Title	*Fast Shutter Coil Temperature Analysis*
Author	*R. Abbott, B. Taylor Caltech*
Date	*23 October 2014*

Overview

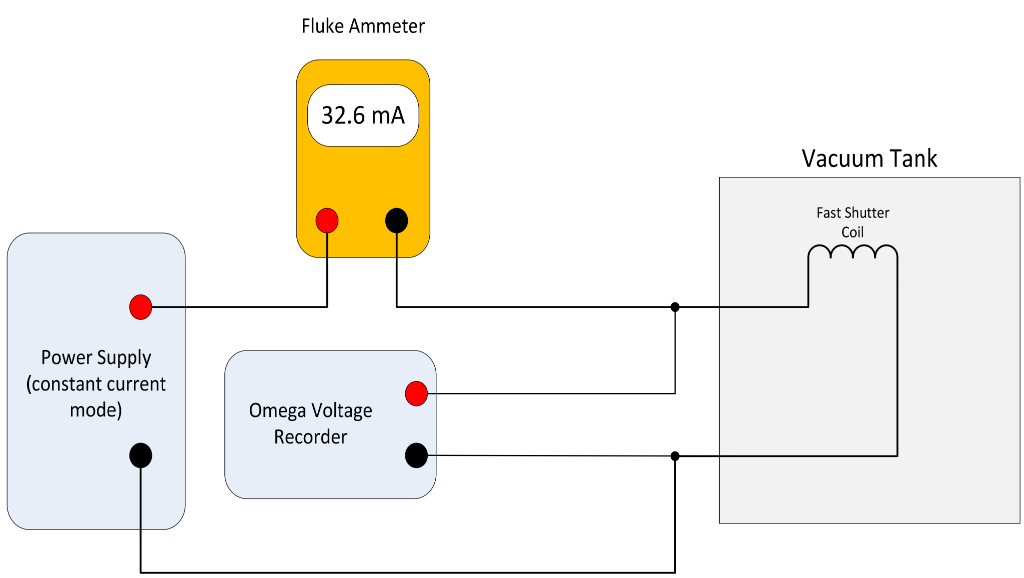
In order to establish a safe maximum steady state current for the LIGO-D1003318 Ultra-fast Optical Shutter, an analysis was done under vacuum ($\sim 7 \times 10^{-8}\ Torr$) wherein the coil that forms the moveable portion of the shutter was characterized in terms of resistance vs. temperature. The ambient temperature in the 40m Lab Bake Facility was ~24C during all tests. A maximum steady state coil current of 100mA was chosen based on the measurements performed in this test.

Knowing the relationship between coil resistance and temperature, a measurement was performed to explore the equilibrium temperature of the coil under vacuum vs. coil current.

