LOW VOLTAGE
THE INCOMPETENT IGNITION SOURCE
DISPELLING THE MYTH

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ABSTRACT

The present, widely held belief is that products powered by “low voltage” (typically less than 24V) electrical energy are incapable of starting fires since there exists an insufficient level of energy to produce sufficient heat and ignition. By analyzing commonly implemented electronic circuits found in a variety if household electronic devices, manufactured using standard wave solder or surface mount technology (SMT) processes, single point failures will be discussed and induced that demonstrate ignition at low voltages, or more precisely, low power levels. Through the application of a thoughtfully designed series of experiments, this paper will demonstrate that voltages as low as 3VDC and power levels in the 3W range or less, are entirely capable of igniting proximate fuel packages sufficient to produce sustained fire in a variety of electronic assemblies.

INTRODUCTION

In the process of investigating a fire scene, fire investigators and forensic engineers routinely harvest, and subsequently inspect in laboratories, a wide variety of electrical appliances, larger gage branch circuit wires and conductors, and electronic assemblies that have the potential to be competent ignition sources by virtue of the perceived “relatively high” energy required to operate, or that is stored within, the devices [supply voltage, lithium ion batteries, capacitors, etc]. The norm for investigators is to focus primarily on such products as potential ignition sources due to a common, yet unsubstantiated belief that only products that can produce ignition sources with higher heat flux are capable of producing sufficient heat energy to ignite nearby combustibles or fuel packages.

Frankly, until the writing of this paper, investigators have generally been trained to search for only the more dramatic, obvious, physical signs of electrical arcing [i.e., beads on heavier gage conductors] and changes in mass resulting from high resistance heating. Investigators have generally equated these phenomena to higher wattage devices, larger consumer appliances, or wiring carrying significant current. This behavior is understandable as no definitive science, testing, or training has yet been offered to the fire investigation community that would familiarize investigators with the more subtle failure modes and fire causes of, and within, small scale electronic assemblies [lower power devices such as remote controls, key fobs, microprocessor operated devices, battery operated devices, and other fine pitch – high density electronic devices].

Furthermore, electronic assemblies are usually packaged within plastic or metal enclosures that sometimes prevent, if the fire did not completely breach the enclosure, the on-scene investigator or engineer from easily observing all of the relevant interior fire damage of the product more closely during the scene processing. Consequently, the contribution to the fire origination by the electronic device or assembly is not always apparent on scene, or even in the lab, and such products are routinely overlooked and dismissed.

The watt/density thresholds for the production of localized heating sufficient to ignite available and adjacent fuel packages [especially those with high heat release rates] presently relied upon by investigators prove to be accurate with respect to “larger” current draw appliances, electronic assemblies, and the corresponding fire development within compartments. However, these thresholds do not necessarily apply to, or proportionally/mathematically reduce to, the smaller world of microelectronic assemblies, sub-assemblies, and circuit boards operating at power levels that are orders of magnitude lower than those measured on typical branch circuit wiring or in larger appliances. Simply, a different phenomenon or mechanism – one that is more electro-chemical in nature on a microscopic scale - for fire development can and does occur at the circuit board level and small–scale microelectronics level.

OBJECTIVE

It is the objective of this paper to broaden the investigator’s approach to the consideration of the area of interest and the origin, and the consideration of products that have formerly been left behind or discarded as being incapable of creating ignition and developing sustainable combustion and fire. This paper will encourage the fire investigator to consider, as possible fire causes, electronic assemblies, circuit boards consisting of fine-pitch components, and wiring that operate at energy levels formerly believed to be “too low” to be competent ignition sources. These products are not only capable of producing localized ignition and sustaining flame, but, depending on how they are connected to remote electronic/electrical products, can also produce fires that are remote or distant from the controlling product, providing an additional challenge with respect to the identification of root cause.

Products of particular interest include devices comprised of high component density, fine-pitch printed circuit boards and microelectronic assemblies operating at a wide range of low voltage and power levels, and even button cell battery-powered handheld devices. They can be products that provide voltages on the order of millivolts, or, supply digital control signals to remote devices connected to a computer network, distributed audio systems, telecommunications systems, etc.

Finally, this paper will provide theoretical, empirical, and illustrative evidence of the electro-chemical reaction that can and does occur on circuit board assemblies, and that is capable of producing ignition and fire at wattage levels as low as 2 to 3 watts total power.

