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Original Paper

New Applications for Pressure Sensors

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Abstract

Design and fabrication of commercial electromechanical products are usually small in size but contain complicated electronic systems. Typically, these small electronic units are packaged in metal or plastic boxes to protect from physical damage and screen out electromagnetic interference. When repairing or calibrating the selected boxes, they should be opened carefully to prevent circuitry damage, avoid unwanted circuitry operation during repairs, and to protect the safety of technical personnel. We designed circuitry with pressure sensor to address these concerns. In our experiments, mechanical components were equipped with pressure sensors and installed under a few screws which kept constant pressure applied to the sensors. Opening of the box, i.e. removing the screws, reduces the pressure applied to the sensors. That instantly changes the value of resistance R_s *of the sensor. Changing* R_s*, in our safety circuitry disconnects power to the unit waiting to be repaired. To the contrary, in military or classified circuit applications, to prevent copying of the circuitry, changing* R_s *could cause destruction of the protected unit (Mil'shtein & Brooks, 2025).*

Keywords

Pressure Sensors, Circuit Protection, Intellectual Property Protection, Laser Safety

1. Introduction

To demonstrate the applications of the Pressure Sensor (PS) turning off any electronic system, and providing safety to technical personnel, we implemented our system into a large commercial product, the Soot Particle Aerosol Mass Spectrometer (SP-AMS) (Carbone et al., 2015; Willis et al., 2014; Drewnick et al., 2005), produced by Aerodyne Research Inc. Our study describes the design and testing of the PS circuit installed on this equipment during repair, maintenance, and tuning of the powerful laser in the SP-AMS.

The SP-AMS uses an intra-cavity infrared laser to vaporize soot and other refractory black carbon (rBC) containing aerosol particles so they can be ionized and detected by a Time of Flight (TOF) mass spectrometer (Drewnick et al., 2005; Jayne et al., 2000). Under normal conditions, the system is considered a class 1 laser, and is completely safe, as the laser is fully enclosed inside of an aluminum vacuum chamber. During maintenance periods, there is a potential for maintenance personnel to accidentally turn on the laser while the laser beam is not enclosed, which of course would be a safety hazard.

This design uses a simple low-cost pressure sensor and a transistor network, to always keep the laser off, unless certain conditions are met. This design is simple enough that it could be implemented for numerous other applications of circuitry protection.

2. Operation Conditions of Mass Spectrometer

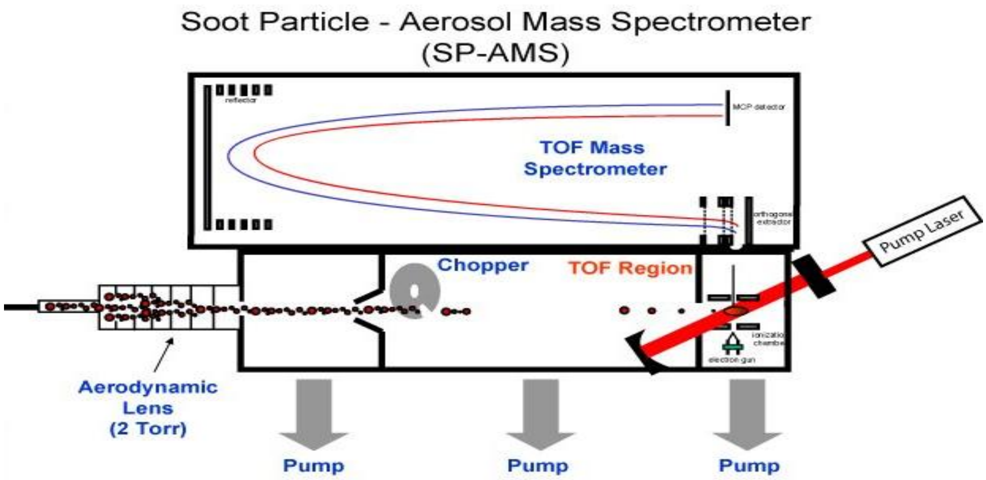

Figure 1. The Components of the SP-AMS from Side View

Figure 1 shows the turbo molecular pumps of the vacuum system (Drewnick et al., 2005; Jayne et al., 2000), the laser, coupling optics, and an imaging camera which is used to measure laser power. With our new circuit implemented, the vacuum system must be turned on and running at normal operating conditions, and both the laser and imaging camera must be mounted in place for the laser to turn on. The turbo pumps create a differentially pumped vacuum system, reaching an ultimate vacuum of 10^{-7} torr. When the inlet is opened, ambient aerosol particles enter the chamber and are focused through the TOF region toward the laser. When aerosols pass through the laser, any aerosol particles which absorb 1064nm light, which are black or brown carbon containing aerosols, and many metals, are flash vaporized. The vaporized aerosols are positively ionized via electron impact ionization, and then the ions are focused into the mass spectrometer via electric fields for detection.

