Chapter 2
Facts Regarding Typical Events

An electronic control is sometimes accused of causing a fire if evidence exists of the product failing due to overheating. If a plastic housing or a printed circuit board, mostly intact with a localized area of black soot or other obvious visible damage, is found the first piece of the map that can ultimately lead to the root cause of the event is at hand and available. In the end perseverance through uncovering clues will lead to an understanding of why the event occurred and how to prevent it from occurring again. In many instances the "how" to prevent it from occurring again with a practical solution will be the most challenging task.

In the case of the event clue being a localized area of visible damage it is a matter of determining how too much energy was forced through too small of an area for too long of a time. The first question to answer is what is unique about this event? Was it an unexpected increase in the amount of energy delivered for a given period of time? Or… was it an unexpected decrease in the expected material's thermal characteristics through which this energy flowed?

In order to provide legal evidence that an event was caused by a specific hypothesis a competent ignition source and a demonstrated first fuel, as defined by NFPA 921: Guide for Fire and Explosion Investigations, must be satisfactorily explained.

When determining if a control is guilty or innocent of causing a fire note the following language from NFPA 921, "Fire cause factors: The determination of the cause of a fire requires the identification of those factors that were necessary for the fire to have occurred. Those factors include the presence of a competent ignition source, the type and form of the first fuel, and the circumstances such as failures or such as human actions that allowed the factors to come together and start the fire."

Forensics involving electronic control investigations would be greatly advanced if there was an accepted metric such as W-Sec, W, Volts or even Amps below which a control could not combust. Some within the forensics community believe that if you don't have 240VAC or 120VAC available to an electronic control it cannot be the cause of an event. This notion may contribute to the very large

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number of fire investigations that result in “cause unknown”. As demonstrated in Chap. 14, a power level of ≤ 3 W can ignite (visible flame) a PCB as well as a DC voltage of 0.59 V. It is also true that a 6000 K arc can be generated from as little as 1 A [1].

A. Self-ignition of Electronics Assemblies

Not knowing the failure modes of electronics assemblies and their propensity for self-ignition can be a very unnerving and potentially very costly business decision.

The following allows a hitherto difficult “self ignition analysis” of any electronics assembly to be accomplished within a reasonable amount of time. The best-case scenario is obviously to deploy the following during the concept, design and initial production stages. A relatively easy “Self Ignition Analysis” can be performed after the basics as presented are understood.

Following is a primarily empirical elaboration of classical physics applied to today’s materials and manufacturing processes.

The answer to the question (W-Sec, Watts, Volts or Amps below which a control cannot combust) is full of qualifying conditions. The short answers are as follows and are based upon results of bench experiments detailed in Chap. 14 of this book. The “below which” is not above and most likely below the values of each experiment. In order to determine and present the “lowest levels” one would have to complete a well thought out DOE (Design Of Experiments) or a similar statistically structured method. This will be left up to any interested party who would like to know the statistical boundary “below which” combustion will not happen.

B. Quantity of Fuel

Just because an arc or a spark is found possible and even probable during FMEA (Failure Mode Effects Analysis) testing, it does not mean that this product can or cannot cause a fire.

C. PCB Conductor Spacing

The subject of minimum PCB conductor spacing is not an easy one. From a design engineer’s perspective there is a very long list of criteria that the physical copper layout and minimum spacing must obey to function properly. From a manufacturing engineer’s perspective minimum spacing is based on the limits of the manufacturing equipment and known process limits. From a forensic engineer’s perspective it may simply be the UL spacing required where 120 VAC or 240 VAC is found within the control.

Minimum spacing will certainly depend on the maximum voltage anticipated given reasonably expected failure modes. Minimum conductor spacing must be specified such that arcing through air or contaminant accumulated over years will not occur.

In practice, the value historically relied upon for an electronic control has been a variant of 340 V [2] as suggested by Paschen’s law. The reality is that hot plasma arcs can occur well below 100 V for narrowing conductor gaps of 1 μm or less. The interested reader is encouraged to consider Vytenis Babrauskas's Ph.D. paper, "Arc Breakdown In Air Over Very Small Gap Distances", Interscience Communications Ltd. From Proceedings of Interflam 2013.

Just because a product is designed and specified such that it *should never* see voltage levels over the level at which an arc can occur, does not mean that an arc could not have ignited the PCB or its plastic housing. If evidence points towards an unlikely arcing event, it is prudent to look for failure modes that could open inductive current carrying paths in the damaged vicinity. Since an inductance will rapidly produce a very high opposing voltage to minimize the rate at which its current changes, it is entirely feasible that an inductive separation arc occurred.

Modeling the peak voltage and energy level due to a PCB conductor separating especially between 0 and 5 μm is not trivial as explained in the ECE234/434 handout available on-line from the University of Rochester [3]. Energy estimates for separation arcs can be made by taking half of the open circuit voltage, times half of the closed circuit current, times the duration of the arc. Energy contained in the arc is therefore:

$$E_{arc} = \frac{1}{2} V_{oc} \times I_{cc} \times D_{arc}$$

One other general statement regarding the potential PCB damage from arcing is that for a DC waveform and an AC waveform having equal RMS (Root Mean Square) values, the alternating current is normally less damaging than the direct current because it may not always reignite its arc after its current passes the zero crossing twice each cycle.

References

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2. Fan, Mark S. and Park, Hyun Soo "Minimum Conductor Spacing for Electronic Packaging". Paper for UNISYS/NASA Electronic Packaging Group, NASA Goddard Space Flight Center, Greenbelt, Maryland, March 24, 1993
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