



## Mechanics/Machinery

### Miniature Piezoelectric Macro-Mass Balance

**This system can be used to verify the mass of multiple samples in pharmaceutical and food-processing applications.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Mass balances usually use a strain gauge that requires an impedance measurement and is susceptible to noise and thermal drift. A piezoelectric balance can be used to measure mass directly by monitoring the voltage developed across the piezoelectric balance, which is linear with weight or it can be used in resonance to produce a frequency change proportional to the mass change (see figure). The piezoelectric actuator/balance is swept in frequency through its fundamental resonance. If a small mass is added to the balance, the resonance frequency shifts down in proportion to the mass. By monitoring the frequency shift, the mass can be determined.

This design allows for two independent measurements of mass. Additionally, more than one sample can be verified because this invention allows for each sample to be transported away from the measuring device upon completion of the measurement, if required.

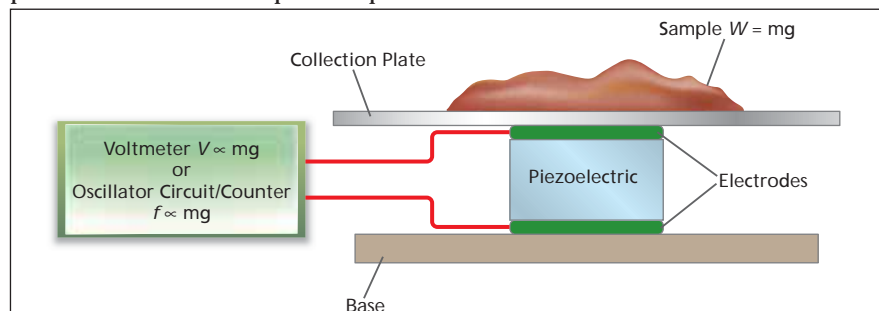
A piezoelectric actuator, or many piezoelectric actuators, was placed between the collection plate of the sampling system and the support structure. As the sample mass is added to the plate, the piezoelectrics are stressed, causing them to produce a voltage that is proportional to the mass and acceleration. In addition, a change in mass  $\Delta m$  pro-

duces a change in the resonance frequency with  $\Delta f$  proportional to  $\Delta m$ . In a microgravity environment, the spacecraft could be accelerated to produce a force on the piezoelectric actuator that would produce a voltage proportional to the mass and acceleration. Alternatively, the acceleration could be used to force the mass on the plate, and the inertial effects of the mass on the plate would produce a shift in the resonance frequency with the change in frequency related to the mass change.

Three prototypes of the mass balance mechanism were developed. These macro-mass balances each consist of a solid base and an APA 60 Cedrat flextensional piezoelectric actuator supporting a measuring plate. A similar structure with 3 APA 120 Cedrat flextensional piezoelectric actuators spaced equidis-

tantly at 120° supporting the plate and a softer macro balance with an APA 150 actuator/sensor were developed. These flextensional actuators were chosen because they increase the sensitivity of the actuator to stress, allow the piezoelectric to be pre-stressed, and the piezoelectric element is a stacked multilayer actuator, which has a considerably lower input impedance than a monolithic element that allows for common instruments (e.g., input impedance of 10 megohms) to measure the voltage without rapidly discharging the charge/voltage on the piezoelectric actuator.

*This work was done by Stewart Sherrit, Ashitey Trebi-Ollennu, Robert G. Bonitz, and Yoseph Bar-Cohen of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-47161*



There are **Two Methods of Measuring Mass**: A direct method uses a voltmeter; an indirect method uses an oscillator circuit/counter.

### Acoustic Liner for Turbomachinery Applications

**This acoustic liner reduces turbomachinery noise of aircraft.**

*John H. Glenn Research Center, Cleveland, Ohio*

The purpose of this innovation is to reduce aircraft noise in the communities surrounding airports by significantly attenuating the noise generated by the turbomachinery, and enhancing safety by providing a containment barrier for a blade failure. Acoustic liners are used in today's turbofan engines to reduce noise. The amount of noise re-

duction from an acoustic liner is a function of the treatment area, the liner design, and the material properties, and limited by the constraints of the nacelle or casement design. It is desirable to increase the effective area of the acoustic treatment to increase noise suppression. Modern turbofan engines use "wide-chord" rotor blades, which means

there is considerable treatment area available over the rotor tip.

Turbofan engines require containment over the rotors for protection from blade failure. Traditional methods use a material wrap such as Kevlar integrated with rub strips and sometimes metal layers (sandwiches). It is possible to substitute the soft rub-strip