There are three conditions that must be met for the SP-AMS laser to turn on. These conditions were chosen so that one can ensure the system is safe to turn on when all conditions are met. First, the vacuum system of the Aerosol Mass Spectrometer (AMS) (Willis et al., 2014; Drewnick et al., 2005; Jayne et al., 2000) must be fully operational. If the vacuum system is operational, that confirms that all aluminum flanges are in place to enclose the laser system. Second, the laser itself must be mounted onto its mounting plate. If the laser is mounted, one can ensure that it is pointing into the enclosed volume. Finally, the imaging camera must be mounted, ensuring that any small amount of excess light which exits the system via a neutral density filter is blocked by the imaging camera.

3. Pressure Sensor Testing

The pressure sensor chosen in this design is the SEN0297, a thin film pressure sensor from DF Robot. We compressed the pressure sensor between the imaging camera and the camera mount and measured the resistance of the sensor under different torques. Table 1 shows the results of this test. The sensor's measured resistance is inversely proportional to torque. The more force on the sensor, the less resistance.

Table 1. The Results of Resistance Measurements under Different Torques. 400 ohms was the Lowest Resistance Measured

Torque (in Lbs)	SEN0297 output (ohms)
0 (no camera mounted)	>60M
20	20k
30	15k
40	10k
50	5k
60	1k
70	770
80	660
90	475
100	400

4. The PS Circuit Design

The system uses two SEN0297 sensors, one mounted under the laser and one mounted under the camera. There is a signal which comes from the AMS pump control electronics when the vacuum system is operational, and that is being used to satisfy the first condition. When the vacuum system is operational, a relay opens inside of the vacuum control electronics. When that relay opens, it turns on a separate relay (RLY 1) in our circuit. Once RLY 1 is engaged, that completes this section of the circuit.

Sensor 1, mounted under the camera, is connected to the base of a 2N4401 NPN transistor (Q1). When Sensor 1 is compressed and has at least 60 in*lbs of torque applied, transistor Q1 turns on. The collector of Q1 is connected to the common pin of RLY 1. The normally open pin of RLY 1 prove is connected to the base of Q2. Sensor 2 is connected between the collector of Q2 and the enable pin of a laser diode driver module. When the vacuum system is operational, and both sensors are compressed with at least 60 in*lbs of torque, current flows and 5 volts is applied to the laser diode driver module, turning the laser driver on. If either sensor or RLY1 disengages, current flow stops, 0 volts is applied to the laser driver, and the laser is off.

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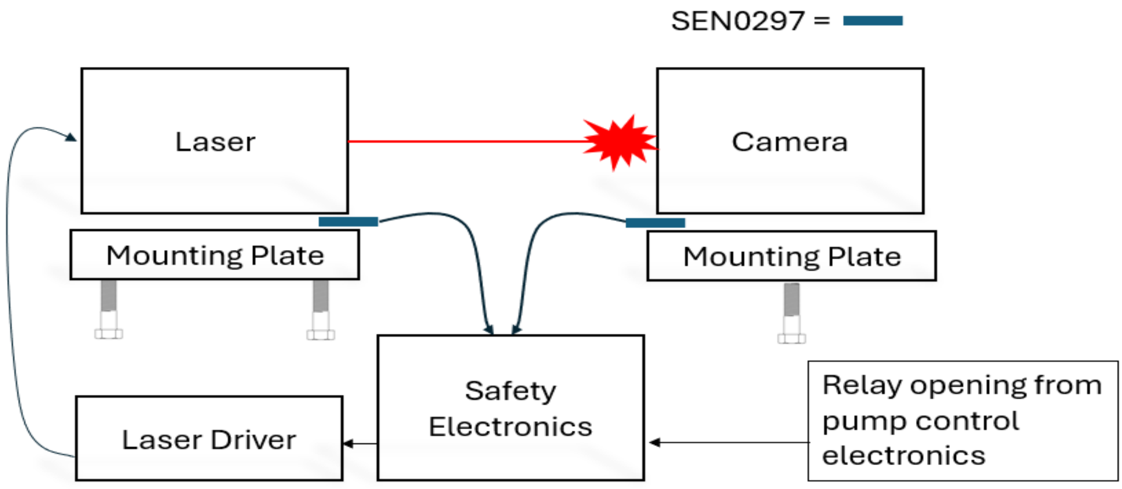

Figure 2. A Block Diagram of the Laser System and Safety Electronics

5. Conclusions

We developed a new method to provide safety to technical personnel while an electronic system is undergoing repair, maintenance or tuning (Mil'shtein & Brooks, 2025). The pressure sensor described above was used in initial experiments with the Aerodyne SP-AMS. This example shows a simple design of a pressure sensor circuit used in very complicated scientific equipment, to keep maintenance technicians safe. Further testing with more robust and/or more sensitive pressure sensors could be done to advance this design. The simplicity of the design allows it to be used in a large variety of electronic systems and allows for integration of almost any resistive pressure sensor one could choose. We do not plan to specify or limit what type of equipment our method could be used on; the applications are almost endless. Experimental proof of PS providing secure operational conditions was recorded while our circuit was implemented onto a very complicated Aerodyne Mass Spectrometer (SP-AMS).

Furthermore, we have proposed similar designs of PS circuits (Mil'shtein & Brooks, 2025) which can destroy any electronic system, when unauthorized attempts to open boxes are undertaken.

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