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Detecting hardware damage using a resistive grid

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ABSTRACT

Dropping a mobile phone or other electronic device can damage not only the enclosure but also internal components, e.g., batteries, printed circuit boards, etc. Sometimes the damage is only internal, with no apparent damage to the casing. Continued use of damaged internal components can result in further damage, e.g., continued use of a damaged USB bridge or battery can result in short circuits or explosions.

Per techniques of this disclosure, a variable resistive matrix is embedded within the casing of the electronic device. If the casing is dented or otherwise damaged, even invisibly, the resistance of corresponding rows and columns of the matrix changes enabling localization of the damage. Components near the damage can be disabled, and the user can be notified to take the device in for service.

KEYWORDS

- Damage localization
- Damage detection
- Resistive matrix
- Inertial motion unit (IMU)

BACKGROUND

Dropping a mobile device, tablet, computer, or other device can damage the physical enclosure and also the components inside. Both plastic and metal enclosures are susceptible to damage from drops. A device that is dropped may not show physical damage to the exterior casing but internal components may be damaged. Examples include battery damage; PCB cracks; solder joint cracks, e.g., on ball grid arrays (BGAs); damaged flex circuits; etc.

Continued use of devices with damaged internal components can result in further damage, e.g., continued use of a damaged USB bridge or battery can result in short circuits or explosions.

DESCRIPTION

This disclosure describes techniques to detect locations of physical damage to an electronic device. Further, based on internal layout schematics, components near the locations of damage are disabled to prevent further damage. For example, if the system detects that a laptop has been dropped which has caused a dent or puncture in the bottom lower portion of the device case near a battery cell, the operating system can disable power connections to the cell. In another example, if damage to a specific part of a PCB, such as a USB-C bridge, is detected, the operating system can disable power and input/output (IO) to the section to prevent short circuits.

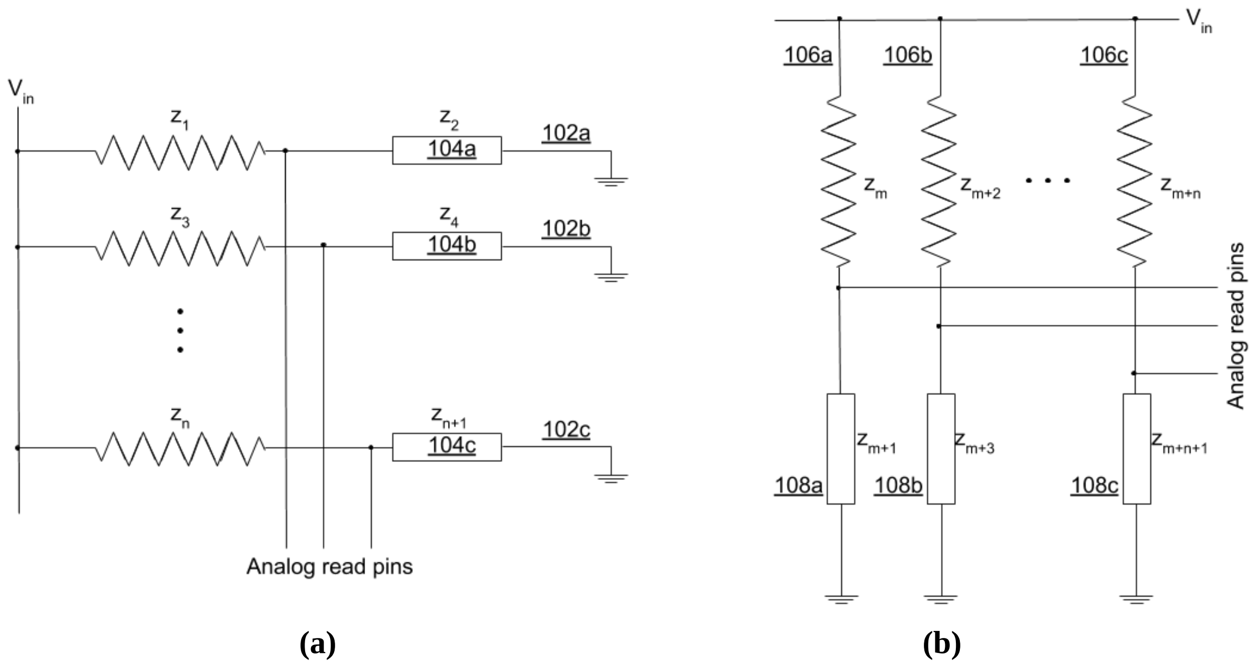

Fig. 1: Resistive grid to detect and localize damage

Fig. 1 illustrates a variable resistive grid or matrix that is embedded in the casing of an electronic device, e.g., the top, the sides, or the d-panel of a laptop casing, to detect and localize damage to the device. The resistive grid includes an X-component (Fig. 1a) and a Y-component

(Fig. 1b). The X-component includes closely-spaced, horizontal bands (102a-c), themselves comprising resistive strips (104a-c) fed by an input voltage (V_{in}) and connected to resistors (z_1, z_2, …, z_n) of fixed and known values. Similarly, the Y-component includes closely-spaced, vertical bands (106a-c), themselves including resistive strips (108a-c) fed by the input voltage (V_{in}) and connected to resistors (z_{m+1}, z_{m+2}, …, z_{m+n}) of fixed and known values.