A DISCUSSION ON PRINTED CIRCUIT BOARDS

Printed circuit boards (PCBs) are a miracle of modern manufacturing that have afforded the progressive miniaturization of virtually all of the consumer and industrial electronics that we all use and enjoy today. Before PCB’s, complex electronic assemblies were manufactured using relatively large-scale wire-wrap or point-to-point wiring techniques. Individual components were simply interconnected using discrete wires across wide spacings (distance between connections), creating a mind-boggling maze of what appeared to be randomly routed and connected wires.

Wire wrapping was developed by, and utilized extensively in, the high reliability aerospace and telecommunications industries, but subsequently found its way into low cost, mass-produced commercial and consumer electronics. For example, the guidance computer for the Apollo command module, designed in the mid 60's, was assembled entirely using wire wrap manufacturing processes. Using the wire-wrap technique, circuit connections were established via the physical wrapping of individual, insulated wires to conductive posts to establish a robust, gas-tight electro-mechanical connection (Figure 1).

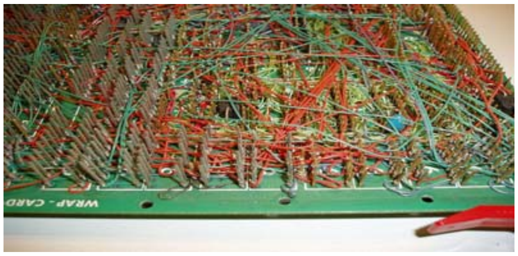

Figure 1: Wire-Wrap Backplane from 1977 Vintage Z80 Computer

Although wire wrapping is an extremely reliable method for which to manufacture various circuits and electronic devices, it is also extremely expensive, manually intensive, and consumes a vast amount of topographical real estate on the substrate board. Furthermore, wire-wrapping can no longer support the high frequencies and data transfer rates of today's digital products due to the extensive length of the wires, giving rise to critical signal race conditions [a phenomena where a particular signal is incorrectly received my a microprocessor before another signal is detected].

However, as previously mentioned wire wrapping was, and still is, arguably the most reliable method of electronic component interconnection for several key reasons. Compared to small-scale printed circuit boards, wire-wrapped connections are less prone to failure [failure effects] from:

1. mechanical and physical stresses
2. thermal excursions
3. **chemical and contamination effects**

It is failure effect number 3, the *chemical and contamination effects* on printed circuit boards, on which this paper focuses its attention, especially with respect to lower energy levels and fire causation.

CONTAMINATION EFFECTS ON PRINTED CIRCUIT BOARDS – A REAL FIRE CAUSE: *What happens to electronic hardware when an electrical short occurs between leads or conductors on electronic hardware in the field?*

The presence of ionic and organic residue, byproducts of the electronic fabrication and assembly process, and pollution from the operating environment, create electrical shorts that can cause a device to malfunction, shutdown, or worse, catch fire. This corrosive residue combines with moisture (humidity is sufficient) to create a unique thermal event on the board surface that can cause even UL94V-0 flame-rated FR-4 laminate to burn and catch fire. Of particular concern, is that this is a problem that appears to be increasing in magnitude in newer consumer electronics that are produced under restrictive and evolving ROHS requirements.

The ROHS requirements are driving the reduction of halides (primarily bromine) as flame-retardants due to carcinogenic properties. These boards, being halide-free, now demonstrate an increased propensity to burn at much lower voltages. Figure 2 shows that a mere 3.3 volts powering the microprocessor by a button cell battery is sufficient to create sustained ignition. Figures 4 and 5 show, respectively, 12 volt and 9 volt battery powered fires. Ignition originating in such devices can sustain flame that can propagate completely along the copper traces of differing voltage, ultimately igniting the halide-reduced plastic enclosures.

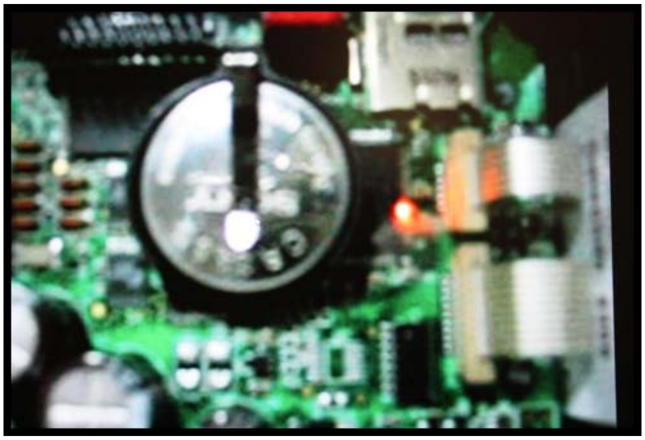

Figure 2: Circuit Board Powered by 3.3V Battery - Burned FR4 PCB shown before evolution to full Involvement (flame seen at right of battery)

