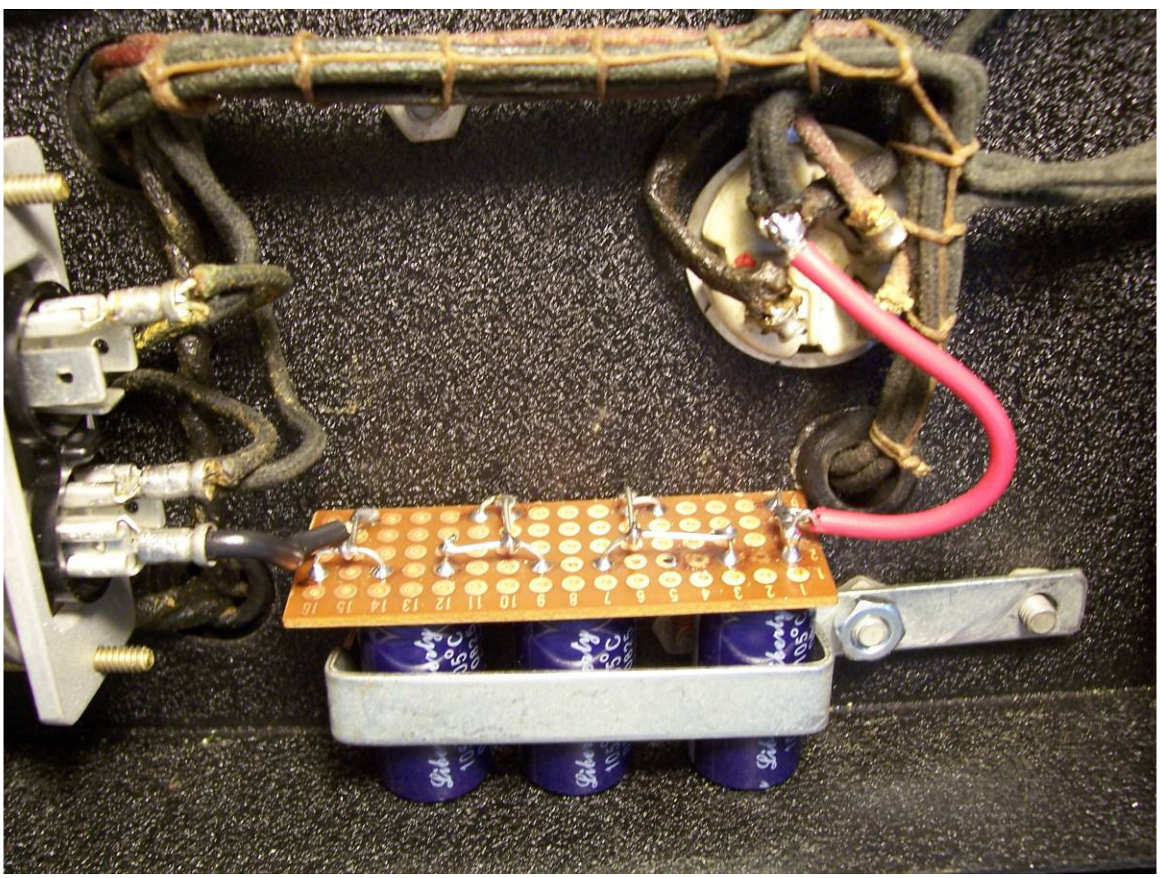

Figure 13 Added filter capacitor bank and connections and fabricated retaining bracket. Positive connects to pin 1 of the rectifier tube socket which is common with the + terminal of C5. The negative side of the capacitor bank connects to the common (chassis ground) of capacitor C6.

Figure 14 The completed Telegon oscillator, View 1

Figure 15 The completed Telegon oscillator view 2

Appendix A

Construction of a Solid State rectifier to replace the 83V

The basic solid state rectifier design consists of two silicon diodes of the 1N4007 type that are rated to a peak inverse voltage of 1000 volts. Two 47 ohm power resistors are placed in series with each diode to provide a voltage drop that is somewhat comparable to forward voltage drop exhibited by the 83V (15V @ 300 mA) although in the case of a resistor, the voltage drop will be a function of forward current. The 47 ohm resistors exhibit a 14.1 volt drop at 300 mA plus the Vf of the diodes which result in a nearly comparable Vf for the 83V at 300mA.

