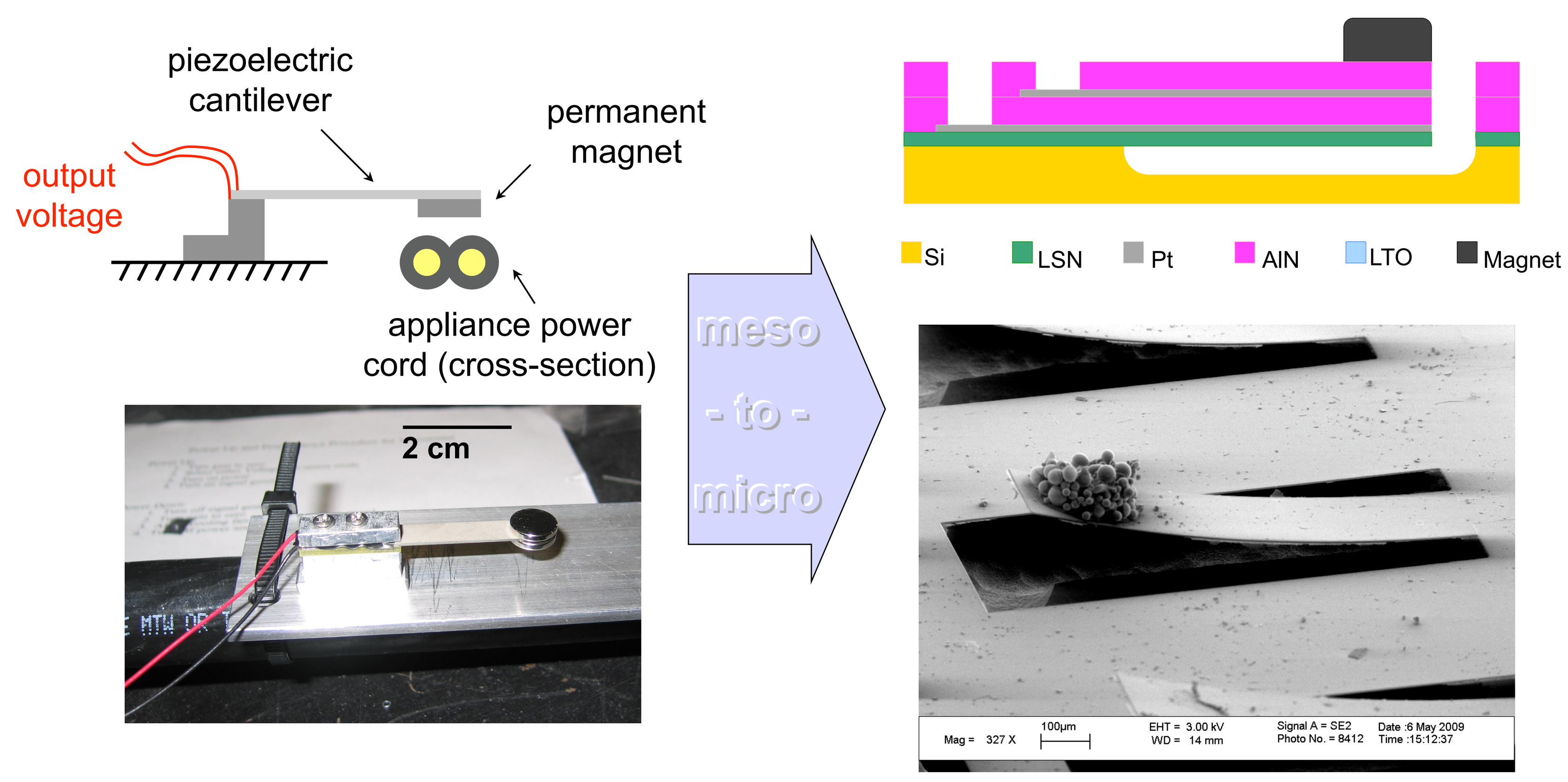
A MEMS AC Current Sensor for Residential and Commercial Electricity End-Use Monitoring