Section 1

Test setup is shown below in Figure 1

Figure 1, Test Setup

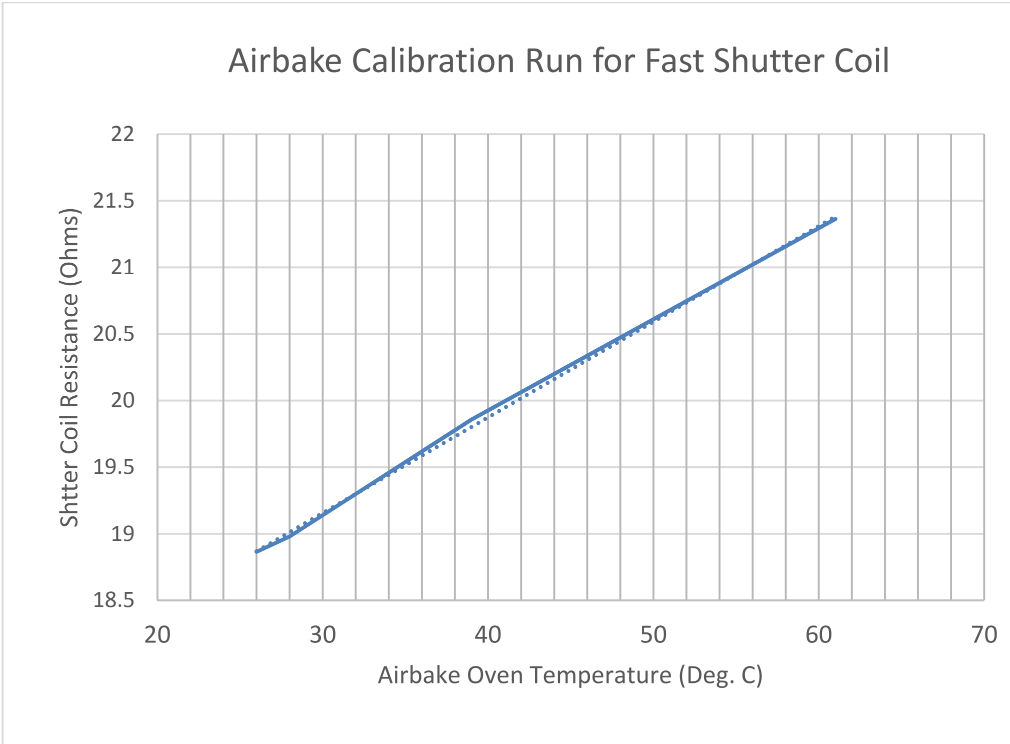


Section 2

A calibration run was performed to establish the relationship between coil resistance and temperature. The coil was placed inside the 40m lab air-bake oven and the oven and data was taken at incremental values of temperature. The result is plotted in Figure 2 yielding the following linear relationship between coil temperature T in units of degrees C, and measured coil resistance R, in units of ohms:

$$T = 0.0718R + 17.001$$

Figure 2, Calibration Curve

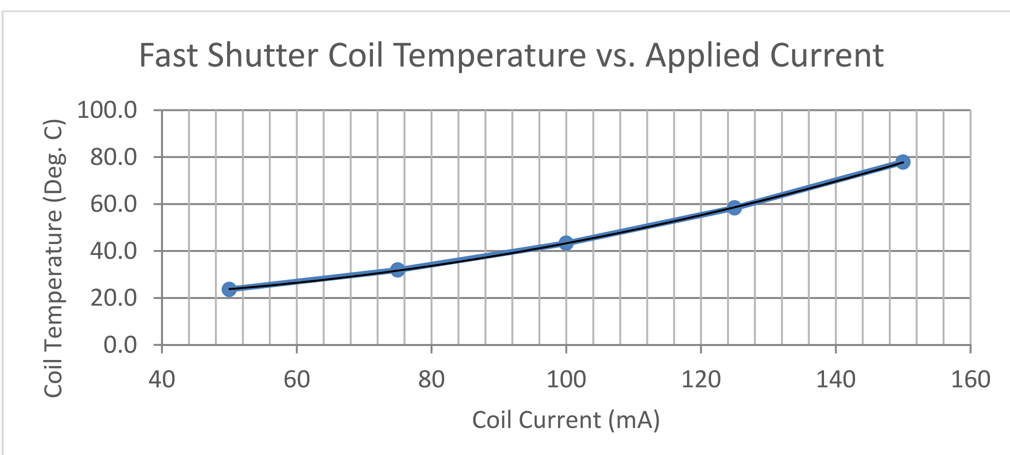


Section 3

With the relationship between coil resistance and coil temperature established, it is now possible to measure the relationship between coil current and equilibrium temperature as shown in Figure 3. This measurement was performed and yielded the following relationship between coil current I in units of mA, and coil temperature T in units of degrees C:

$$T = 0.003I^2 - 0.0593I + 19.275$$

Figure 3



Conclusion

Having established the relationship between coil current and equilibrium temperature, and given a desire to limit the steady state coil temperature to be less than 45C (roughly 20C above ambient), a maximum steady state current of 100mA was chosen yielding a predicted equilibrium coil temperature of 43C.