The starting point is a tube base that will fit the chassis socket allocated for the rectifier. In the example shown here, the failed 83V tube's base was carefully removed by desoldering the glass envelope extension wires and the tube/base bonding adhesive broken down until the tube and base were separated. The tube less the base is shown in

Figure 17. Figure 16 displays the schematic of the solid state rectifier and identifies the components used to construct the replacement rectifier.

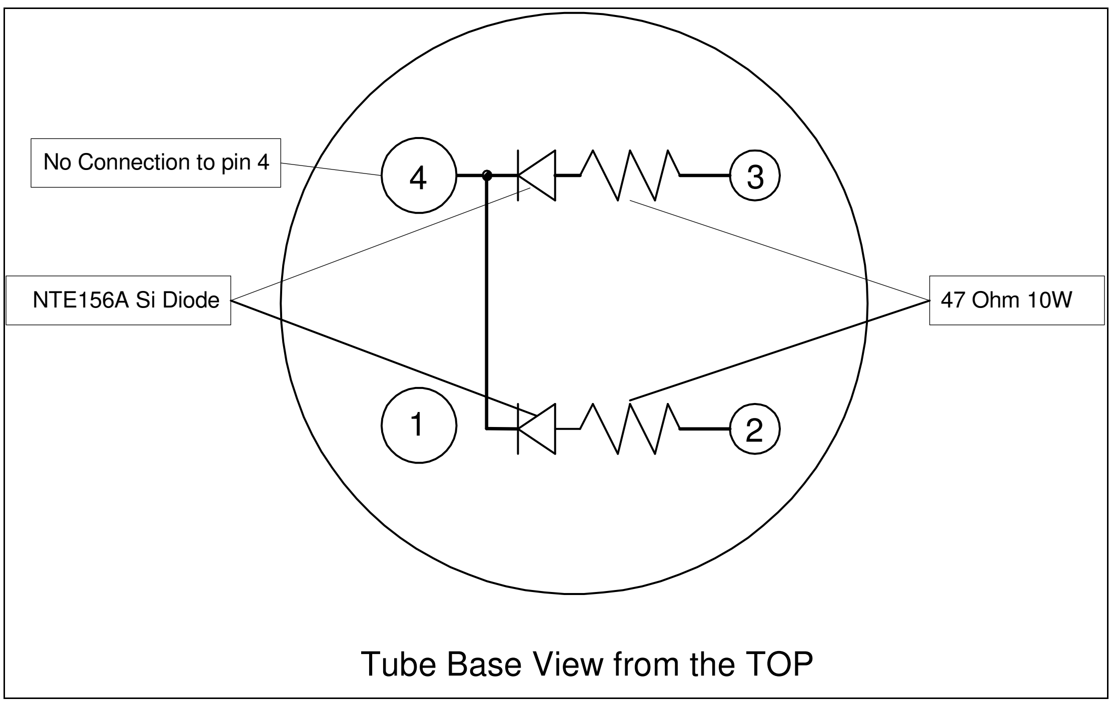

Figure 16 Schematic of the solid state "83V" rectifier, note that there is no connection to pin 1

The diodes and resistors are installed into the base as shown in Figure 18. There is no connection made to pin 1 and heat shrink tubing should be installed over the upper exposed leads of the power resistors. Figure 19 shows a vented cover that was constructed from ¾ in. schedule 40 PVC and turned down on one end so that it would fit inside of the tube base. A simple finger guard made from two 3/32 in. diameter metal rods was drilled into and installed at the top as shown in Figure 20. The completed cover was painted black and then glued onto the tube base. The completed solid state rectifier is shown in Figure 21.