E.S. Leland, P. Minor, C.T. Sherman, Prof. P.K. Wright, Prof. R.M. White

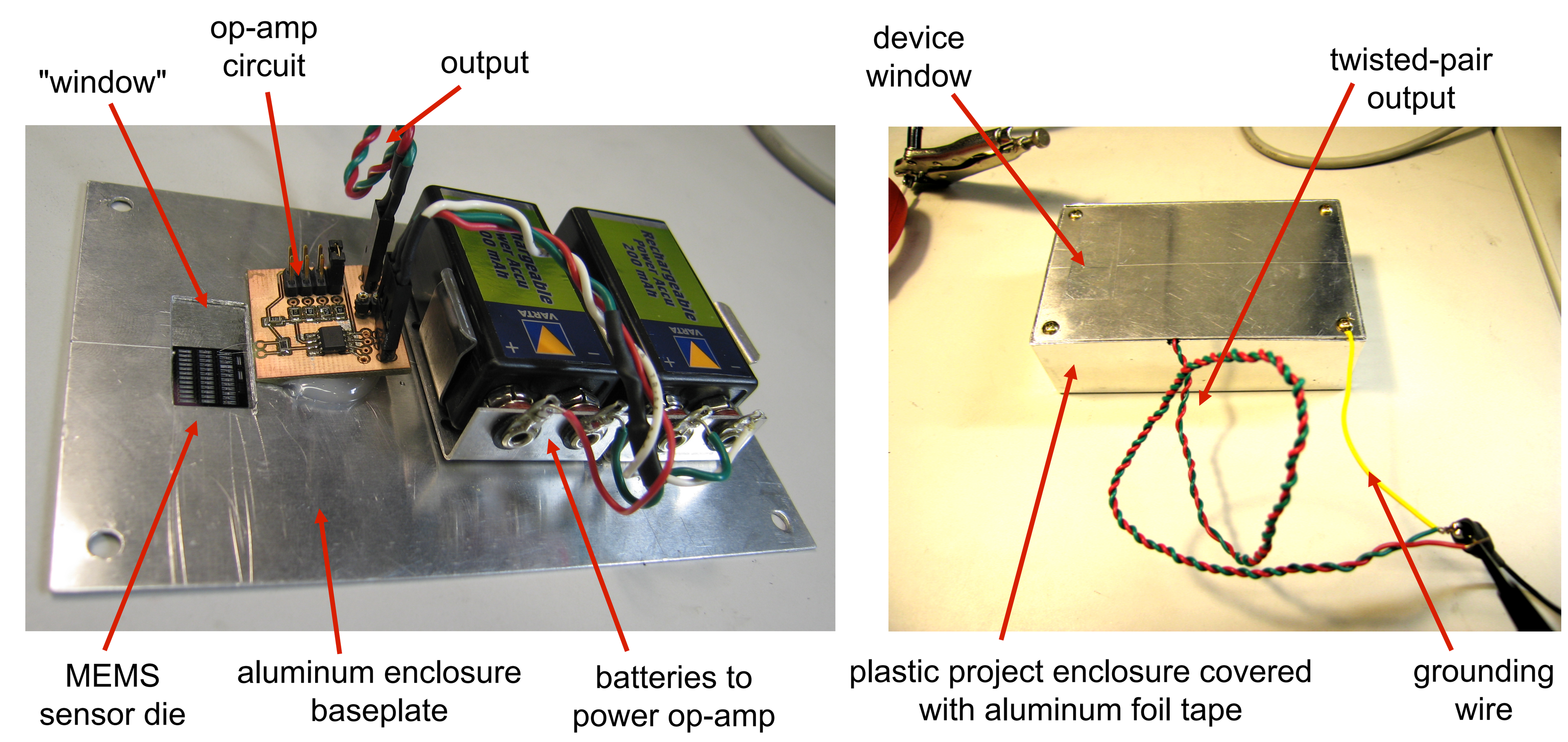
University of California, Berkeley

A passive, proximity-based sensor for AC electric current



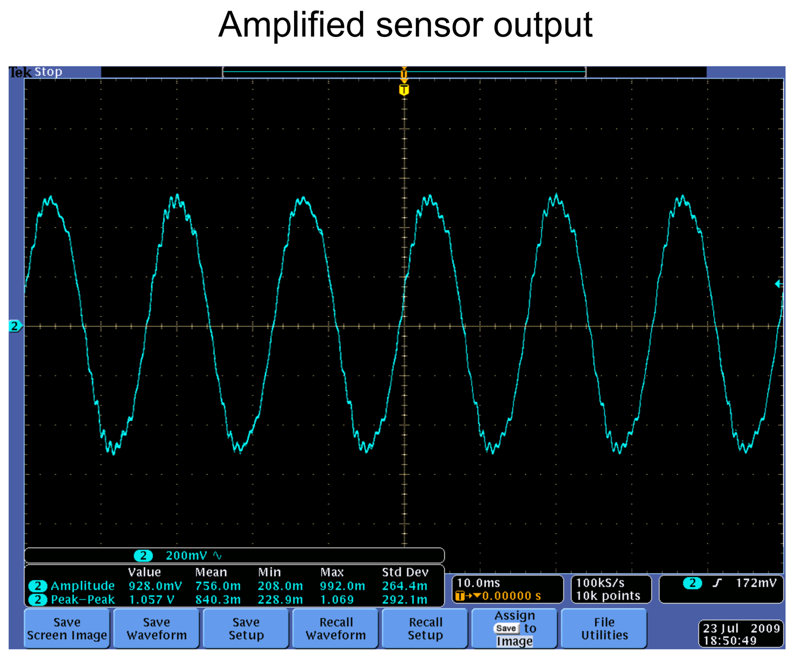
- The sensor consists of a permanent magnet mounted to the free end of a piezoelectric cantilever
- The magnet couples to the wire's magnetic field, deflecting the cantilever and producing a signal
- MEMS-scale prototypes have been successfully demonstrated using aluminum nitride as the piezoelectric material and dispenser-printed NdFeB-epoxy composite micromagnets

