A More Accurate Capacitance Measurement Technique for NIF High Energy Density Capacitors

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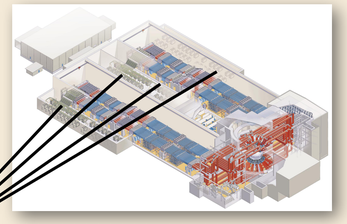
The National Ignition Facility (NIF) is home to the largest and most powerful laser in the world. The Power Conditioning System (PCS), which contains an array of 4000 capacitors, supplies the electrical energy to the laser amplifiers. Failure of one of these capacitors results in a loss of one 1.8MJ PCS module and causes delays in NIF's research while repairs are made. This sensor is part of an array of tools used to analyze and track the health of the PCS capacitors.

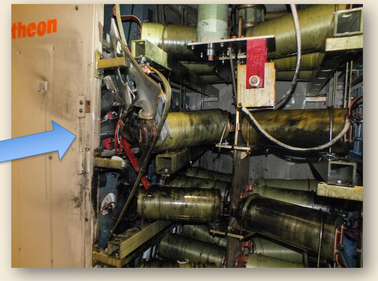
Introduction

The National Ignition Facility uses 4000 capacitors installed in 192 PCS modules to provide up to 400MJ of electrical energy to the laser amplifiers.



These capacitors are discharged through 100 miles of coaxial cables into 7680 flashlamps, providing gain to the laser. (Left: NIF Capacitor)

NIF has experienced 4 capacitor failures in the last 8 years…



…resulting in programmatic delays while the repairs are done.

NIF takes great effort to avoid capacitor failures. The Capscan sensor will be one of the tools used to monitor the capacitor banks.

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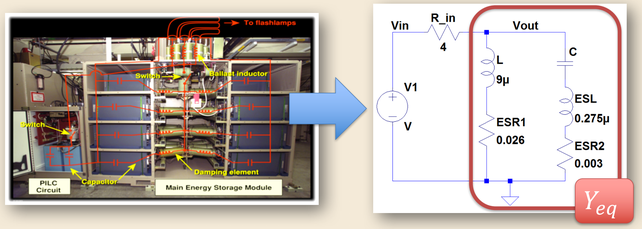
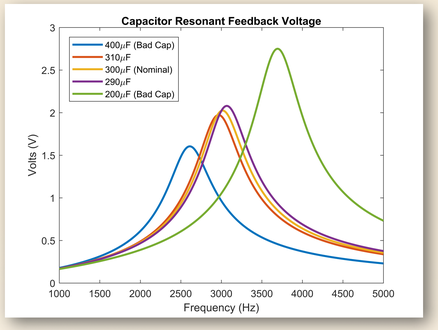
Methods

The Main Energy Storage Module (MESM) is a complicated circuit consisting of 20 capacitors and damping elements. It can be approximated as an RLC circuit with parasitics.



Changes in capacitance indicate a failing capacitor.



The circuit resonates at approximately 3 kHz. To determine the exact resonant frequency, the Capscan sensor sends a series of AC frequency sweeps through the MESM while monitoring the output current and voltage at each frequency. Using the equation

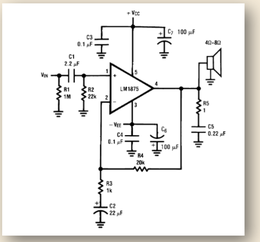
$$Y_{eq} = \frac{1}{\frac{1}{j\omega_{res}C} + j\omega_{res}ESL + ESR_2} + \frac{1}{j\omega_{res}L + ESR_1}$$

the capacitance of an individual capacitor in a PCS module can be determined without performing a time-consuming capacitor disconnect procedure. If the capacitance deviates from acceptable values, it will be replaced.

Next Steps

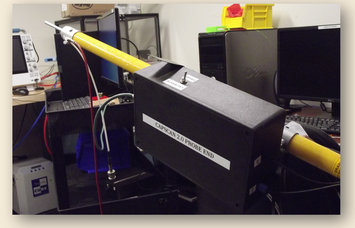
As this project continues, the ultimate goals are to…

- Design an easy-to-use, next-generation Capscan sensor that can **accurately measure capacitance with a resolution of less than 10 µF.**

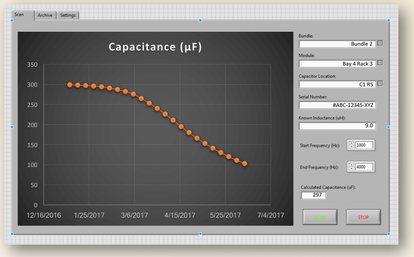


Source: TI LM4780TABD/NOPB Documentation

- **Replace the previous-generation Capscan sensor**, which was restricted to low signal levels, slow, difficult to operate, and made inconsistent measurements due to parasitic elements.



- Develop a computer application that enables engineers to **analyze and track the capacitance of each capacitor over time,** allowing degraded capacitors to be removed from service before they fail.



- **Deploy** the next-generation sensor to each of the 4 NIF capacitor bays.

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