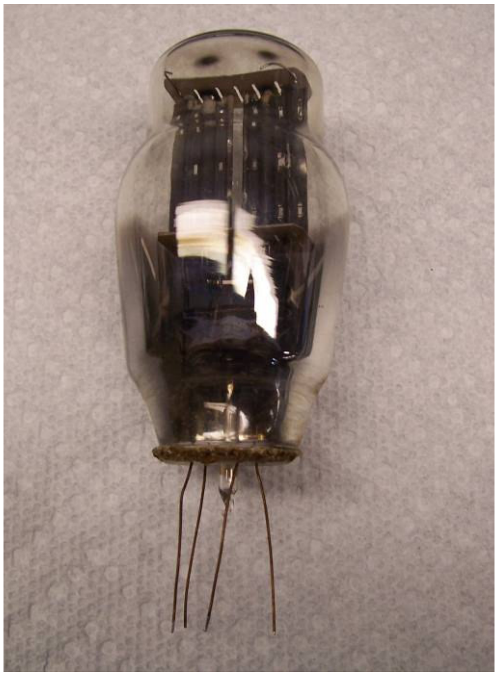

Figure 17 Failed 83V rectifier tube shown with base removed

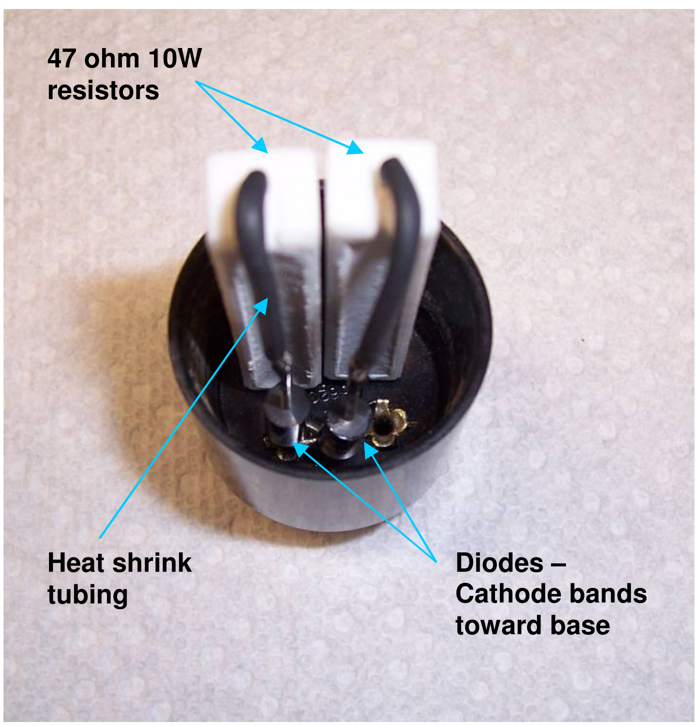

Figure 18 Top view of the solid state rectifier

Figure 19 Protective cover for the solid state rectifier made from ¾ inch schedule 40 PVC

