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James E. Small

Electronic Control Fires

A Design, Manufacturing and Forensic Technical Perspective

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USA

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This book is dedicated to my wife Margo and my daughters Jill and Sarah

Preface

The primary intent of this book is to put into plain words how to determine whether a suspect electronic appliance control is the cause of a fire or the result of a fire. It is distinctive in two ways: first, in its evaluation of low voltage, low power (0.6 V, $\leq$5 W) fires and second, in its intent to disseminate valuable information that should not be hidden for personal gain.

The author has been asked multiple times during depositions if what he had just said was "*common knowledge*." It pained him to respond that it was not. This did not change the facts of the case but certainly changed what evidence was harvested and examined in pursuit of the truth. The judge and/or jury was saddled with the unenviable task of determining someone's guilt or innocence without all of the evidence being recognized and therefore not examined.

This book is also somewhat unique in its intended audience of those technically responsible for design, manufacturing, and forensic responsibilities. Its direction is to link the design, manufacturing, and forensic technical communities together as much as possible, thereby allowing each to ensure a final product that will not end up in litigation or at least not be found guilty during litigation. Empirical data provided will prove invaluable in determining the guilt or innocence of an electronic control. Solutions are also suggested when appropriate.

It is very unusual for design or manufacturing organizations to be familiar with NFPA 921. The NFPA, Guide for Fire and Explosion Investigation, is referenced since it provides invaluable forensic technical insight for both the design and manufacturing groups. This insight will allow the designer to know "how robust" their product must be to allow for a good night's sleep and yet not add crippling costs. The two best friends any electronic control can have are a well-documented FMEA (failure mode effect analysis) and an audited risk mitigation plan that encompasses the issues laid out in of this book.

It is a number game. The electronic control arena can be especially risky from a life safety and/or product liability standpoint for low-volume production (1000 per year). The good news is that a one-in-a-million problem is not likely to happen. The bad news is that the product may not have the financial backing to insure against reasonably expected failures, poor design, supplier component variation, unanticipated shipping issues or customer misuse, etc. A product can have a problem that occurs only in one out of every ten thousand households. With over 133 million households in the USA alone in 2014, it is reasonable to expect at least 13,300 homes to experience an unlikely event as defined in Chap. 1.

The other end of the spectrum that is typically much more difficult to deal with is when hundreds of thousands or millions of "identical" products have been produced within a five-year period or so. The more individual the parts and processes from which the final product exists and the more varied its environment, the more complex any potential product forensic investigation will be.

Any product that startles someone by smelling hot, smelling like smoke or arcs and sparks presents a serious issue for those financially and emotionally responsible for its existence. It is not necessary for a unit to erupt into flames, destroy property, and potentially take innocent lives to create a product nightmare. Just the fear of this due to an overlooked new product introduction failure generating smoke or sparks in a home or in shipment can be disastrous if the issue is not dealt with quickly and rationally.

As with all things in life, it is very difficult, if not impossible, to prove something cannot possibly happen. It is much easier to prove something can happen. It is important to note that a level (voltage, current, power, or energy) below which a product fire cannot exist is never claimed. The bench experiments presented in Chap. 14 can be cited to prove levels and conditions at which a fire can exist but not a level at which a fire cannot exist. The experiments in Chap. 14 are designed to demonstrate how little voltage, power, and energy are actually necessary to allow an event to occur.

The author has been intrigued with electronics since he first watched the slowly building glow of tubes in his Hammarlund shortwave amateur radio receiver in the early 1960s. He was awestruck at the conversations he heard magically coming from around the world. Electronics technology was at that time beginning its rapid rise that has touched virtually every aspect of humanity. As with any advance in knowledge, boundaries are always being tested. We always want more for less and that translates into more discrete conductive material in smaller areas. This also translates into higher energy densities. One limiting factor of increasing energy densities is that of the all-too-well-known event that is the focus of this book.

The information that follows is either referenced, is demonstrated through experimentation, or has been learned through many years of new product designs, development, and production cycles.

To the excited, curious and fearless engineer a word about change. In the exciting worlds of research, new product design, and development, embrace change and embrace the associated risks. However, once you "pull the trigger" for a new high-volume product, restrain your urge to make it better when time is too late for adequate testing. It is entirely possible to make a seemingly minor change to eliminate a problem with very minor consequences, while creating a much less likely problem, however with horrible consequences.

