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Honors Project: CuCl Laser Power Supply Circuit

INTRODUCTION

The purpose of this project was to construct a functioning power supply circuit for a CuCl Laser. This circuit would need to output 15,000 Volts and approximately 0.060 Amperes in order to provide sufficient electrical energy for both the sublimation and the lasing of the copper atoms. Using existing online and print sources, such a circuit was engineered by constructing a high-voltage power supply, attaching it to a homemade rectifier, and attaching the rectifier to both capacitors and high-voltage output wires.

METHOD

I. High-voltage power supply

A high-voltage power supply kit was purchased and assembled by the experimenter. The circuit schematic for the transformer is shown below:

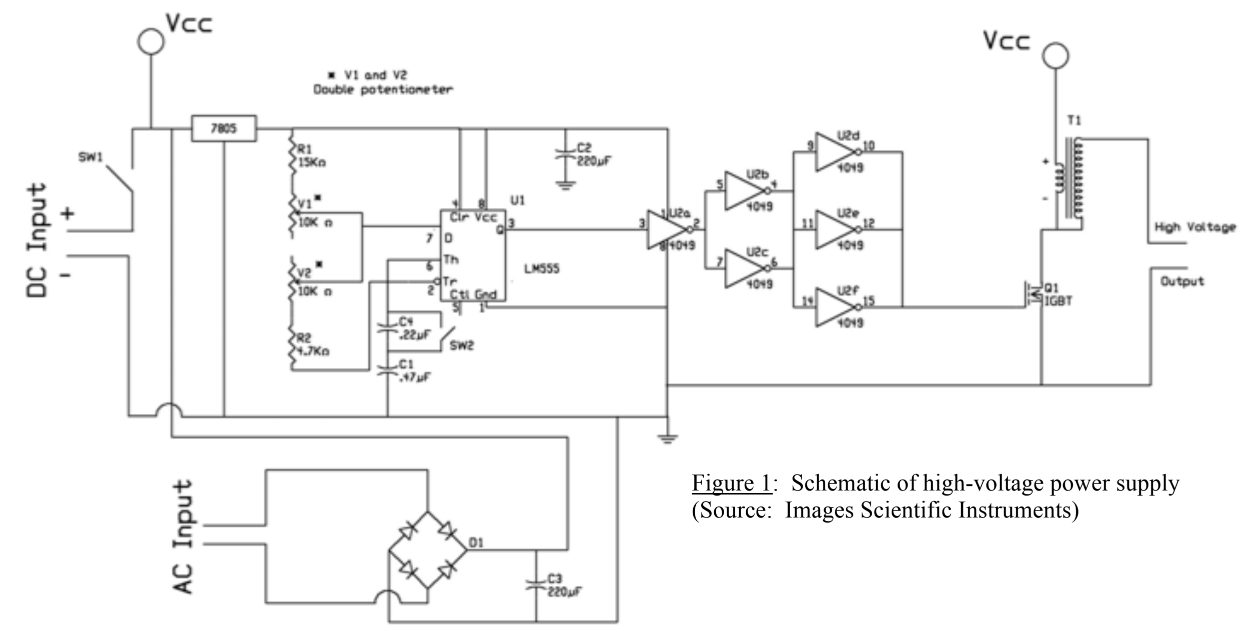


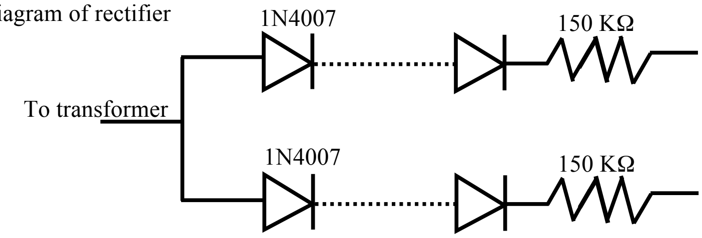
Figure 1: Schematic of high-voltage power supply
(Source: Images Scientific Instruments)

Due to a fallible wall transformer, a 24VDC input was chosen. The above circuit works in the following manner: when switch 1 is closed, a DC voltage is introduced and passes through a 7805 voltage regulator in order to control the input voltage. The current then flows through resistors, a double-ganged potentiometer, and a capacitor. Changing the resistance of the potentiometer changes the voltage that will pass through the LM555 timer and therefore changes the frequency of the final output AC voltage. After passing through the aforementioned resistors and capacitors, the current then flows through the LM555 timer, which is simply an integrated circuit composed of transistors, diodes, and resistors that outputs very regular and controlled pulses of current. This timer has two possible modes: astable and monostable. Its astable mode is employed in this circuit so that the pulse frequency can be controlled, as previously mentioned, by resistors and capacitors. After passing through the timer, the now pulsed current goes through the 4049 hex inverting buffer which, as the name suggests, inverts and buffers the current pulses, in order to transform the square wave current function outputted by the timer into a sine function, or an alternating current. The current then passes through a transistor. Transistors are semiconductors, usually silicon, doped with other metals, usually aluminum, that regulate current and amplify voltage. They achieve such a regulation through gaps in the metallic energy bands of silicon that occur at points where aluminum is inserted. Since aluminum has one less electron than silicon, an electron "hole" appears at the dope site, and thus, from the frame of reference of the orbiting silicon electrons, acts as a positive charge. This difference in charge sets up an electric field, and this electric field allows current to flow. Since current flows only in one way (from the negative electrons to the positive "holes"), the transistor used in the circuit is installed so that current can flow from the 4049 integrated circuit into the high-voltage transformer, but not from transformer to the 4049 circuit. After the current passes through the transistor, the current then flows through the high-voltage transformer, which uses electromagnetic induction to step up the voltage to approximately 15,000 V. As a direct consequence of the first law of thermodynamics, however, the current must be reduced by the same factor that the voltage is increased. The output current is approximately 40-60 mA. After assembly, the transformer was placed in a plastic box for safety reasons.

II. Rectifier

Once the desired output voltage and current had been achieved, the AC voltage had to be transformed into DC voltage so as to provide regular electric energy to the lasing tube. This transformation was achieved by constructing a rectifier. A rectifier is a series of diodes that transforms AC to DC. A diode is a circuit component that allows current to flow in only one direction, and works on much the same principle as a transistor. The allowed current is termed the "forward current," the input side of the diode is the "anode," and the output side of the diode is the "cathode." Since current can only flow in one way, half of the sine wave of the AC voltage is lost with each period. The rectifier was built by connecting 50 high-voltage diodes (1N007) in series twice and by connecting the anodes of the two starting diodes to the high-voltage transformer. A 150 KΩ resistor was then attached at the final cathode of each branch of the rectifier to serve as a bridge to the output wire. The following is a diagram of the rectifier:

Figure 2: Diagram of rectifier



After assembly, the solder points were coated with nail polish to prevent arcing, and room temperature vulcanizing rubber was inserted between to two branches, also to prevent arcing. Finally, the whole rectifier was inserted into a PVC pipe for safety reasons.

III. Final connections

After the current had been manipulated sufficiently, the circuit was assembled to resemble the following diagram:

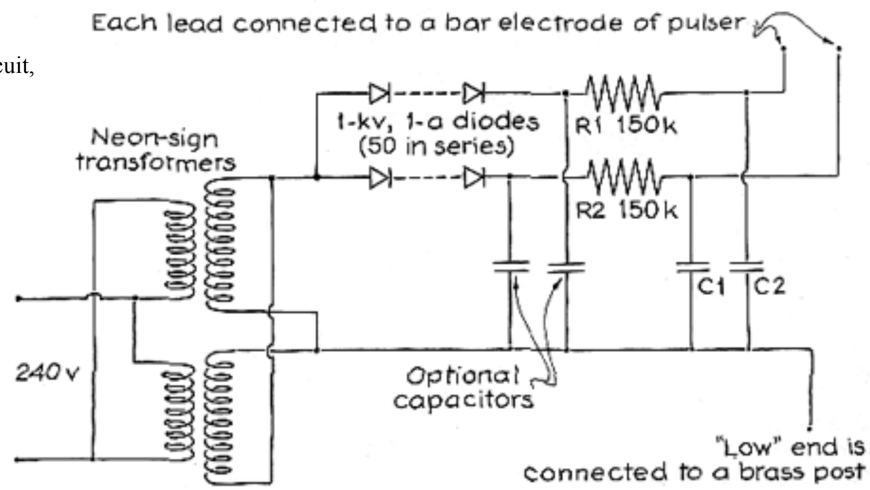


Figure 3: Finished power supply circuit, minus modifications
(Source: Jearl Walker)

Some modifications were made, however: one high-voltage power supply powered by 24VDC instead of two neon-sign transformers powered by 240VAC was used and the optional capacitors were foregone.

The output wire of the high-voltage transformer was attached to the anode side of the rectifier, and one 0.022 μF capacitor rated at 16,000 V, as well as high-voltage output wire, was attached to each cathode output of the rectifier. The capacitors are included to smooth out the output current. The other leads of the capacitors were attached to a ground wire. One point of the ground wire was soldered to the negative terminal of the high-voltage transformer.

IV. Future Use

This circuit was constructed to power a CuCl laser. The two output wires will eventually be connected to a pulsar that will deliver pulses of electricity to the lasing tube via a brass post. The lasing tube will be evacuated using a vacuum pump, solid CuCl and gaseous neon will be introduced to the tube, and the whole tube will be heated to provide activation energy for sublimation. The other point of the ground wire not connected to the high-voltage transformer will be connected to another brass post on the lasing tube.

CONCLUSION

Through the construction and analysis of this project, many principles of physics, both practical and theoretical, were learned. Soldering and other electronic skills were learned, and knowledge of circuit physics, electromagnetism, and quantum solid-state physics was greatly augmented. The other components of the laser will be built eventually, but probably not in this semester.

Bibliography

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