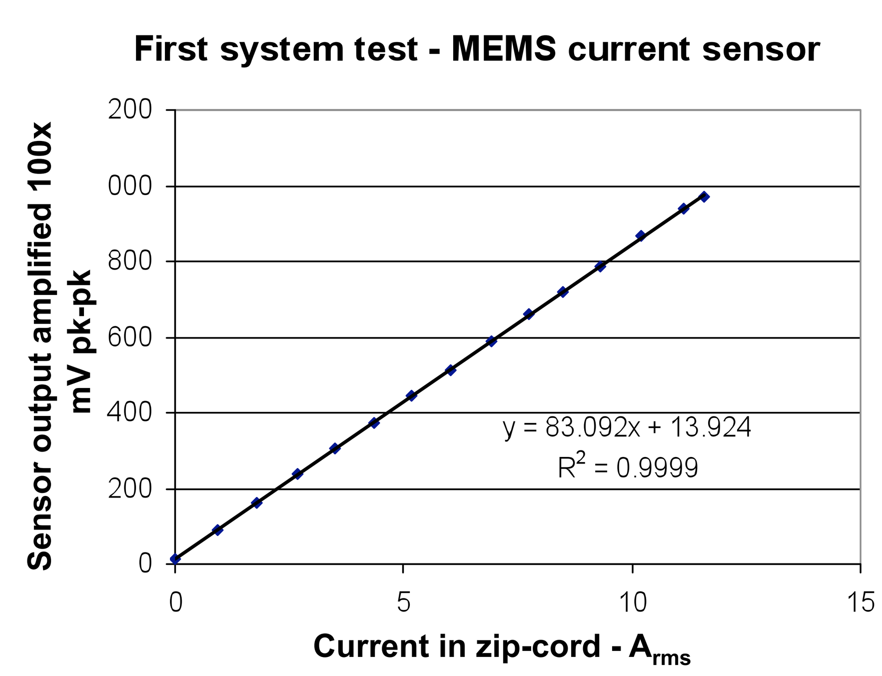
Assembling the test apparatus



- A TI OPA129 op-amp is used to amplify the MEMS sensor's signal
- The entire device is encased in a shielded enclosure to minimize electromagnetic interference
- The MEMS die sits in a "window" cut in the enclosure, separated from the wire to be measured by the thickness of aluminum foil tape (~25 microns)

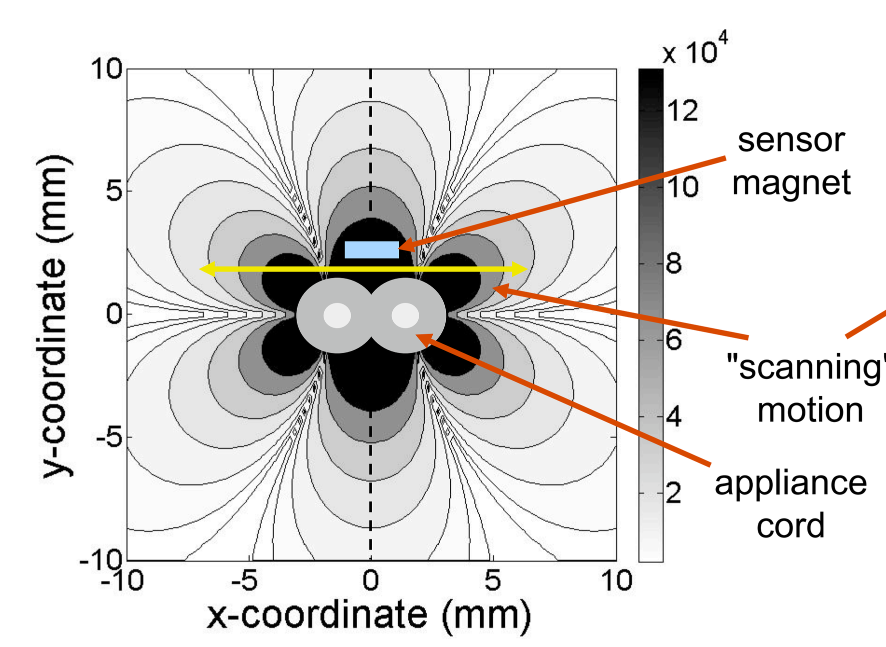
Preliminary test results show linear sensor behavior