Babrauskas reports "much less than 24 V is sufficient to cause arc tracking."[1] Bernstein reports that arc tracking between wire conductors can occur in 6 volt battery circuits, provided the batteries have sufficient current capacity to sustain the arc.[2] It is important to note that typical A/V remote controls are powered by as little as 3 volts, or as much as 9 volts. Munson demonstrates arc tracking, and board ignition, at voltage levels as low as 3 volts dc (<3 watts total power) generated from a button cell battery between adjacent copper traces. Munson also demonstrates that ignition of printed circuit boards is not just a surface phenomenon, and can occur within circuit board laminates and beneath layers of protective conformal coat.

The actual mechanism that creates board ignition, specifically low voltage board ignition, follows. As the circuit board is exposed to heavy no clean flux during the soldering process, and the flux is not fully heat activated as a result of a process that is not in full statistical control, the optimum condition for dendritic growth (the unintended short circuit) occurs. The three elements needed for dendritic growth are: contamination, moisture, and bias.

As the dendritic short forms across adjacent circuit paths, the FR-4 board material is thermally overstressed. In fact, the first dendrite to grow across the circuit paths can complete the short circuit, only to be of insufficient current carrying capacity to sustain the power for any length of time. In some instances, this causes the dendrite to fuse open electrically, where a second or third more robust dendrite can grow until one of sufficient size exists that can that can ultimately carry sufficient current to overheat the board and ignite the available weak organic acids. The orange glow seen in Figure 2 is the result of the copper traces burning to the ground plane, the fire is consuming the copper and the board epoxy. This fire will continue to burn, consuming available contamination (i.e. flux residue), copper, and board epoxy as it moves along the board surface. For reference, the flux residue level (weak organic acid) found on this assembly was measured at an incredibly high 174 ug/in^2, with the maximum safe level being 25 ug/in^2 or less. Further complicating the situation is that today's circuit boards are populated using fluxes that contain no rosin (varnish). It was the rosin that historically encapsulated the hardware and board residues, making them benign to the aforementioned conditions and risks optimum for dendritic growth.

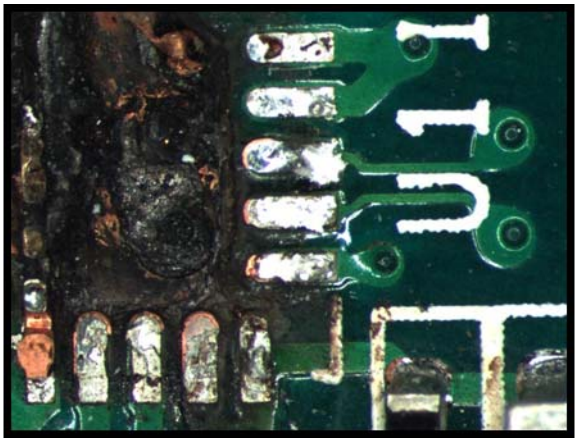

Figure 3: Circuit Board Powered by 3.3V Battery - Burned FR4 PCB Section

The electronic controller shown in Figure 4 was exposed to a moisture rich operational environment and had high flux residues on the 12 volt power supply rails and relay circuits. This particular board was depowered before full fire involvement and destruction occurred. The flux residue was measured at an off-the-scale level of 2993 ug/in^2 (with the requirement being less than 150 ug/in^2 for these spacings and voltages) and was the result of a selective soldering process on the through hole components (a somewhat manual, and difficult to control process that can leave behind high levels of residual contamination).