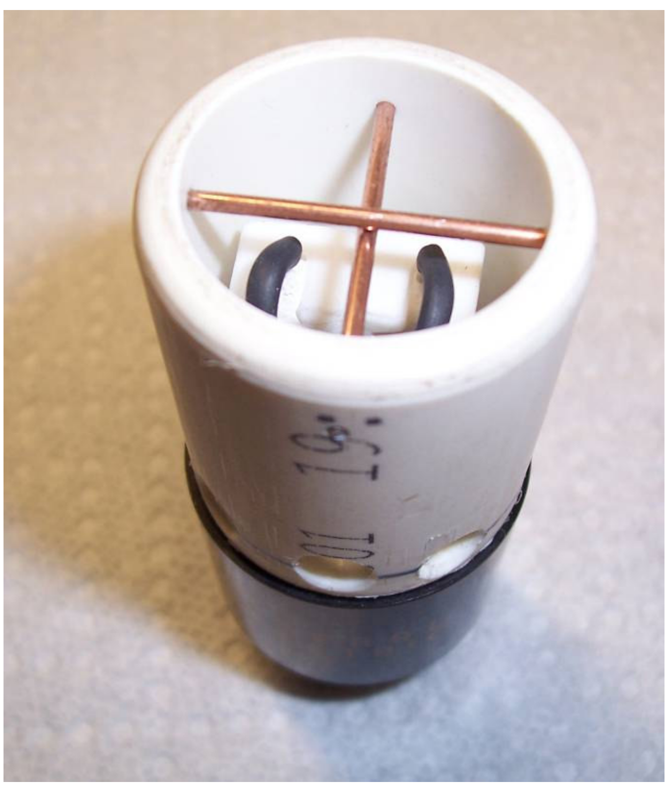

Figure 20 The assembled solid state rectifier, note the finger guard at the top

Figure 21 The completed solid state "83V" rectifier

Appendix B

Telegon Oscillator waveforms

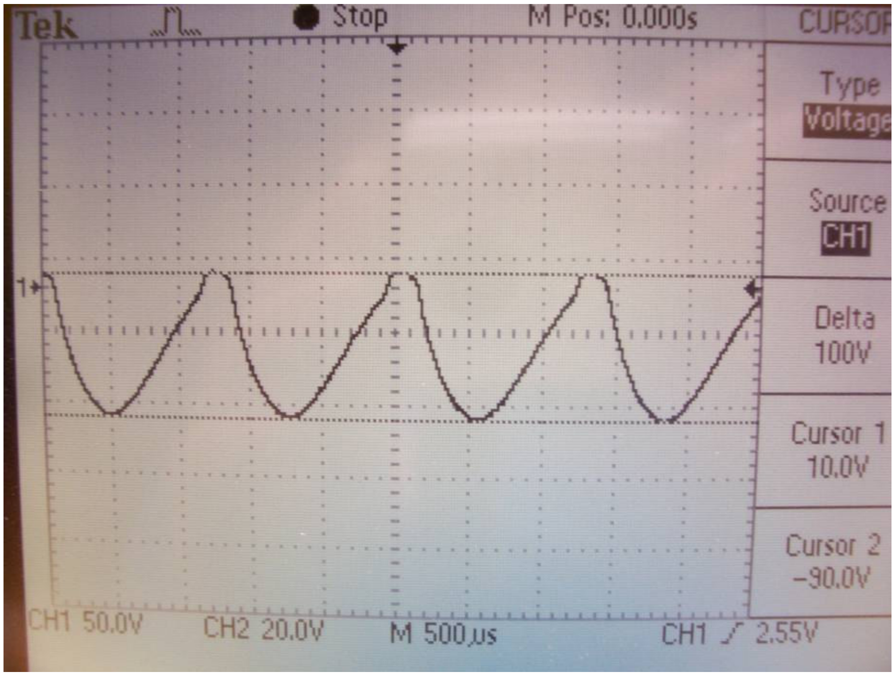

Figure 22 6L6G oscillator signal at pin5 of the oscillator tube relative to ground – note the signal swings between +10 and -90 volts at the oscillation frequency very close to 800 Hz (period of 1250 us)