Fort Wayne, IN, USA James E. Small

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A great deal of the information presented in this book was made possible due to my exceptionally good fortune to work closely with so many talented people over the years and especially the following three gentlemen. Richard Vicars, the General Manager of Kodiak, Fire & Safety Consulting (now Jensen Hughes) forensic engineering facility in Fort Wayne, IN, Terry Munson, the founder and CEO of Forsite Inc., in Kokomo IN, and Dan Churchword, the President and founder of Kodiak Enterprises, Inc.

High-volume production and reliability idiosyncrasies continue to be discovered through my good fortune to have worked with Richard Vicars countless hours in a mutually driven and relentless quest to understand that which we knew “could not possibly happen.”

Most contamination-related information presented in this book has been gleaned over the past 25 years through Terry Munson and his amazing team’s generous use of his facility plus his personal insight to help quench my curiosity.

Dan Churchward has pushed my artificially imposed “possibility boundaries” through his gifts in the field of forensics and for knowing the really hard questions that can be asked during litigation. His participation in the creation of and his passion for NFPA 921, Guide for Fire and Explosion Investigation, in concert with his excellence in general, have been and continue to be a powerful force in my life.

Dan has also provided a great deal of his personal time in making this book pertinent and valuable for the forensic community.

I also want to thank Dr. Vyto Babrauskas, author of the *IGNITION HANDBOOK*, and hundreds of technical papers dealing with fire science for reviewing a draft manuscript of this book. Vyto has provided me with invaluable editorial comments, especially regarding his revelations about Paschen’s law.

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Last but not least, I want to thank my amazing wife Margo, for her encouragement in completing this book and for her countless hours of exceptionally patient, detailed proofreading, and graphics assistance.

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About the Author

James E. Small is an electrical engineer retired from United Technologies Hamilton Sundstrand Aerospace Division in CT. James has held senior engineering positions at United Technologies Electronic Controls, Honeywell's North America Homes Division in Golden Valley, MN, and their Life Safety Division in CT. He was also the director of Research and Development at Emerson's Weigand Appliance Controls Division in AL. Since 2006, he has devoted his insatiable curiosity to solving mysterious electronic control-related product issues working with his colleagues primarily at Kodiak Fire and Safety Consulting (now Jensen Hughes) in their Fort Wayne, IN, facility as a consulting engineer and expert witness. He has also provided recent in-house consulting during the new product development phase for several Fortune 500 companies prior to their release of new electronic control-related products.

He is experienced in all aspects of electronic design from concept through production. He holds nine US patents, all related to the design of electronic appliance controls. As the director of Emerson Electric's R&D, Weigand Appliance Controls Division, he drove breakthrough designs of electronic controls and unique infrared heating components for present-day smooth glass cooktop residential ranges. As the director of Honeywell's North America Homes Engineering Organization within their Automation and Controls Solutions (ACS) business unit, he was deeply involved in revolutionary electronic control concepts, designs, and manufacturing innovations. During this time, Honeywell's ACS business unit was awarded Minnesota's prestigious annual "Tekne" Award for three of his organization's new products based on customer ease of use and ease of manufacturing. Jim has taught Six Sigma/Lean courses extensively through Purdue University's Technical Assistance Program/Manufacturing Extension Partnership (TAP/MEP) and has taught Masters Level Statistics as Adjunct Faculty at Indiana Wesleyan University. Jim holds a BSEE from Purdue University and an MBA from Indiana Wesleyan University. James began his own consulting business in Fort Wayne, Indiana, early 2006. More information regarding James can be found at lowwattagefires.com and he can be reached at jesmall65@gmail.com.

Introduction

The phrase "electronic controls" conjures up different images for different people. Many believe a control is "electronic" if we interact with it by the use of a digital display such as a 7-segment LED (light-emitting diode) or a LCD (liquid crystal display). Electronic controls in the context of this book will refer to any electronic assembly that includes components such as a printed circuit board, resistors, and capacitors that controls another appliance, such as a washing machine.

We are virtually surrounded by "electronic controls" in today's way of life. We can go to sleep watching TV and are kept comfortable by a heating and cooling system. Some even set the firmness of their mattress by the press of a button. We are kept safe by a security system, and smoke detectors as we sleep. The TV, heating and cooling system, air mattress pump, security system and smoke detectors each have their own electronic control.

Each morning before we awake, the heating and cooling thermostat automatically makes our house the perfect temperature. We awake due to a preset alarm and delight in a warm shower. A sonic toothbrush and an electric razor may also be called upon prior to our morning toast, microwaved egg burrito, and perfectly brewed coffee. The thermostat, morning alarm, water heater, sonic toothbrush, electric razor, toaster, microwave, and coffee maker each have their own unique electronic control.

While drinking our coffee, we click an electronic control to remotely start our car so that it will be nice and toasty or cooled down (the temperature is controlled by another electronic control) before we get in. We then use another "key fob" electronic control to unlock the car before we are on our way. So each morning, we have used at least 10 electronic controls before we even get out on the road!

The list of electronic controls in our life is a very long list indeed, and each of these electronic controls is unique. Four electronic controls are depicted in Figs. 1, 2, 3, 4, 5, and 6. When many electronic controlled products in our daily life function properly, we tend to take them for granted and forget they are even there. Unlike thirty or forty years ago, consumers today have a more "throwaway mentality." Feeding this throwaway mentality is the belief and experience that whatever

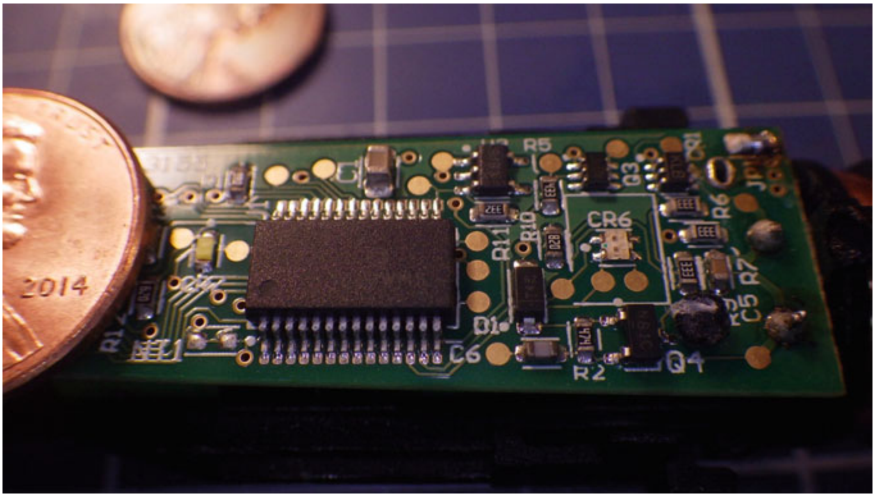

Fig. 1 Lower portion of an ultrasonic toothbrush electronic control

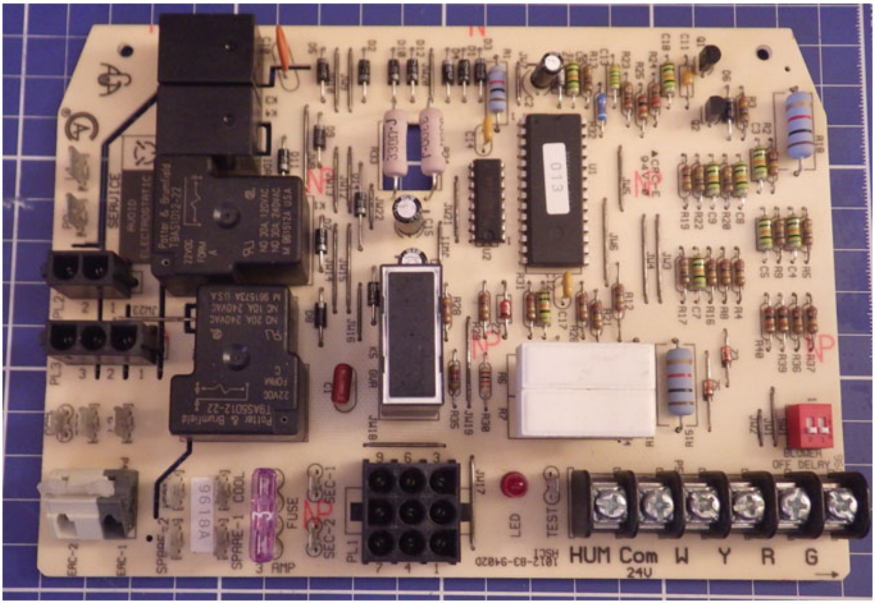

Fig. 2 A residential furnace electronic control

we buy today will be replaced in 6 months to 3 years with something better and perhaps less expensive.

