Construction of a Low Temperature Plasma Probe Capable of Ambient Ionization of Samples for Mass Spectrometric Analysis

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Introduction

- Ionization of Mass Spec Samples often use plasma sources.
- Same plasma sources may be large and costly.
- This method builds off of a previous model for a low temperature plasma probe.
- The probe is handheld and uses an AC square wave.[1]
- The first probe was build using 125 kHz using a step up transformer to produce a dielectric barrier plasma.
- The second probe was build to power a piezoelectric transformer to generate a piezoelectric plasma, using a 20 V power supply.

Methods

Components used in circuit:

- 555-Timer
- N-channel MOSFET
- Transformer
- 9V Battery
- Resistors
- Capacitors
- Potentiometer

The 555-timer's frequency is variable based on how it is wired.

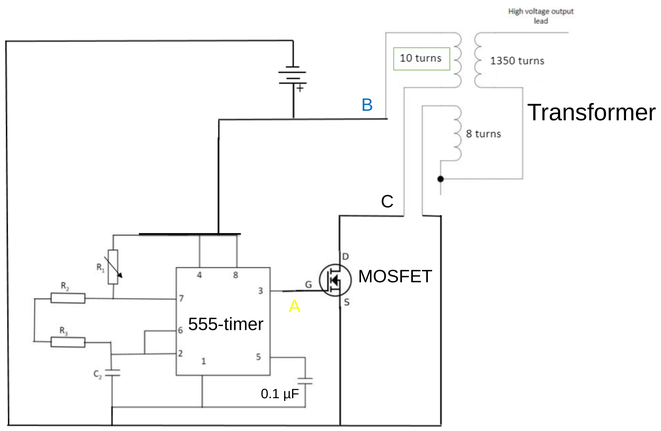

Figure 1. *A diagram of the circuit used. A 2 kΩ pull-down resistor from the gate of the MOSFET to ground is not shown*

Equations Used to Determine the Output of the 555-Timer

Time High = $T_1 = 0.693(R_1 + R_2)(C)$
Time Low = $T_2 = 0.693(R_2)(C)$
Frequency = $f = 1/T = 1.44/(R_1 + 2R_2)(C)$
Duty Cycle = $T_{ON} / (T_{ON}\ T_{OFF}) = ((R_1 + R_2) / (R_1 + R_2))$ %

Results: Dielectric Barrier Plasma

When the circuit was designed to generate a dielectric barrier discharge plasma, a plasma was achieved in ambient temperature under the following conditions:

R_1 = 1KΩ
$R_2 + R_3$ = 10 k Ω
C_2 = 470 pF

Output signal from test point A (Figure 4):
Frequency = 110 kHz
Duty Cycle = 55.07%
V_{out} = 9 V

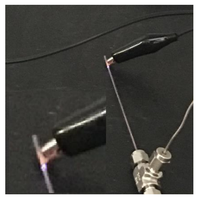

Figure 2. *The dielectric barrier plasma generated in ambient conditions.*

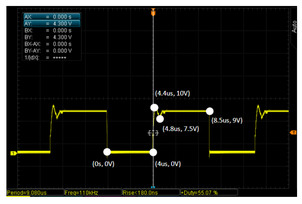

Figure 4. *Oscilloscope data depicting the frequency and duty cycle of the output of the 555-timer*

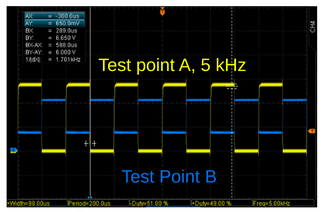

Figure 5: *The signal measured from the output of the 555-Timer (yellow) and the signal measured from the N-Channel MOSFET (blue) to show signal inversion*

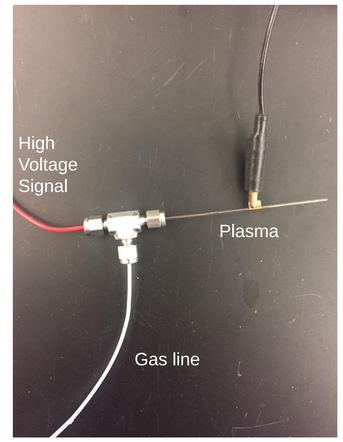

Figure 3. *A labeled diagram of the plasma probe*

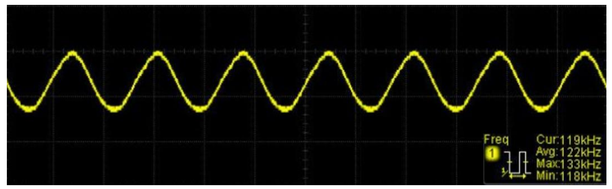

Figure 6. *The resultant waveform from test point C. The signal is 119 kHz, 1.35 kV, the sine wave properties are unexpected but work for plasma generation.*

Results: Piezoelectric Plasma

Plasma generation has not yet been achieved. The following conditions were used:
R_1 = Potentiometer ranging from 7 kΩ to 75 kΩ
$R_2 + R_3$ = 90 k Ω
C_2 = 100 pF

Output signal from test point A (Figure 4):
Frequency with R_1 as 7 kΩ = 55 kHz
Frequency with R_1 as 75 kΩ = 77 kHz
Duty Cycle = 64%
V_{out} = 9 V
Same waveform as when the dielectric barrier plasma is used

Output signal from test point B:
20 V DC signal

Discussion

- Dielectric barrier plasma generation was successful
- Piezoelectric transformer's signal (test point B) is a DC signal.
- The 555-timer's signal driving the MOSFET for the piezoelectric transformer worked as expected.
- Piezoelectric transformers resistance should be tested, or equivalent resistor should be used in place for testing.
- When small resistor (i.e. 10 kΩ) is used, test point A performs as test point B with inversion of signal.

Summary and Conclusions

- Piezoelectric transformer deviates from expected functionality.
- Dielectric barrier plasma is achievable under ambient conditions with air.
- Signal differs when power supply vs. 9v battery is used.
- Potentiometer is capable of deviating the frequency by a large amount.

Future Work

- Continue diagnostic testing on the piezoelectric transformer.
- Complete the piezoelectric transformer.
- Use inert gas with the dielectric barrier plasma
- Collect Mass Spec data on various samples using these plasma probes.
- Compare MS results using these probes to other ionization methods.

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University of New Hampshire

References

1. Wiley, J., Shelley, J., Cooks, R.; **2013**. *Anal. Chem.* 85, 6545-6552