

# HOW TO DIAGNOSE AND FIX EVERYTHING ELECTRONIC



Have fun and save money  
by repairing your own  
electronics

Learn to use test  
equipment, including  
the oscilloscope

See how an expert  
pinpoints circuit faults  
quickly

**Michael Jay Geier**

*Foreword by*  
Richard Doherty,  
Research Director,  
The Envisioneering Group

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# How to Diagnose and Fix Everything Electronic

Michael Jay Geier



New York Chicago San Francisco Lisbon  
London Madrid Mexico City Milan New Delhi  
San Juan Seoul Singapore Sydney Toronto

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*This book is dedicated to my parents, for putting up with their young son's taking everything in the house apart, even though it scared them to death; to my brother, for providing me with a steady stream of broken items to fix and the encouragement to figure them out; to Greg, for sharing countless happy teenage hours fiddling with circuits, projects and walkie-talkies; to Rick, for always believing in and promoting my talents; to Cousin Jerry, for some of my earliest guidance in electronic exploration; and to Alvin Fernald and Tom Swift Jr., whose fictional technological exploits kept me spellbound through most of my childhood and made me believe anything was possible with a handful of transistors and the know-how to make them wake up and do something.*

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## About the Author

**Michael Jay Geier** has been an electronics technician, designer and inventor since age 6. He took apart everything he could get his hands on, and soon discovered that learning to put it back together was even more fun. By age 8, he operated a neighborhood electronics repair service that was profiled in *The Miami News*. He went on to work in numerous service centers in Miami, Boston and Seattle, frequently serving as the “tough dog” tech who solved the cases other techs couldn’t. At the same time, Michael was a pioneer in the field of augmentative communications systems, helping a noted Boston clinic develop computer speech systems for children with cerebral palsy. He also invented and sold an amateur radio device while writing and marketing software in the early years of personal computing.

Michael holds an FCC Extra-class amateur radio license. His involvement in ham radio led to his writing career, first with articles for ham radio magazines, and then with general technology features in *Electronic Engineering Times*, *Desktop Engineering*, *IEEE Spectrum*, and *The Envisioneering Newsletter*. His work on digital rights management has been cited in several patents. Michael has a Boston Conservatory of Music degree in composition, was trained as a conductor, and is an accomplished classical, jazz and pop pianist, and a published songwriter. Along with building and repairing electronic circuitry, he enjoys table tennis, restoring old mopeds, ice skating, bicycling, and banging out a jazz tune on the harpsichord in his kitchen.

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# Foreword

There is a keen sense of personal accomplishment to be gained from fixing something yourself that might otherwise have cost a fortune to repair or been recycled ahead of its time. Michael Jay Geier has known this joy since childhood. Now, for the first time, he shares his secrets in written and pictorial form.

I've known Michael across three decades, multiple time zones and dozens of entertainment and technology projects and consulting gigs we've tackled together. Quite simply, Michael sees electronic products as songs or symphonies of components, specialized parts working in harmony when they leave the manufacturer.

Yet individual musicians may be missing or off-key when the product fails from age, misuse or random component failure. Like the keen orchestra conductor he was trained to be, Michael quickly zeroes in on what parts of a broken electronic product are out of tune, using many skills he will teach you in this book, along with instruments to sense and measure things beyond the human senses of sight and sound. Fixing and extending the life of products we love, including things no longer being made and for which there is no ready replacement, is a valuable skill worth developing and nurturing.

Musicians see patterns well and communicate their art to larger audiences. Michael's expertise in troubleshooting consumer electronics is unmatched. Here, he shares the patterns that come easily to him with a broad audience of readers who want to enjoy their consumer electronics products longer, can't afford traditional repairs, fear their favorite irreplaceable gadget could be lost or further damaged while at the shop, or want to keep alive something old or obscure enough that no repair facility has the resources to work on it.

I put myself through college repairing consumer electronics and entertainment products. As much as I learned, when I first met Michael, I knew within days that he had a gift for troubleshooting far faster than my own. Jealousy soon faded as I saw he was confident and professional in his communications skills, and he loved sharing his insights and tricks.

Many TV, camcorder and video player manufacturers have employed lessons learned from Michael's shop repairs to improve their next-generation products and make them more durable and dependable. Michael has made his mark on improving product designs for more than two decades now.

I personally know several consumer electronics repair shop employers who hated to see Michael go. Yet not a one denied that Michael's time there and sharing of expertise made the entire shop better at repair and gave customers their serviced products back faster and with more reliability against ever failing again.

Herein, Michael shares his hunches, skills and insights at a level any dedicated reader can absorb and apply. Enjoy the satisfaction that comes with learning to repair your own equipment. And spread the word—it's about as green and economically smart as you can be!

Richard Doherty, Research Director  
The Envisioneering Group  
Seaford, New York  
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## Introduction

*Everything*. That's a scary word, one I almost avoided including in the title. Can any book actually cover *everything* about a topic? Yes and no. Yes, in the sense that the principles and techniques you'll learn can be applied to the repair of every kind of consumer electronics device presently being made or likely to be sold in the near future. No, in that it's impossible to fit each of the thousands of types of components and countless varieties of gadgets in the world into one volume. Covering all of them in deepest detail would take a library, and a good-sized one at that.

The focus of this book is on today's electronics, most of which are digital in nature, and the kinds of problems you're most likely to encounter. It might seem like there isn't that much one can service in modern digital gear, compared to the older analog circuitry. Dense boards populated by rows of chips with leads too close together even to poke at with a test probe don't seem like good repair candidates, do they? Luckily, those areas aren't where most failures occur, and there's still plenty of accessible circuitry to work on! In fact, some common problems in today's gear were rare or nonexistent in earlier technology, and they're quite repairable.

Exotic and very obsolete components and their associated products aren't covered in this book. Electron tubes, once the mainstay of all electronics, are pretty much gone, so we won't spend time on their peculiarities and specific troubleshooting methods. If you want to repair tube-type guitar amplifiers, you can find books dedicated to them. Similarly, we won't be discussing microwave ovens, which also have tubes, or transmitting amplifiers of the sort used by amateur radio operators. Nor will we take more than a passing glance at cathode ray tube (CRT, or picture tube)-based TVs and monitors. The CRT had a good long run, from the 1940s until just a few years ago, but it's a dead technology, thoroughly supplanted by flat-panel displays. Servicing CRT sets is rather dangerous, so please find a book devoted to them if you have an interest in, say, restoring antique TVs. What's covered here is relevant but not comprehensive enough regarding that topic to keep you safe around those high-voltage beasts.



Some obsolete technology is still in common use and may remain so for years to come, so we'll explore it. Tape-based video recording continues to be used in some digital camcorders. VCRs, which are rapidly disappearing as high-definition TV (HDTV) obsoletes them, may be the only key to recovery of precious home movies yet to be transferred to digital media. Serious audio devotees treasure their analog tape recorders and turntables and will never replace them with CD or MP3 players. We won't spend much time on the old formats, but the troubleshooting techniques covered here are applicable to their repair.

Most of today's digital equipment still contains analog circuitry for audio or video output, microphone input, voltage regulation and such. Home theater receivers use analog amplifier stages, and many have old-fashioned, linear power supplies as well, because they're electrically quieter than newer, pulse-driven designs. In fact, the best audiophile-grade stereo gear is pretty much all analog and will likely remain that way. Even digital radio and TV receivers use analog stages to amplify and separate incoming signals before digital decoders extract the data. So, troubleshooting techniques specific to analog circuitry are far from antiquated; they continue to be relevant in our digital era.

In this book, it is assumed that you have probably opened an electronic device at one time or another and checked a fuse. Perhaps you know a resistor when you see one, and maybe you've even soldered or done some basic troubleshooting. Still, we're going to start from the top, ensuring you're a sound swimmer before diving into the deep end. And dive we will! Beginning with a look at the tools you'll need, we'll explore setting up your home workshop. We'll discuss the best types of workbenches and lamps, and where to put your gear and tools. We'll take a close look at the most useful test instruments, where to find bargains on them, and how to operate them. Getting good with an oscilloscope is key to being a crack shot tech, so we'll explore a scope's operation in detail, button by button.

Using other test equipment like digital voltmeters and ohmmeters is also crucial to effective repair. We'll focus on commonly available test gear, without spending significant effort on very expensive, exotic instruments you're never likely to own. We'll examine how to take a product apart, figure out what's wrong with it, replace parts and close it back up again. Finally, we'll look at tips and tricks for specific devices, from optical disc players to video recorders and receivers. Here's a quick breakdown of what's in each chapter.

## **Chapter 1, "Prepare for Blastoff: Fixing Is Fun!"**

- Why repair things? Environmental and economic factors, learning, fun, preserving rare and obsolete technology, potential profit.
- When is a product worth repairing, and when is it better to cut it up for parts?

## **Chapter 2, "Setting Up Shop: Tools of the Trade"**

- Necessary items, from hand tools to test instruments, and how to buy them. Must-haves, nice-to-haves, and expensive goodies to dream about.
- How to select a workbench and set it up, and where to put it.

### Chapter 3, “Danger, Danger! Staying Safe”

- How to avoid getting hurt while servicing electronics: electrical and physical hazards, eye and ear protection.
- How not to damage the device you’re repairing: causing electrical and physical damage.
- Ensuring user safety after product repair.

### Chapter 4, “I Fix, Therefore I Am: The Philosophy of Troubleshooting”

- General troubleshooting principles: why things work, why they stop.
- Common mistakes and how to avoid them.
- Organization of modern devices: microprocessor brains, nervous system, muscles and senses.
- The “art” side of electronics: manufacturer-specific quirks and issues.
- What fails most often and why.
- Failure history and how it helps diagnose problems.
- Preliminary diagnosis based on symptom analysis: dead, comatose and nearly working.
- Case histories.

### Chapter 5, “Naming Names: Important Terms, Concepts and Building Blocks”

- Electrical units: volts, amps, resistance, capacitance, and so on.
- Circuit concepts: how parts connect and how current moves through them. Series and parallel.
- Signal concepts: how changes in voltage represent information. Waveforms. Analog and digital representation.
- Building blocks: common circuits used in many products. Amplifiers, oscillators, frequency synthesizers and power supplies.

### Chapter 6, “Working Your Weapons: Using Test Equipment”

- Digital multimeter: measuring voltage, current and resistance.
- Oscilloscope: detailed, button-by-button operation, including delayed sweep measurements.
- AC and DC signal components, rolloff and other issues affecting measurement strategy.
- Soldering and desoldering techniques.
- Bench power supply: voltage and current considerations, DC plug polarity.
- Transistor tester.
- Capacitance meter.
- Signal generator.

- Frequency counter.
- Analog meter: when to use it, interpreting the wiggling meter needle, tests not possible with a digital instrument.
- Contact cleaner spray: what to use it on, what not to.
- Component cooler spray: solving thermal intermittents, considerations for safe use.

## **Chapter 7, “What Little Gizmos Are Made of: Components”**

- Common parts: capacitors, clock oscillators, crystals, diodes, fuses, inductors and transformers, integrated circuits, op-amps, resistors, potentiometers, relays, switches, transistors, voltage regulators and zeners.
- Varieties of each type of part.
- Symbols, markings and photos.
- Uses: what components do in circuits.
- What kills them.
- How to test them out of circuit.

## **Chapter 8, “Roadmaps and Street Signs: Diagrams”**

- Block, schematic and pictorial diagrams.
- Learning to read diagrams like a story: signal flow, organization in stages.
- Symbols and call numbers.
- Good, average and bad diagrams.
- Part-by-part analysis of individual stages and their functions. Amplifier example.
- Organization of larger structures. Switching power supply example.
- Practicing reading: looking for stages and structures in radios and DVD players.
- Working without a diagram.
- Case history of troubleshooting an LCD TV without a schematic.

## **Chapter 9, “Entering Without Breaking: Getting Inside”**

- Separating case halves: hidden snaps.
- Disconnecting ribbon cables.
- Layers: disassembling in order, use of digital photos and nested cups.
- Disassembly tips for common products: receivers, VCRs, DVD players, flat-panel TVs, turntables, video projectors, MP3 players, PDAs, cell phones, camcorders, digital cameras and laptop computers.

## **Chapter 10, “What the Heck Is That: Recognizing Major Features”**

- What various sections of circuitry look like: descriptions and photos.
- Recognizing sections from components specific to their functions: inductors, power transistors, and so on.
- Power supplies: linear and switching.
- Backlight inverters.

- Signal processing areas, analog and digital.
- Digital control sections.
- Output stages: discrete transistors and integrated modules.
- Mechanisms: video head drum, capstan motor, laser optical head and DLP color wheel.
- Danger points.

### **Chapter 11, “A-Hunting We Will Go: Signal Tracing and Diagnosis”**

- Where to begin, based on observed symptoms.
- Dead, comatose or crazy, alive and awake but not quite kicking.
- Intermittents: thermal and mechanical, bad solder joints, board cracks, positional and vibration-sensitive.
- Working forward or backward through stages: when each technique is appropriate.
- Stages, test points and making sure you’re in the right place.
- Zeroing in on bad components.
- Desperate measures: shotgunning, current blasting and LAP method.

### **Chapter 12, “Presto Change-O: Circuit Boards and Replacing Components”**

- Desoldering through-hole and surface-mount components.
- Choosing replacement parts: new, from your stash and from parts machines.
- Substituting similar parts when you can’t get the exact replacement: vital characteristics that must be matched or exceeded, and allowable differences in capacitors, diodes, resistors, transistors and zeners.
- Installing new parts: through-hole and surface-mount, mounting power transistors.
- Finding components: standardized, proprietary, local, mail-order, new and surplus.
- Saving damaged boards: bridging broken conductors and bad layer interconnects.
- