Optical Anti-theft Power Cord Technical Test Results

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1. Basic Concepts

The Anti-Theft Power Cord (ATPC) prevents theft of electrically powered apparatus by detecting the physical removal of the equipment's power plug from any electrical power outlet and setting an alarm state that must be disarmed in order for the equipment to operate. This system is designed to 1) be extremely difficult to defeat during theft, 2) be very immune to creating false alarms, and 3) go unnoticed by the owner during normal operation.

The ATPC contains a standard 3-prong plug equipped with an InfraRed (IR) reflection sensor set in the ground prong that detects the plug's removal from any socket. The sensor consists of an IR light-emitting diode (LED) and a phototransistor. The phototransistor converts the reflected output of the IR LED into an electrical current, which is then directed to the ___ unit. As the sensor set is removed from the socket, the reflectivity of the socket surface changes and causes the output level of the phototransistor to vary in correspondence to the changes in the magnitude of reflected light, as illustrated Figure 1. While the plug is being removed, the changes in the output of the phototransistor will trigger an alarm.

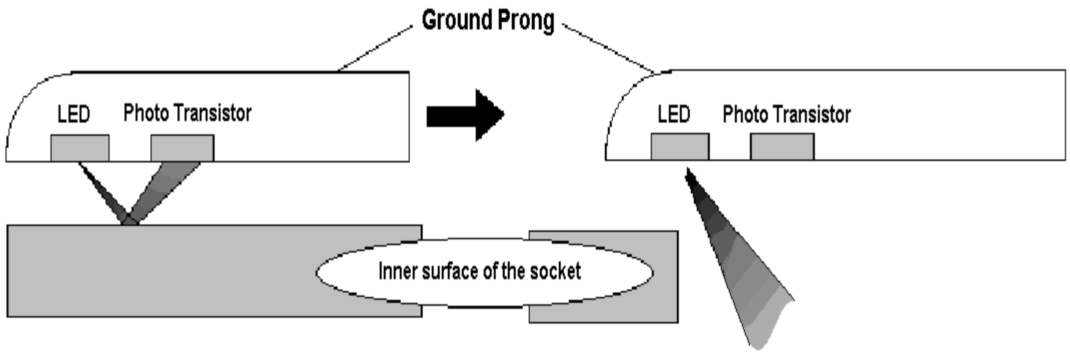

Figure 1: As the prong is removed from the socket, the optical sensor will no longer detect the reflection from the surface.

In this section, we describe the test results. Details shown here are unknown to the regular user and are only available in password-protected section of the antitheft power cord software. They are presented to demonstrate the wide variety of tests to which the system has been subjected.

2. Self-Calibration and Alarm Tests for Different Sockets

Every individual power socket as well as every socket design has different internal optical characteristics. Hence the key to this operation is the embedded software in the smart sensor that self-calibrates to any socket. When the sensor plug is inserted into the socket, the system automatically measures the unique reflectivity of the given socket and establishes its reference point. This calibration is invisible to the user. After a short calibration period (less than one minute) the system can be put in the alarm mode.

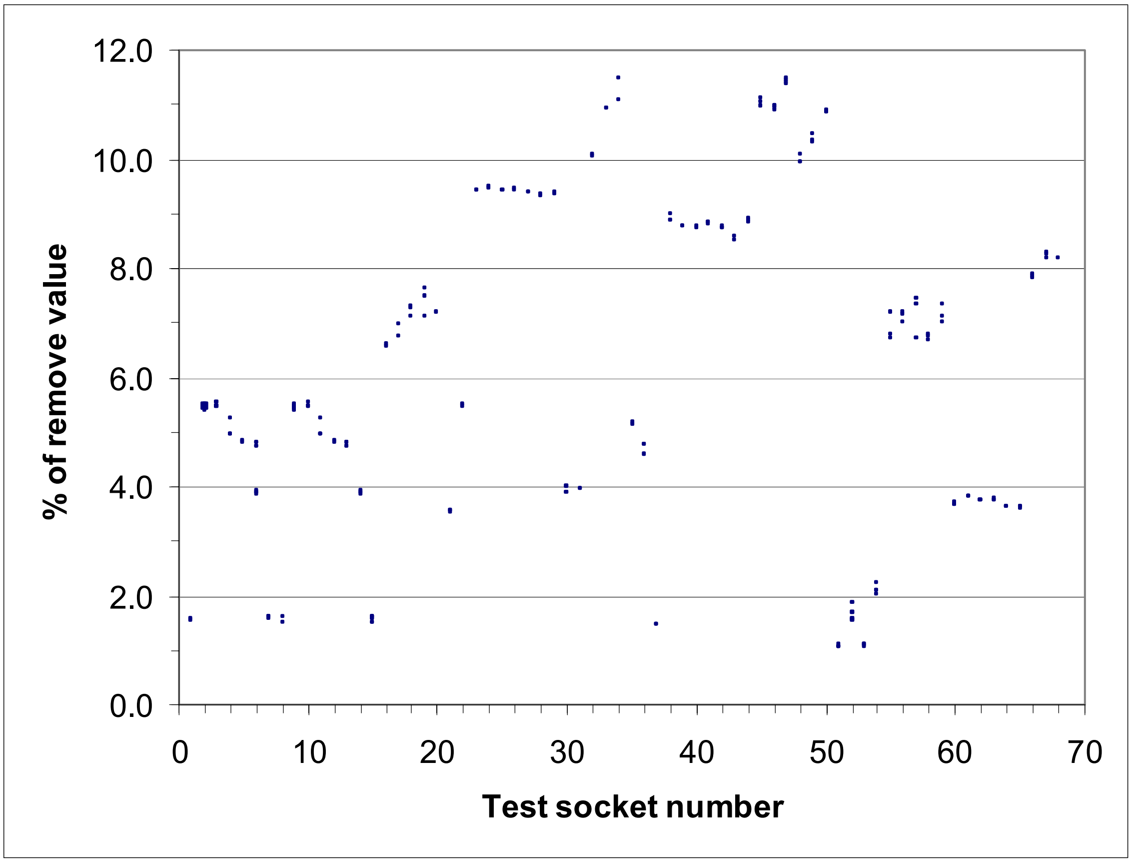

Figure 2: Range of inserted optical sensor values for with tested sockets relative to the removal state.

Figure 2 shows the range of calibration values for a test sample of 68 different sockets of various designs. Each socket was measured many times; the figure shows the variations with each given socket. Sockets measured ranged from wall sockets, power bars, to simple extension cords. As different coloured sockets had different optical variations, our test sockets covered common colours ranging from black to white, and less common colours including dark brown and bright red. In every case, the system self-calibrated to the socket, detected the removal of the plug, and triggered the alarm.

3. Alarm Activation During Removal

Section 2 showed that the anti theft power cord can easily adjust to a wide range of sockets and detect removal. In all socket settings, the detection algorithm has proven reliable. As reflectivity varies considerably along the path between full insertion and complete removal, the sensor also detects changes (as small as a few millimetres) in sensor position within the socket. Figures 3 and 4 compare two sample variations in sensor output in relation to the depth of insertion of the plug in tests performed on the wide range of power bars and wall sockets.

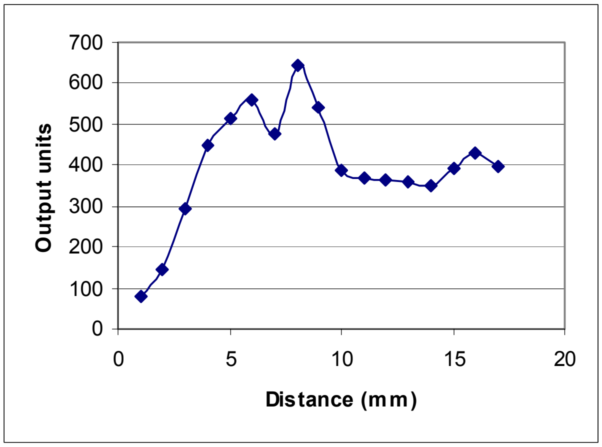

Figure 3: Sensor output vs depth in socket sample 1 with high signal when fully inserted (17 mm)

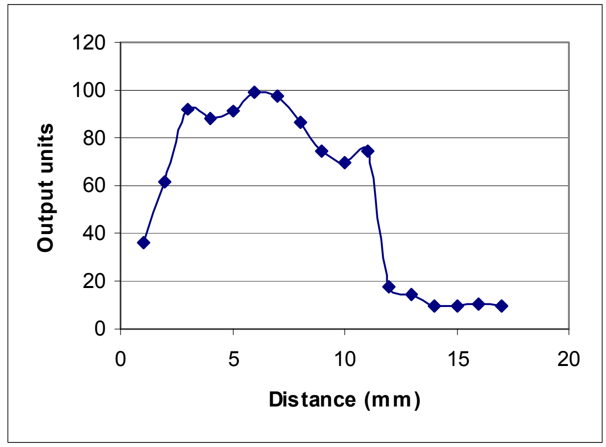

Figure 4: Sensor output vs depth in socket sample 2 with low signal when fully inserted.

These measurements were made using a precise test system of lab sample sockets and only one prototype ATPC. These tests show that significant changes occur while the sensor is in the process of being removed from the socket. These show significant decreases and increases in levels of reflectivity before removal, and a large decrease well before removal from the socket. Since only a few percentage change is needed for detection, the alarm state is activated while the sensor is still within the socket but is in the process of being removed; this means that there is nothing that can be done to prevent the detection of this state while the plug is within the socket. Figures 3 and 4 show the increases and decreases in reflectivity levels in both high output and low output sockets. Regardless of the level of output for a fully inserted plug, the alarm state is fully activated before the plug is removed.

4. Speed of Plug Removal Tests

Could a tricky thief defeat the system by either rapidly or slowly removing the plug? The ATPC software was designed with this in mind. The system measures socket parameters at such a high rate that rapid removal cannot avoid the detection of changes within the socket as noted in section 3. Tests of removal at speeds below 0.3 second always resulted in alarm activation. Even if faster removal were possible, the alarm would activate upon full removal.

As Figure 2 shows, even a particular socket type has considerable variation of optical parameters at full insertion; it is therefore not possible to replicate the conditions within the socket to fool the sensor. (I don't like this sentence, it implies that there is opportunity for fooling the sensor if the exact optical parameter were available, makes no sense as there would never be time, anyway)

What about very slow removal? As Figures 3 and 4 show, variation of position within a socket is well above the activation level of several percents. Slow removal simply results in an earlier activation of the alarm state while the plug is still within the socket. Removal times of less than 1mm per minute still resulted in activation. At that rate, it requires more than 20 minutes to remove the plug from the socket.

5. Stability with Time

The anti-theft smart sensor system recalibrates itself on a regular basis so common conditions like temperature changes will not cause false alarms.

6. Stability with Powercord Movement

While the ATPC must deter unauthorized removal, it must not be so sensitive that common movements of the power cord other than removal result in alarm states. A set of "wiggle tests" was performed on all socket types where the plug was forcefully moved to the extremes in the socket in all directions without starting to pull the plug out. Measurement of the sensor and the resulting changes during this wiggle operation was noted. In practice, if the plug is not pulled from the socket, the 3 electrical prongs significantly limit the plug movement. Signal changes of 0.1%-3.5% were noted. These are well below the threshold for alarm states. No alarm states resulted from these tests.

7. Conclusions

The anti-theft powercord has been tested over a wide range of sockets and operating conditions. In all cases it has displayed self-calibration to sockets, stability during normal operation, and detection of alarms during removal.