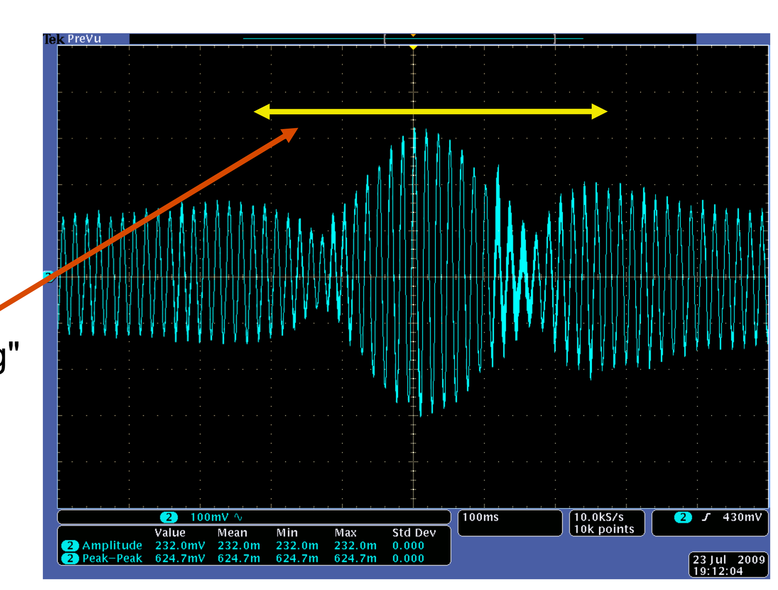




- Sensor response is highly linear measuring currents up to 11 A in a two-wire "zip-cord"
- The sensor's fundamental frequency of about 1.23 kHz is visible on top of the 60 Hz sensor signal
- Device sensitivity (unamplified) is approximately 0.3 mV/A

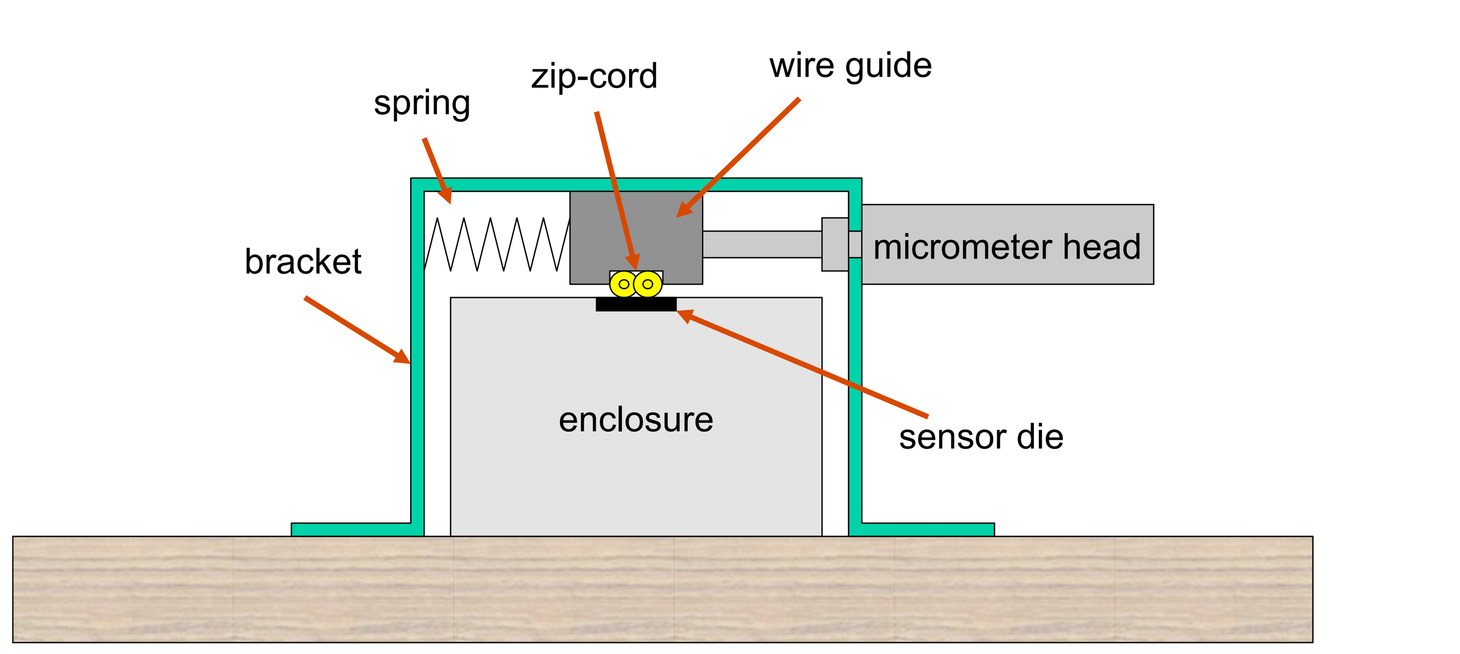
Test results confirm non-intuitive analytical models





