

INTRODUCTION TO E-GUN ELECTRONICS (AND TEST OF CHILD-LANGMUIR LAW)

INTRODUCTION:

Gridded electron guns (GED) and triode vacuum tubes (TVT) share the same basic operating principles. For example, GDEs can operate as amplifiers (see e.g. J. Harris Ph. D thesis – IREAP website). In addition, the electronics principles for pulse-forming are not exclusive to e-guns. As you'll see in this exercise, a triode circuit can be pulsed using the same circuitry as in the UMER e-gun. In fact, the avalanche pulser is a spare one for UMER.

Furthermore, the breadboard TVT has a cathode that is very similar to the cathodes in the UMER and LSE guns, but operates with fixed heater voltage (standard 6.3 V AC), has a fixed distance to the triode plate (anode), and, obviously, has no Pierce electrode. Another difference is the low “accelerating” voltages employed in the breadboard, which makes it convenient for bench tests of pulse forming circuits. It is even possible to test the Child-Langmuir law as in the e-guns.

The scope of this experiment will be limited to: 1) understanding the principles of pulse forming lines (PFL), 2) the operation of a control grid in a triode gun, and 3) test the validity of the Child-Langmuir law in the triode configuration. Additional exercises can be envisioned related to other aspects of triodes and gridded electron guns. The students are welcome to explore and try their own ideas.

The main components for this experiment are:

- 1) Test gun breadboard (see Figure 1 below): It consists of a EIMAC 7698 planar triode, a $\pm 15\text{V}$ DC power supply for grid bias control, a 6.3 V transformer for the cathode heater, etc.
- 2) Avalanche pulser (blue box): based on a transistor circuit. The transistor is biased with a voltage around 125 V, for an output of approximately half of that for charging the coaxial delay line.
- 3) Coaxial-cable delay line: 33 ft. of RG-58 coaxial cable with an open end. The avalanche pulser together with this cable provides the pulse forming line (PFL) for the gun breadboard.
- 4) Delay switch box: provides a flexible way of obtaining different pulse widths by means of 5 switches that connect to RG-174 cables inside the box.
- 5) Ballum transformer: especial transformer for electrical isolation from the breadboard main ground (base plate).

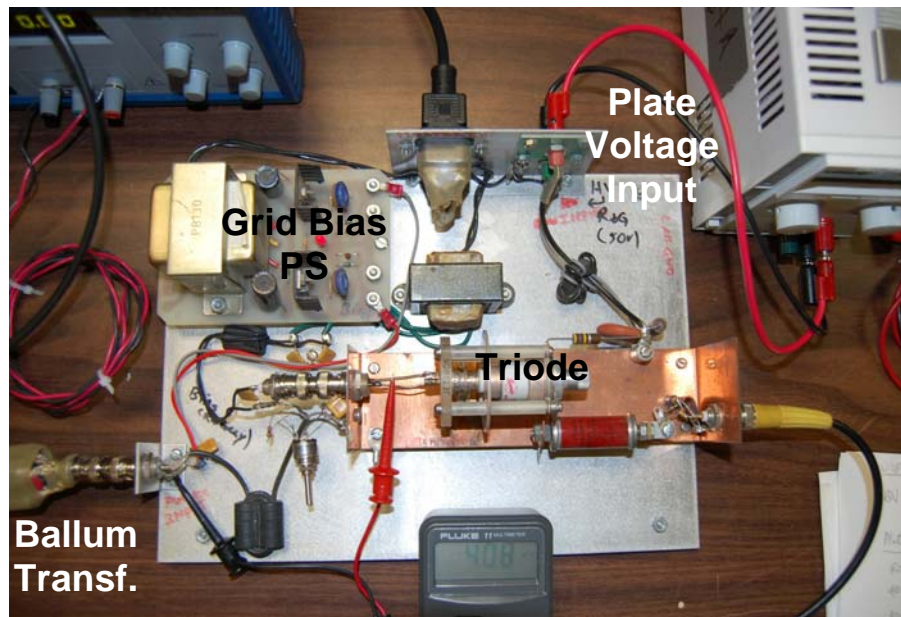
BACKGROUND:

Literature on transmission lines as delay lines (e.g. Malmstadt, Enke and Crouch, *Electronics and Instrumentation for Scientists*, Benjamin-Cummings, 1981, p. 305-306); Ronald F. Koontz, "Pulse Transformer Design Report For U. of MD Plasma Physics Lab", February 6, 2001 (unpublished); Ronald F. Koontz, "Electron Gun and Pulser Studies", Dec. 10th, 2000 (unpublished). For triodes, the standard reference is Karl R. Spangenberg, *Vacuum Tubes*, McGraw-Hill, 1948 (you'll find in this book, for example, that Maxwell had essentially solved the triode electrostatics problem long before the invention of vacuum tubes!).

EQUIPMENT:

Electron-gun simulation breadboard (made by R.F. Koontz' Hermosa Electronics, Menlo Park, CA), avalanche pulser (2N2222A Transistor), RG-58 coaxial cables (33 ft and other lengths), RG-174 delay box, ballum transformer, 0-120 V Xantrex power supply, B-K Precision 12 V power supply, Stanford pulser, Agilent oscilloscope, Fluke voltmeters.

Figure 1: Gun test breadboard

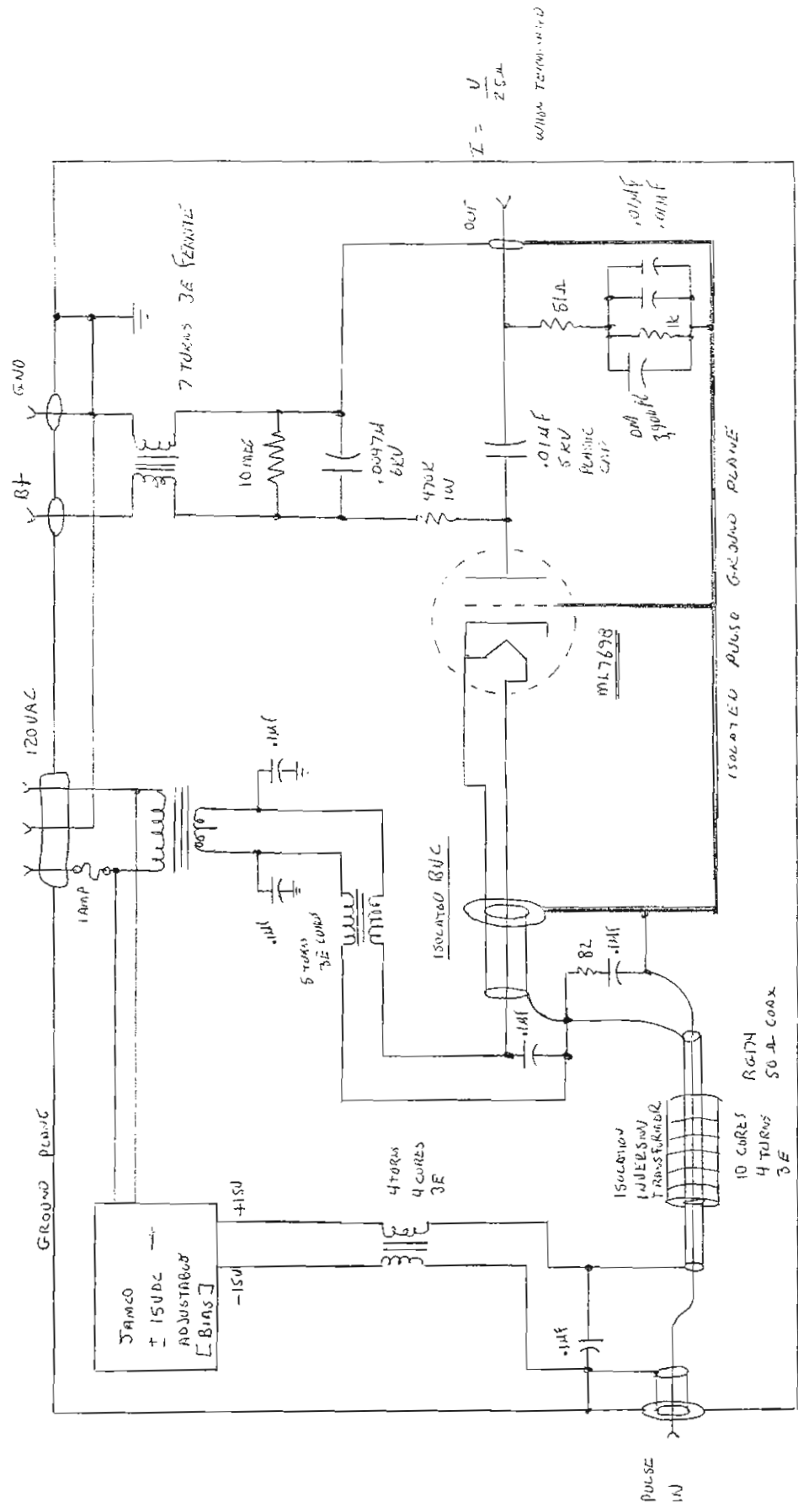


PROCEDURE:

1. Study the circuit diagrams attached (especially the one for the breadboard) and identify the main components. Also identify the associated hardware (pulser, power supplies, ballum transformer, cables, etc).
2. Connect the 33ft. RG-58 coaxial cable to the “delay” input of the avalanche pulser (blue box), and measure and record the peak amplitude of the avalanche pulser output on the scope. Use a x10 Tektronix attenuator (50Ω, 2W) when connecting to the scope (with 50Ω termination).