The X and Y components of the resistive grid are overlaid, e.g., placed over each other. The resistive strips change resistance as the material of the casing stretches, e.g., the resistive strips effectively function as stretch sensors. The known, fixed resistors are surface mounted (SMD). The input voltage being divided between the fixed resistor and the resistive strip, a change in the resistance of the resistive strip causes a change in the voltage at the junction of the resistive strip and the fixed resistor. The junction of the resistive strip and the fixed resistor is connected to an analog read pin that reads the stretch value by measuring the voltage at the junction.

If any part of the casing is dented or damaged, the resistance of a specific row-column pair of the matrix changes relatively more than surrounding areas, enabling detection of the damage and the location of impact. Based on a schematic of the internal layout of the device, components that are near the area of impact are identified. If the components are determined to be damaged, or if the likelihood of damage to the component is high, or if the risk of further damage is high, then the component can be shut down and the user can be notified to take the device in for service.

The resistance measurement occurs independently at every constituent band of the vertical and horizontal sections of the matrix. If a certain point, e.g., an intersection of a horizontal and a vertical band, is damaged and the strips are stretched the most in that location, a controller determines the point by finding the X-band and the Y-band with the greatest stretches. This is similar to the mechanism used in keyboards to determine the key that is being pressed.

Stretch thresholds and tolerances are tunable. For example, an alert can be set for stretch values that exceed a certain threshold, such that damage at multiple locations can be detected.

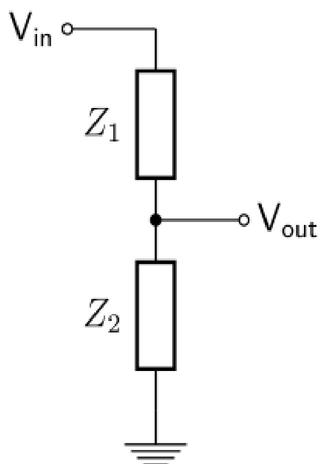

Fig. 2: Voltage divider included within a band of the resistive matrix

Fig. 2 illustrates a voltage divider included within a band of the resistive matrix. The input voltage V_{in} is applied to a series circuit comprising a fixed, known impedance Z_1 (with no reactance) and a known, calibrated resistive strip Z_2. The output tap V_{out} is the analog pin that a microcontroller reads to determine the stretch based on the change in resistance. The resolution of an analog-to-digital converter at the front-end of the microcontroller determines the output range. For example, a 10-bit analog-to-digital converter (ADC) provides a range of [0, 1023] to represent the voltage range 0 through V_{in}.

In addition to the resistive matrix, damage detection can be augmented by readings from an on-board inertial measurement unit (IMU). IMUs, which can measure sudden acceleration or jerks, can detect drops and help eliminate false positives. In addition, IMU signals can be processed by a binary-classifying machine learner to determine if the IMU signals are indicative of the device being dropped.

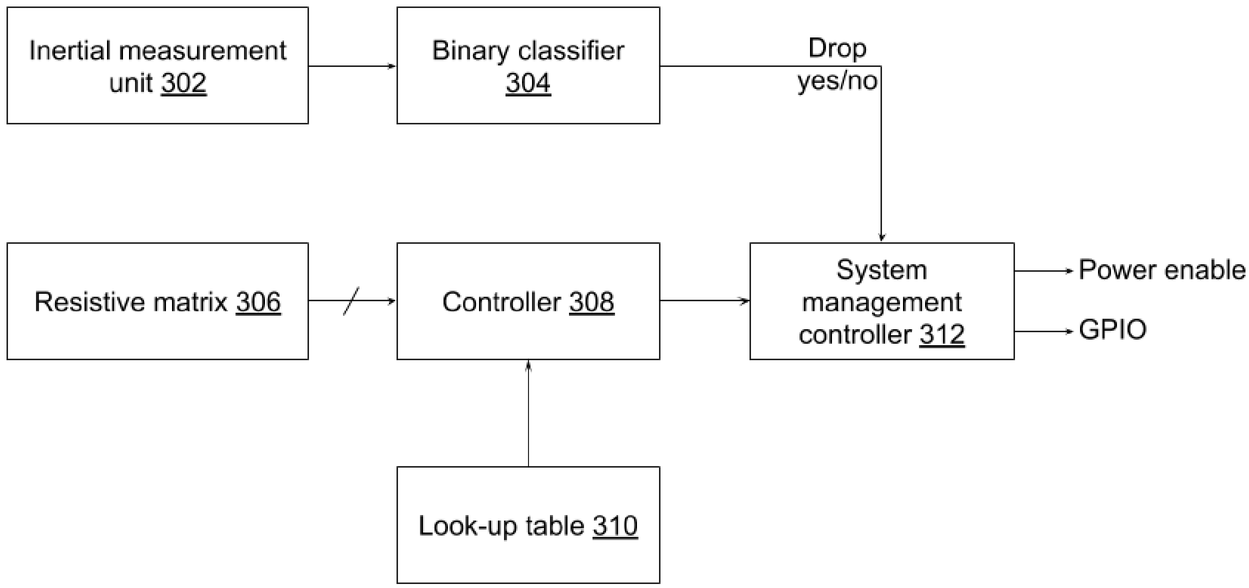

Fig. 3: Damage localization using a resistive matrix and IMU readings

Fig. 3 illustrates damage localization using a combination of a resistive matrix embedded in the device casing and readings from an on-board inertial measurement unit, per techniques of this disclosure. An IMU (302) provides motion data regarding the device, e.g., velocity, acceleration, etc.to a binary classifier (304), which can be a machine learning model. The binary classifier analyzes the motion data to determine if the device experienced a physical drop, and provides the determination (Drop: Yes/No) to a system management controller (312).

The system management controller can either be a dedicated chip or can be integrated with the CPU as a system-on-chip. The resistive matrix (306) and controller (308) determine the location of the damage, if any, to the device, as explained before. The controller uses the (x,y) location of the damage as a key to a look-up table (310) that includes the locations of the internal components of the electronic device to identify components that may have suffered damage.

The controller provides a list of potentially damaged components to the system management controller, which combines the controller output with the determination of the binary classifier to take action as necessary. Examples of system management controller actions include sending power enable/disable signals to potentially damaged components to shut down such components or their subsystems. Other example actions can be to check sense-resistor values: a higher-than-expected current flow is indicative of a short circuit, causing the activation of protection functions defined in the system management controller. These protection functions can send GPIO commands, or change the PMIC rail outputs or control settings to disable power to the damaged component(s).

The techniques described herein enable more informative hardware diagnostics. The location of the drop, the damaged components, the shut-off components, etc. can inform the repairability of the device, what repairs are needed, and what type of service center the device is to be sent to, without having to open the device. The techniques can also provide insight into how much unexpected or rough handling a product went through prior to its failure.

Example: Battery cell damage

Larger phones, tablets, and notebook computers may have multiple cells in their battery pack. It is possible to drop and damage a cell if the dent pushes through the cell itself. It is also possible to drop a device onto a sharp object and actually puncture the cell. In this case, the damage is likely to be identifiable. If the battery management system (BMS) has a switch, e.g., a field-effect transistor, for each cell, the techniques of this disclosure communicate with the BMS to open the FET channel to the damaged cell. The techniques alert the user that there is damage to the battery, and request the user to take the device in for service. Since the techniques enable the removal of battery cells soon after damage, the risks of device overheating and/or explosion are reduced.

Example: Damage to a printed circuit board, a subsystem thereof, or to a charging or IO port

It is possible for a dent, puncture, or crack to damage a specific part of a PCB. It is possible for this damage to be entirely internal and not show substantially on the device exterior. The techniques described herein can determine the location of the damage and of nearby components. Traces in the area that have sense resistors are determined. The sense-resistor values are read to determine if there is a short circuit. In reading the sense-resistor values, the damaged area may be exercised. Alternately, a wait time can be introduced until the operating system enters a state that exercises the damaged area before reading the sense resistors. An example of this may be damage to the Wi-Fi/Bluetooth chip but not to the PCB hosting the chip. Localized damage, including shorts if any, is detected, and the power rail to the component is disabled. The user receives a report that Wi-Fi/Bluetooth functionality has been disabled due to physical damage and is requested to get the device serviced.

CONCLUSION

Per techniques of this disclosure, a variable resistive matrix is embedded within the casing of the electronic device. If the casing is dented or otherwise damaged, even invisibly, the resistance of corresponding rows and columns of the matrix changes enabling localization of the damage. Components near the damage can be disabled, and the user can be notified to take the device in for service.