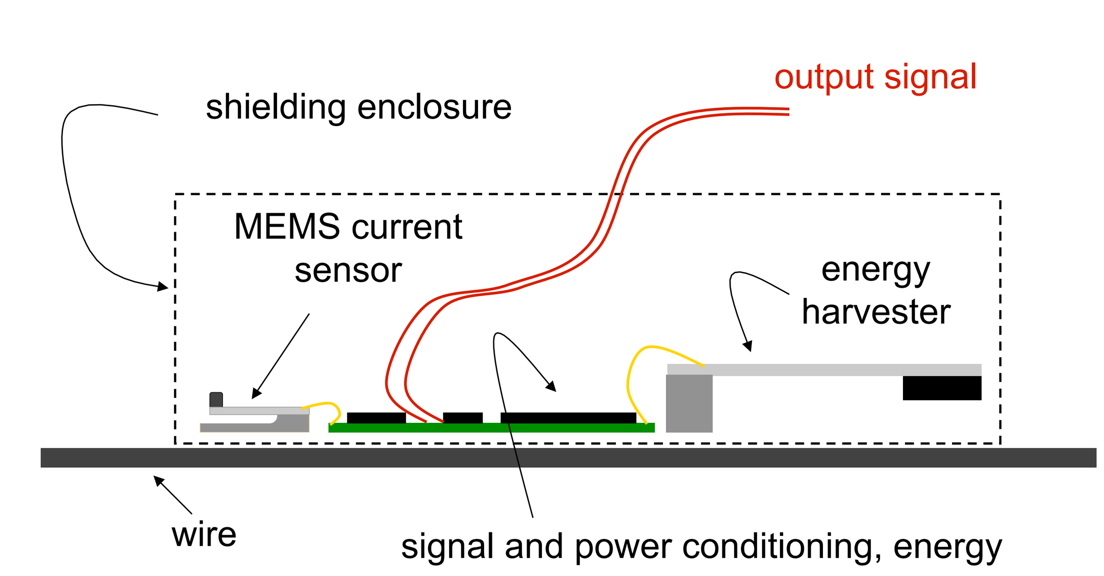
- The plot on the left shows the "force field" around a two-wire power cord. The darker regions indicate where the sensor's magnet will experience the greatest force. Adjacent dark regions are actually opposite in sign, which would result in a 180-degree phase shift in sensor output from one region to the next
- The oscilloscope output on the right shows the sensor's output as it is "scanned" over the power cord. These results clearly validate the theoretical model
- The phase indeed shifts between alternating regions, from 18-degrees lagging the AC current waveform to 162-degrees leading

Precise device characterization test plan



- A custom-designed bracket has been fabricated in the machine shop to allow precise positioning of the power cord relative to the sensor device. The "wire guide" component can be swapped out to accommodate different sizes and shapes of wire
- Different device designs (cantilever size, electrode configuration) will be tested against multiple gauges of single-wire and two-wire power cords
- Of particular interest are spatial sensitivity and minimum measurable current for each configuration

Work-in-progress: A self-powered current sensor demonstration device



- Combine MEMS sensor with an energy harvester employing the same design principles to create a truly self-powered, self-contained sensor package
- Energy harvested from the power cord will be stored in an on-board capacitor and used to run the sensor's op-amp circuit on a duty cycle

DR ETD Demand Response enabling technology development — UC Berkeley | CBE | BMI | CEC
BSAC
Ford
pier Public Interest Energy Research "Research Powers the Future"
BWRC
BMI Berkeley Manufacturing Institute