Prior to our product development cycle becoming 6 months to 3 years, it would have been thought absurd and totally unacceptable for electronic products to fail

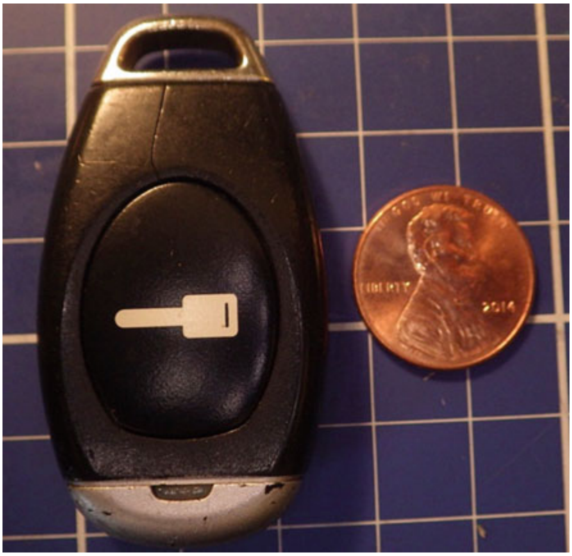

Fig. 3 An electronic control designed to start a vehicle remotely

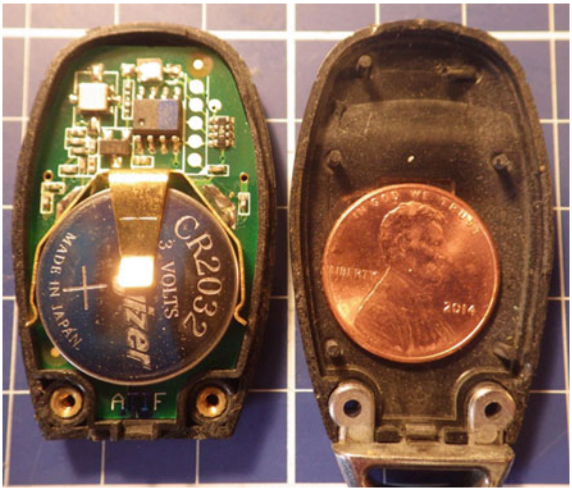

Fig. 4 Contents of the control depicted in Fig. 3 of an electronic control made to start a vehicle remotely

or need replacement after only 3 years. For this reason, a great deal of time and thought was spent on engineering to make certain known failure modes over a 20+ year time frame were minimized, safe and any life safety issues for the homeowner were all but eliminated. In comparison, today's low expectations for product longevity have promoted more inexpensive products and quick-to-market design and manufacturing processes with an increased propensity for the chance of things that can go wrong, to go wrong.

Fig. 5 An electronic control designed to lock and unlock a vehicle remotely

Fig. 6 Contents of the control depicted in Fig. 5 of an electronic control that will lock and unlock a vehicle remotely

In this book, many of those things that can go wrong are discussed from the perspective of both the design and manufacturing functions and clarified for the responsible forensic team. It is the intent of this book to make known many pitfalls of this fast-paced new risk-laden product introduction environment and help minimize the number of electronic control fires and other menacing events of today.

Chapter 3 provides a detailed list of many “things that can go wrong.” It is my hope that a design team would take this list to heart and make certain any new electronic control they introduce will not be subject to any of its many possible downfalls.

The astute forensic team who did not evolve through the design, manufacturing, and field service worlds of electronic controls will find this book particularly enlightening and extremely valuable in his or her role as an expert witness.

New, and extremely valuable, empirical data are provided and discussed at length in the later chapters of this book. These data become a very powerful tool in the hands of a skilled attorney and expert witness.

The design and manufacturing teams will find lists of “things that can go wrong” and do go wrong so often today. Having this information early in the product development cycle can remove a great deal of stress from the lives of those responsible for today’s many new product introductions.

How to quickly uncover and fix many unwelcome problems due to shortened product life span is the focus of “Electronic Control Fires,” the first ever monograph on this topic.