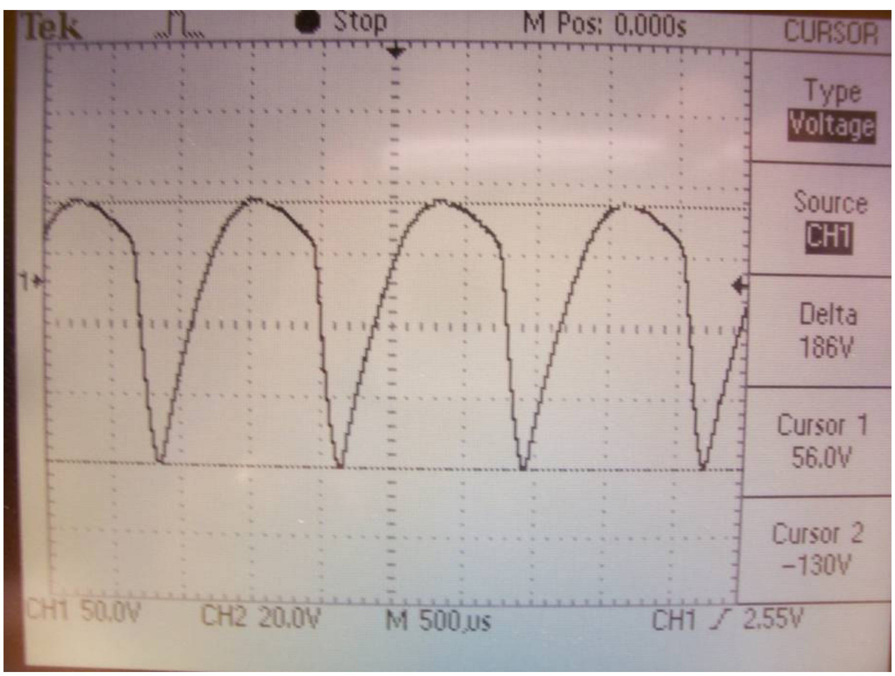

Figure 23 Power output tube pin 5 (tube nearest the back of the chassis) – note the signal swings from 56 to -130 volts at the frequency of oscillation.

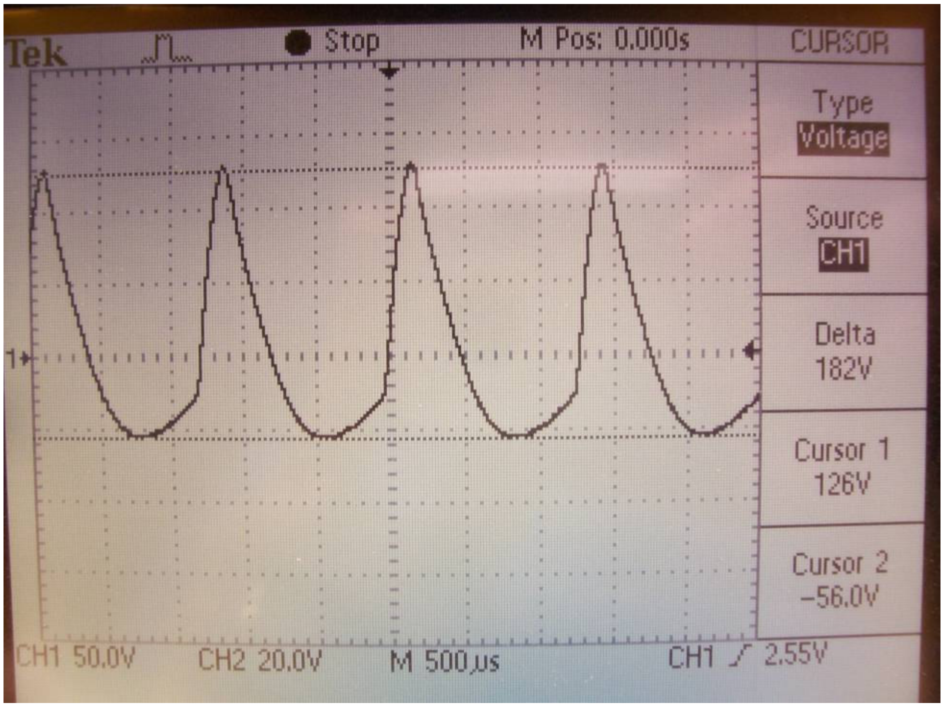

Figure 24 Power output tube pin 5 (6L6G tube in the middle of the chassis) – note the complementary signal swing of +130 to -56 volts.

Figure 25 Waveform at pin 8 of either 6L6G power amplifier tube.

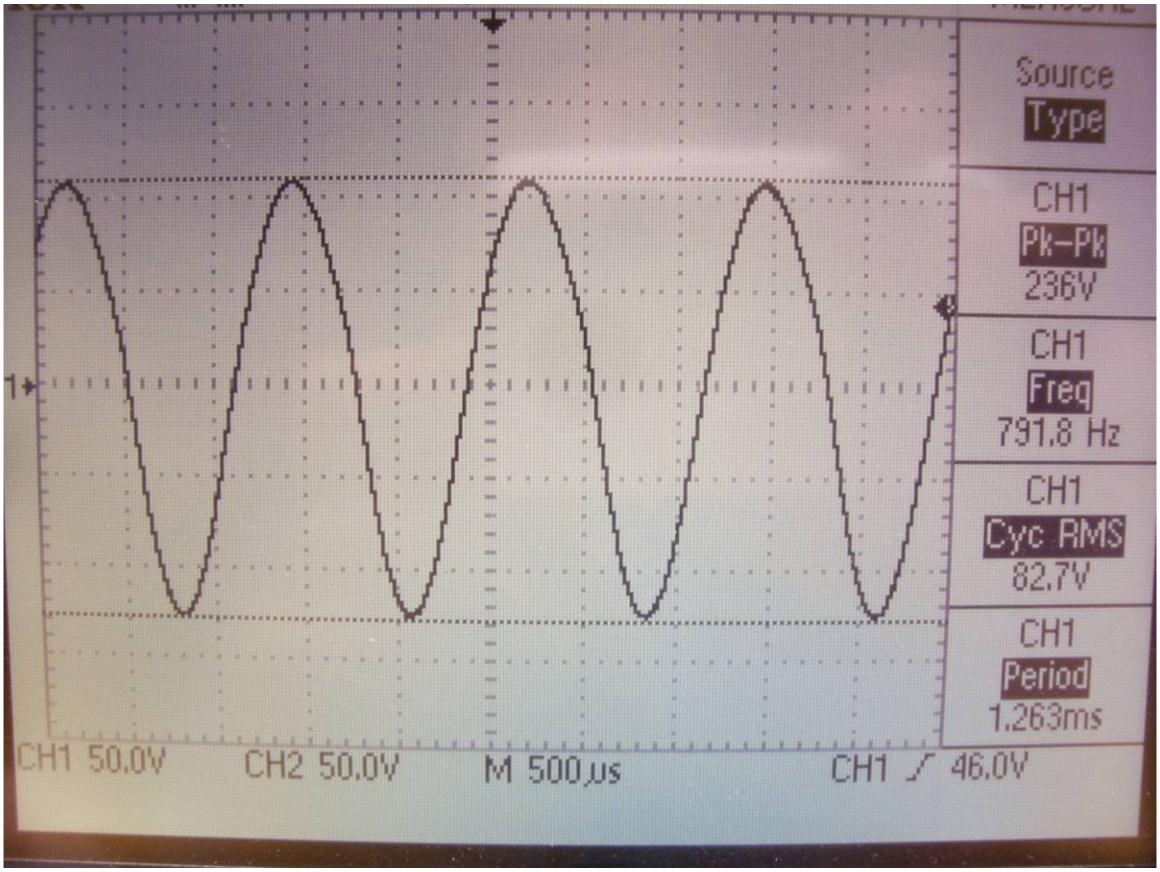

Figure 26 The final output with the simulated Telegon system load connected

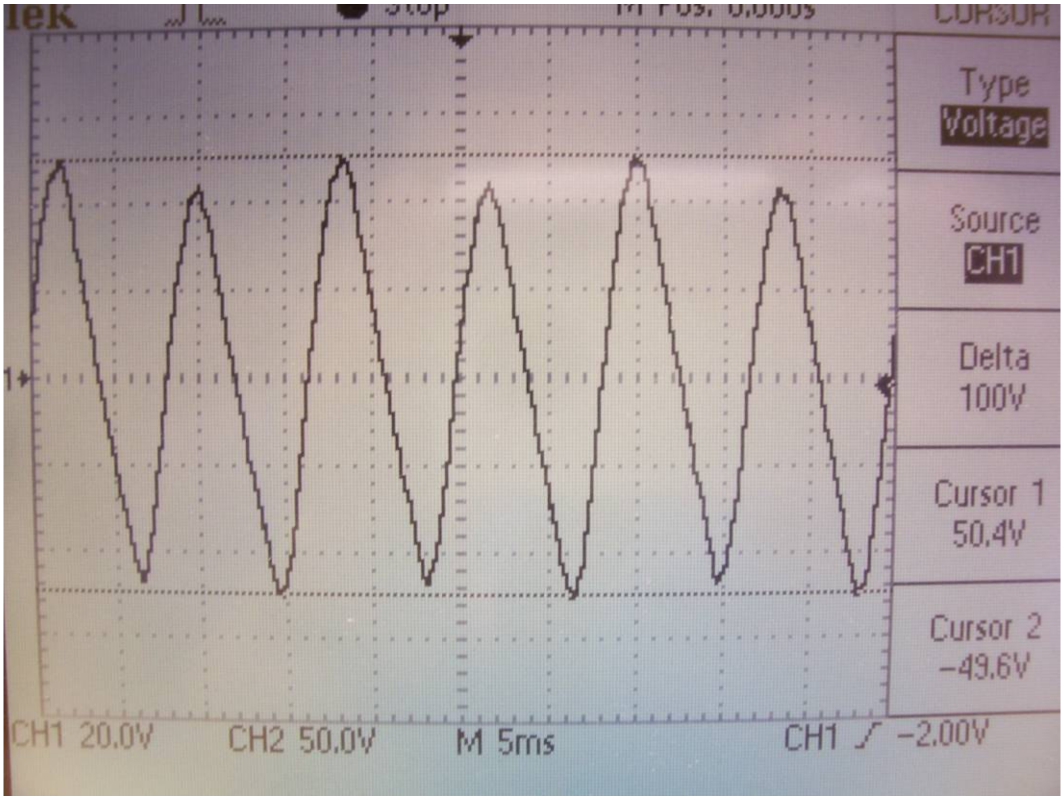

Figure 27 High voltage ripple of 100V ptp with C5 only

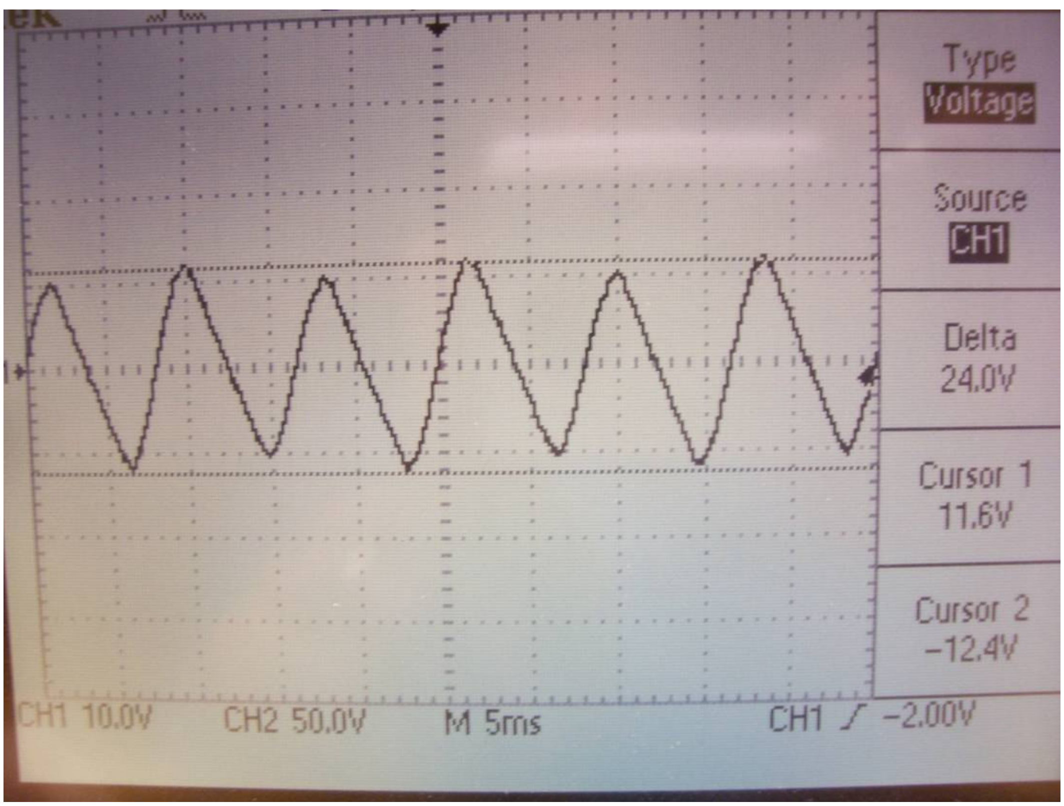

Figure 28 High voltage ripple with C5 and the 16uF capacitor bank added, 24 Vptp