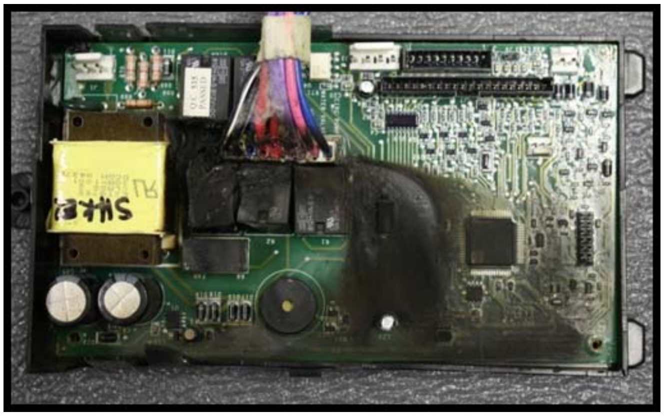

Figure 4: Circuit Board Powered by 12V Battery - Burned FR4 PCB - Depowered

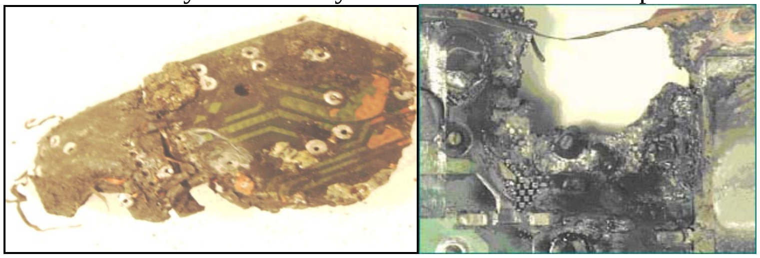

Figure 5: Circuit Board Powered by 9V Battery - Burned FR4 PCB

Ionic contamination is not only a problem across circuit board traces, but atop small-scale surface mount components attached to the circuit board as well (Figure 6). The following photos show before and after images of dendritic growth on the surface of a chip capacitor held between electrodes. The 0805 size capacitor was attached via a marginal soldering process and was biased with 2.5 volts in application. The component was cleaned post manufacturing, albeit, not very well. A short 34 seconds later, the dendrite seen in the right photo completely grew once bias was applied and completely shorted the two electrodes together, causing the device to fail.

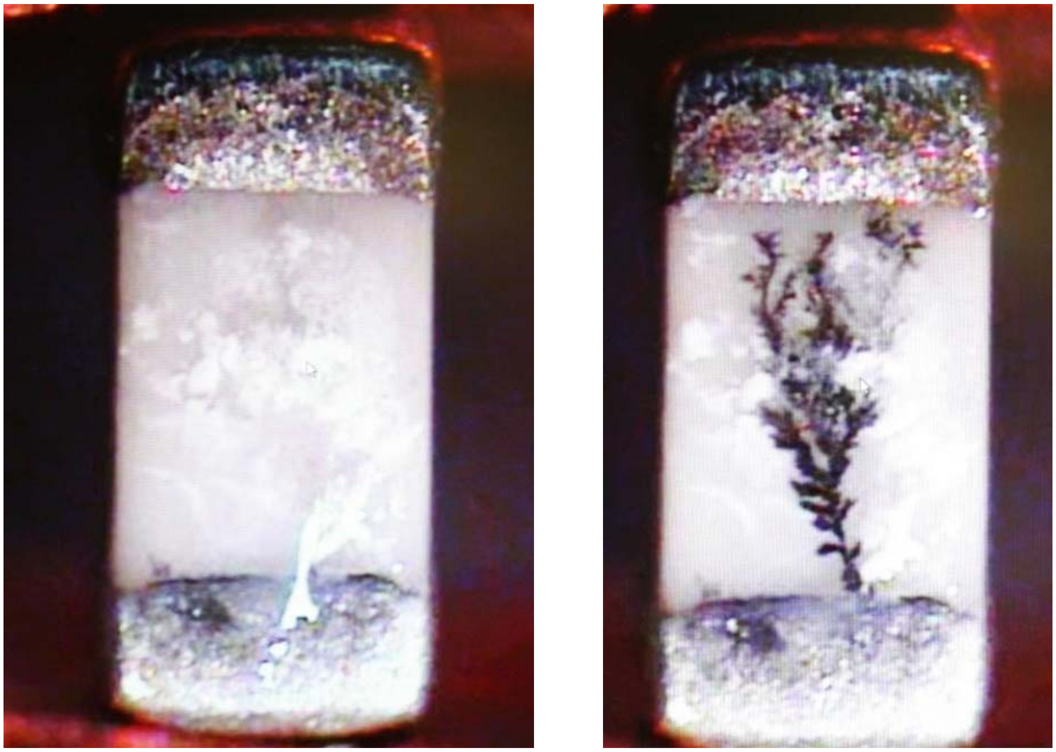

Figure 6: Surface Mount Capacitor before and after with 2.5 volts applied for 34 seconds

If this dendrite grows on the board surface between the component and board, as opposed to the top surface as in this example, it will produce thermal overstress that will actually ignite the board laminate, and ultimately, the housing of the device as well depending on its flame retardant properties. Board materials such as CEM -1 and CEM-3 burn very aggressively under these types of shorting conditions and when thick layers of flux create a fuel source to continue to feed the dendrite formation, the conditions are optimum for low voltage fires of electronic hardware. The authors have experienced multiple fires of this nature. One of the most interesting being a very low power automotive remote key fob that burned through the user's pants pocket.

WHY IS IT SO IMPORTANT TO HAVE CLEAN CIRCUIT BOARDS?

To make a reliable and intrinsically safe (from a fire development standpoint) electrical connection on a printed circuit board, the board, and all of the components that populate it, must be "clean." But what does "clean" really mean and why is cleanliness so important?

Simply, the fuel source for these dendritic shorts is ionic and organic contamination from the assembly process or external fluids/moisture – these substances make the boards "dirty". Ionic contamination is a measure of the “dirtiness” or contamination left behind from the board fabricator. It can be sulfuric acid etch residues, tap water residues that are high in chloride, sulfate, sodium and ammonium residues. The flux residue for cleanable fluxes (fluxes that are required to be washed away post processing) contains aggressive chlorides, bromides, methane sulfonic acids, sulfates, and ammonium residues. The no clean fluxes (fluxes that “theoretically” require no post solder cleaning) contain a blend of problematic organic acids. These acids are succinic, malic, maliec, glutaric, adipic, and propanoic. These acids become benign when completely heat activated by a soldering processes that is in full control. However, in many cases and in many processes throughout the world, the acids never fully reach the state where they are no longer reactive, causing them to be moisture absorbing, conductive and highly corrosive. When these residues (not completely heat activated) combine with a moisture event from environmental humidity, steam, or even something as severe as a water droplets on the board, electrical shorting and fires can and do occur.

WHAT HAS CHANGED SINCE THE DAYS OF WIRE WRAPPED BOARDS?

The contamination effects on electronic assemblies were pretty much a “non-issue” on wire wrapped assemblies due to the relatively wide spacing between interconnections and the lack of fluxes, solvents, and cleaners used to create the electrical connection. Essentially, no substances were introduced that could produce unintended sneak circuits between nodes, connection points, voltage rails, etc. Furthermore, the wires that carried the signals and voltages were all insulated and protected against accidental “touching” to one another via the introduction of conductive contamination.

Printed circuit boards, especially fine pitch (with spacing on the order of 3-10 mils), do not have the luxury of being completely free of external contamination, and their performance relies directly upon the lowering or removal of such contamination to “acceptable” levels. This is due to the fact that the copper traces (equivalent to wires in wire wrapping) are exposed to the environment on the outer layers and are in extremely close proximity to one another (lead spacing on the order of 10 mils), making these connections and traces susceptible to electrical bridging in the presence of ionic contamination. In simple terms, this electrical bridging first occurs in the form of dendritic growth, followed by arc tracking, ignition of the weak organic acids/laminate, and fire development. A more insidious malfunction involves the development of leakage paths that cause signal corruption, and operational failures, on devices controlled by microprocessors, without even producing localized heating.[3]

With respect to the reliability and safety of printed circuit board assemblies, are we perhaps reversing our course with our relentless pursuit for cost reduction and miniaturization? For example, compared to today’s PCB’s, wire wrapped boards were advantageous due to the relatively wide spacing’s between interconnections (50 to 100 mils apart) as previously discussed. Early printed circuit board technology (assemblies manufactured before the 1990’s) were also advantageous to today’s technologies due, in part, to the use of rosin-based flux (that is not in use today). Rosin based flux provided a robust barrier against moisture. With moisture being one of the three primary ingredients for dendritic growth, this made the boards highly resistance to the development of such problematic shorts, and when shorts did occur on such assemblies, it was typically only on the very high voltage assemblies that experienced and severe condensing moisture. Rosin fluxes needed to be cleaned, and were effectively done so, with Freon© solvent, a known Ozone Depleting chemical that was also eliminated from the market for environmental reasons in the 1987 – 1991 time frame. Hence, the shift away from rosin fluxes to more process-sensitive, environmentally friendly, low solids, no rosin systems over the same time frame.

There exists a sobering truth about today's electronic assemblies. 100% of today's consumer electronics are made without rosin flux (moisture resistance), use fluxes that do not "require" cleaning (leaves contamination behind more readily), use solders that contain no lead (creates more difficult soldering processes), and use boards that contain no halides to prevent the board from burning if a shorting or corrosions event were to occur.

Many of the PCBs incorporated in today's consumer electronics are inexpensive, single layer CEM1 laminate; basically a form of paper or cardboard substrate embedded in epoxy resin. More complex products such as computers or notebooks utilize a more sophisticated and thermally stable CEM3 or FR4 variety that incorporate multiple layers to increase the circuit density. Further complicating the issues mentioned are the many process variables and quality differences amongst "like" board technologies, translating into a rather large difference in flame rating performance, in many cases, performance that is even contrary to the provided specifications.

With the advent of ROHS (Reduction of Hazardous Substances), the removal of bromides (flame retardant) from PCB was initiated. In many cases, this effective flame retardant is being replaced by absolutely <u>nothing</u>. Those assemblies that are incorporating some level of flame retardant material, cannot claim the same level of protection formerly provided by bromine. Simply, the replacements don't perform as well as Bromine, cause porosity problems in the board material, and can create inner-layer shorting (through the red phosphorus). Munson has testing new board technologies that do no perform as well under UL 94V flame rating testing as historical products.

So, keeping boards clean - controlling the processes that contribute to cleanliness and the environment that the boards are exposed to – has become an increased challenge for process engineers in order to keeps boards both reliable, and more importantly, safe. In fact, it has become the only recourse that an engineer has in his or her arsenal to practically ensure safety. Boards simply do not perform, from a flame retardant standpoint, as they did a mere ten years ago.

A DISCUSSION ON THE SUPPLY CHAIN – WHY THE DRAMATIC CHANGES?

The issues that cause the electronic failures experienced today are more complex, process sensitive, and more extensive than they have ever been. And the failures and safety issues are even more insidious. This is due, in part, to a variety of changes that have occurred over the last 20 years with respect to ROHS, electronic commoditization, aggressive cost reduction efforts, and global supply chain management by those not cognizant of the inherent pitfalls illuminated in this paper. The elimination of Rosin flux, the tighter board spacings, the removal of effective flame retardants, and the increased sensitivity of active circuits are all the *far to quick* response to the global market's demand for higher technology that is not only faster, but small and cheaper too. Furthermore, with the recent proliferation of consumer electronic devices, electronics are no longer consciously used in clean, dry, environmentally controlled places. Today's consumer electronics are continually subjected to a wider environmental impact by users who do not fully understand the problems that can occur when, for example, electronics and moisture combine.

Under such conditions, low voltage hardware can short, thermally overstress, and the laminate can combust. The absence of flame retardants in today's products is causing more electronics to catch fire due to humidity exposure and new and dangerously high levels of board contamination (levels never seen in previous, historical technologies). The tremendous pace of the pursuit to outsourcing virtually every electronic assembly has also created an extensive supply chain full of "price only" buyers who simply lack the understanding of the processing and fabrication residues that must be effectively controlled to achieve good field performance in the products they purchase.

Furthermore, subcontractors are not building hardware in accordance with any relevant industry specifications for cleanliness, because they have not progressed with the testing techniques required to do so. They are still using requirements developed in the in the 1960's to 1990's that were only applicable to rosin flux and solvent cleaning processes. Since today's fluxes are so very different from Rosin flux, and require proper activation through a thoughtfully controlled process in order to become benign, today's fluxes must be treated differently and with more intention. Only 25% of the hardware built today is cleaned post soldering. The only requirement for shipment, with respect to contamination, is a highly ineffective visual inspection that cannot detect ionic contamination at levels that are detrimental to the hardware. Furthermore, many assemblies do not get the historical benefit of burn-in or even simple functional testing.

BROADEN YOUR AREA OF ORIGIN: REMOTE FIRE CAUSES - A CASE STUDY

Over the last 10 years, the number of electronic products in a typical home in the United States has increased by over 100%. The average home now has over 26 consumer electronic appliances or portable electronic devices.[4] As homes become more inundated with smart electronic devices such as MP3 players, cell phones, remote controls, key fobs, home theaters, electric toothbrushes, etc., the typical homeowner is likely to experience increased episodes of electronic/electrical product failure by sheer growth in numbers (holding reliability for all products constant). Some of these products will fail in a way in which they will initiate a fire locally, at the product itself (area of origin/cause). However, more insidiously and as previously discussed, some of these products will fail in a manner in which they create fire significantly remote from their original location on the structure or compartment (area of cause).

But how does a device with an internal failure mode produce a fire remote or distant from its location? In reality, there are many ways, however, a practical example, and one that has been experienced multiple times in the field by the authors of this paper, involves home audio equipment fires.

In the following case study, the fire investigator managing the scene chose a severely burned stereo speaker as both his area of fire origin, and cause. But how can this be? Speakers are typically unpowered [passive] devices, as was the subject speaker in this case study. Additionally, the homeowner reported that the stereo was turned off at the time of the fire (an all too common response, and one that the lead investigator rightfully challenged). Admittedly, the investigator chose a reasonable point of origin via the fire patterns and relevant damage, and in the context of his training up to this point, was pretty much correct in his approach and initial conclusion. But the belief that the speaker simply burned due to a malfunction in the reportedly unpowered speaker cone itself requires an extensive series of empirical tests and analyses to prove this hypothesis. It also requires that the stereo had been powered on and playing music, probably very loudly, at the time of ignition.

Most, if not all, speaker assemblies utilize UL94V flame retardant rated materials (however, the performance of many materials is random and unpredictable at best, especially with the introduction of the aforementioned ROHS requirements and the difficulty in controlling quality for products originating from the Pacific Rim). So if the speaker were to be over-driven due to excessive volume, any excessive heating of the respective coil wire would not, in theory, be able to ignite the cone material (or if it did, the flame would promptly self-extinguish). There would need to be continuous amperage applied to the speaker in order to possibly achieve sustained combustion.

So we know that unpowered speakers do not spontaneously combust. And if we give credence to the statement by the homeowner regarding the amplifier having been powered off, logically, how could the speaker have caused the fire? Fortunately, the entire contents of the room, including the amplifier, were harvested. When the amplifier was unwrapped for documentation, the engineers invited to the inspection simply snapped a couple of seemingly obligatory photos and promptly moved on to the next piece of evidence. They simply were not interested in this product from a causation standpoint. After all, it wasn't even fire damaged!

At Kodiak's request and per a prescribed and agreed-upon protocol, the amplifier was subsequently powered up by pressing the "soft start" ON button while connected to exemplar speakers taken from the same home. The amplifier produced clear and audible music, even at full volume, at least for a period of time (more on this later). The amplifier was then powered off by pressing the soft OFF button. Note that even when the power button on the amplifier is in the OFF position, it really isn't powered down. Most electronic products are never really powered off. These are called phantom loads. Simply, the microprocessor in the device is always powered up and waiting for inputs from the user. One of those inputs is the recognition of a depressed "power on" button on the front panel of the amplifier. So power is usually flowing through the product.

The subject speaker was subsequently analyzed and revealed an over-current or melting open [like a blown fuse filament] of one of two speaker coil wires as it exited the litz wire. The wire was clearly electrically overstressed. So how does this occur on an unpowered speaker?… creating a length of wire that is fused open due to localized internal heating, not fire melt [because the other litz were was intact]?

At this point in the investigation, the team was still preoccupied with trying to understand how an unpowered speaker could spontaneously combust. More attention was focused on the amplifier, which was clearly very remote from the area of origin. Knowing that microprocessor controlled electronics can misbehave for a variety of manufacturing or environmental reasons as previously discussed, it was decided to raise the humidity of the amplifier (simulating a simple rise in the home). Within several seconds, a strange phenomenon occurred. As the humidity was raised just 5 points, from 35% to 40%, the amplifier actually turned on by itself. No big deal right? So what if we hear a little music when we don't call for it, right? That doesn't necessarily create a fire.

Well, the problem isn't necessarily that the amplifier actually powered on spontaneously. The bigger problem is **why** the amplifier powered on spontaneously? This is a clear indication of a software or environmentally induced malfunction, proving that the microprocessor was confused and received an errant command. This allowed the music to continue to play through all of the exemplar speakers, but the left front exemplar speaker (the same channel that was wired to the subject speaker) started to distort ever so slightly after a period of time. Note that we raised the humidity to achieve this result. This is a key point in the investigation, as embedded software (firmware) is not affected by humidity.

While the speaker was playing distorted music, a spectrum analyzer was connected to the speaker output of the amplifier on the subject channel to study the signal more closely. Something unusual was observed on the instrument display. The measurement revealed that the speaker was not only seeing the appropriate audio signal, but it was also seeing an incorrect, constant 12V DC voltage - like hooking a car battery directly across the speaker. About 30 seconds into the testing, the music started to distort and the DC voltage proceeded to overheat the exemplar speaker coil, which consequently erupted into flames, consuming all of the materials within the speaker basket before the investigation team extinguished the fire.

The main circuit board, also containing the amplifier section, was removed and inspected. A white film was observed atop certain areas of the circuit board. These were visible signs of contamination. The board was sent to a lab for ionic contamination testing.. There were also visible signs of contamination. Ionic contamination levels from manufacturing byproducts of greater than 10 ug/in2 were detected via ion chromatography, creating unintentional circuit paths or sneak circuit to the power on circuit as well as the audio processor, in other words, root cause.

In summary, if something this subtle can occur on a device like this, causing a propagating fault that creates a fire in a product across the room, then what about other electronics in the home with even smaller traces widths and component density in the home?

Some additional scenarios to ponder?

1) A failure of a home network router that introduces high voltage and current onto the cat 5/5E wires that is routed throughout the home. Formerly, cat 5/5E would have been dismissed as “low voltage” data wire. But what if it is unintentionally carrying higher than rated fault current, driven by a class II transformer, as a result of a remote fault on a product connected to it?
2) Television remote control with two AAA 1.5V batteries. Can turn on appliances due to contamination on board without human intervention. Can also sustain ignition and burn on its own. Typically dismissed as potential fire causes.
3) A low voltage control that commands the operation of higher voltage loads through relays or contactors.
4) Cell phones not plugged into chargers
5) Key fobs for your car

CONCLUSION

The proliferation of consumer electronics in the home, and the ever-increasing and never ending push to miniaturize them, continues to introduce new challenges for the fire investigation community. The utilization of manufacturing processes that are increasingly more difficult to control from a cleanliness perspective, and the drive to reduce hazardous substances [such as formerly effective fire retardant agents in PCB’s], are combining to create the “perfect storm” with respect to printed circuit board ignition. Furthermore, the management of these critical process parameters required to ensure reliable and safe operation of printed circuit boards in the hands of the consumer continues to be an overwhelming challenge for many companies sourcing product from contract manufacturers in the pacific rim.

Consequently, for investigators who wish to improve their accuracy in identifying the root causes of the fires they investigate, virtually <u>all</u> electronic devices in the area of origin (and area of interest) must be considered as potential ignition sources. Devices geographically remote from the area of origin, even those located in a compartment completely unaffected by fire, must also be considered if connected to such devices via data cable, coax, or like wiring.

- No longer is it acceptable to turn a blind eye to products that are arbitrarily considered to be “low voltage”

- No longer is it acceptable to ignore devices formerly believed to be incapable of developing enough heat to initiate a fire
- No longer is it acceptable to apply conventional compartment fire development principles to small-scale electronic assemblies and devices

BIOGRAPHY OF AUTHORS

Richard J. Vicars is a managing electrical engineer with Kodiak Fire & Safety in Fort Wayne, Indiana. Prior to his role with Kodiak, Richard spent the majority of his career developing world-class failure analysis capabilities for Fortune 100 companies such as ITT Defense and United Technologies, as well as being instrumental in the successful start-up and growth of a tier-one medical device manufacturer, Paragon Medical, Inc. While at United Technologies, he was recognized by Yuzuru Ito, UTC's corporate VP of quality, for developing the "most effective failure analysis and root cause capability" within the corporation. He was also recognized by the U.S. Army (CECOM) for outstanding contribution to the development, manufacturing, and deployment of the SINCGARS battlefield communication system while with ITT. He continues to serve as a chair and charter member of IEEE's PSES Failure and Forensic Analysis Technical Committee since 2009. Richard holds a BS in Electrical Engineering from Purdue University and an MBA, as well as a Six Sigma Black Belt and ISO Lead Auditor certification.

Terry Munson is the president and founder of Foresite Inc., a failure analysis and consulting laboratory for electronics contract manufacturers, fabricators, and OEM clients. Foresite's role has been an investigative team leader with over 3,000 companies for past 18 years, working on a multitude of circuit board related problems. Foresite works with Fortune 100 companies, and with newly formed third world contract and subcontractor "mom and pop shops", in Europe, Asia, Indonesia, South America, Mexico, Canada and the USA. Foresite has seen some creative manufacturing processes and has implemented substantial enhancements to such processes. Foresite has FDA approved rescue cleaning processes for medical device hardware, as well as FAA approved coating, removal, and remediation cleaning processes for avionic hardware. Terry Munson has been working on electronics hardware since the 1985. While starting at Delco Electronics in the Advance Packaging Group using and developing Ion Chromatography and localized extraction protocols that are part of the IPC TM 650 test methods group and JEDEC component specifications. Mr. Munson has been active in 27 committees for the IPC, SMTA, and ASTM committees and has received the IPC Presidents Award.

Jim Small…

Chris Parrish…

ENDNOTES

1) Babrauskas, V., Ignition Handbook, p. 313, Fire Science Publishers, Issaquah, Washington (2003)
2) Bernstein, T., Electrical Fires: Causes, Prevention, and Investigation, pp. 116-134 in Greenwald, E.K. ed., **Electrical Hazards and Accidents: Their Cause and Prevention**, Van Nostrand Reinhold, New York (1991).
3) Hillman, C., Improved Methodologies for Identifying Root-Cause of Printed Board Failures, p. 7, **Microelectronics Failures Desk Reference, 5th Edition**, ASM International, Materials Park
4) 12th Annual Household CE Ownership and Market Potential Study, Consumer Electronics Association (2010)