3. Use the ballum transformer to connect the avalanche pulser output to the input of the test breadboard.
4. Set the grid bias voltage (need a small screw driver) to 15V (see Figure 1 above, which shows 4.08V for that voltage).
5. Connect the output of the breadboard to the scope (with 50Ω termination), making sure that the plate voltage is set to zero. In reality, “zero” on the display of the Xantrex power supply is not actually zero: Monitor the plate voltage with an additional voltmeter.
6. Set the plate voltage to 10V, and adjust the small rheostat at the back of the triode for maximum signal amplitude on the scope.
7. Increase the grid bias voltage and see if you can cut off the breadboard output signal. Try other plate voltages. Do not exceed 55V.
8. Remove the input cable to the breadboard and connect it to the scope through a x10 Tektronix attenuator. Add a x2 Tektronix attenuator to the output of the avalanche pulser and measure the new peak amplitude on the scope. Make sure that it is approximately one-half of the one recorded in step 2.
9. Repeat steps 6-7. Record your observations.
10. Child-Langmuir I: return to full-amplitude output of the avalanche pulser, and to 15V grid bias voltage. Measure and record the peak amplitude of the output on the scope for plate voltages of 5, 10, 15..., 55V. Make sure to monitor the plate voltage (Xantrex power supply) with a voltmeter.
11. (Time permitting) Child-Langmuir II: with no plate voltage applied, and a x2 attenuator connected to the output of the avalanche pulser, measure the peak output current as a function of grid bias voltage.

ANALYSIS / QUESTIONS:

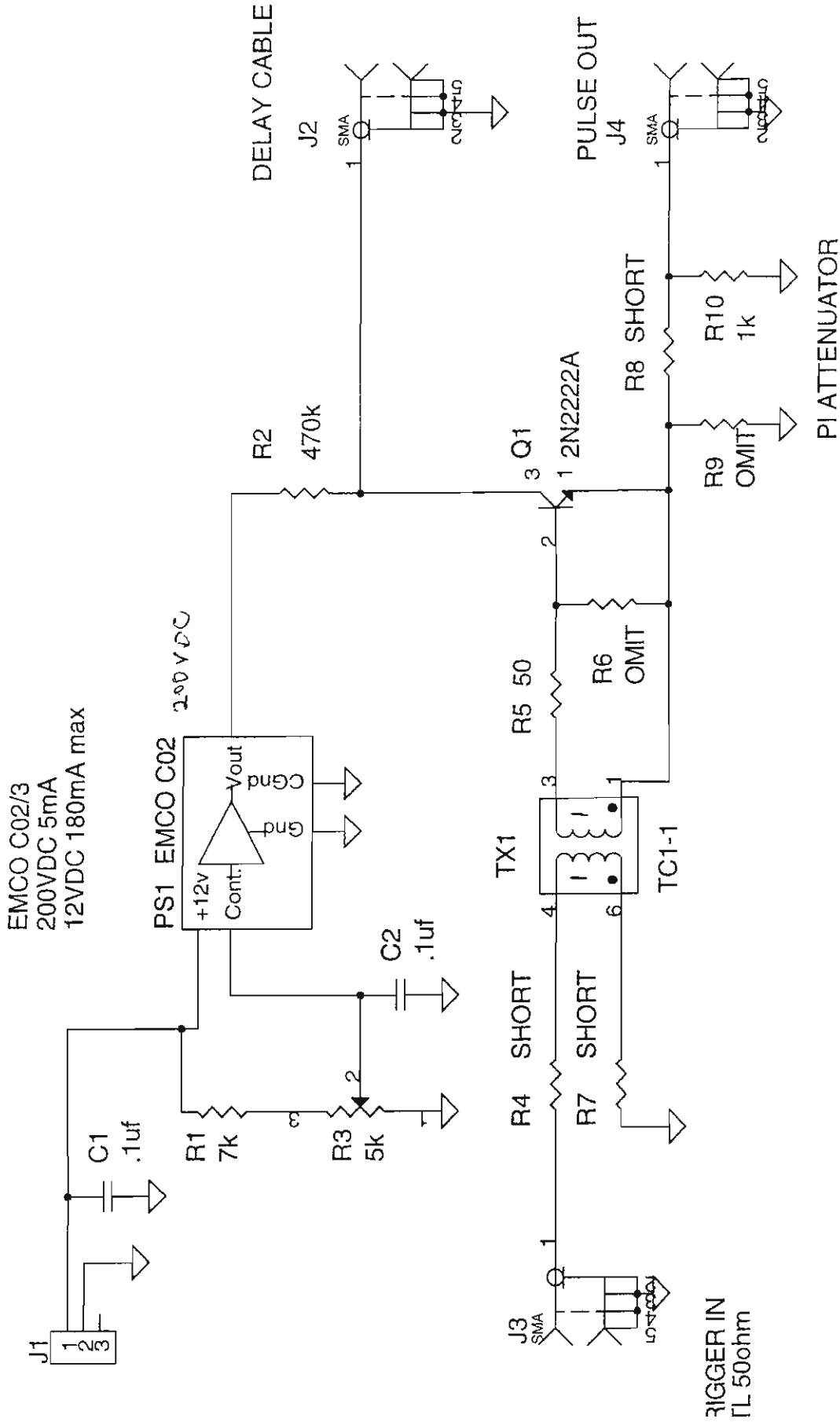
1. Tabulate your results and include measurement errors.
2. Find the characteristic inductance and capacitance per meter for RG-58 coaxial cable. Calculate the intrinsic impedance and the phase velocity of TEM waves in the cable. What fraction of the speed of light is the phase velocity in RG-58?
3. Research and discuss briefly the operation of the PFL used in the experiment.
4. Discuss the operation of the control grid based on your observation in steps 7-9.
5. Plot Output Current vs. Plate Voltage (data taken in step 10) and do a least-squares power fit. How is your "Child-Langmuir" law compared with tests in UMER and LSE by your classmates? Discuss.
6. (Bonus) Plot Output Current vs. Plate Voltage (data taken in step 11) and do a least-squares power fit. Can you deduce a realistic value for the cathode-grid gap distance?



$$Z = \frac{V}{25 \mu A}$$

WINDING TERMINALS

HERMOSA ELECTRONICS
 GUN TEST BREADBOARD
 SK-UMD-12300-R0
 B



Title		Avalanch Pulser	
Size	Document Number	Rev	
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Date:	Thursday, July 12, 2001	Sheet	1 of 1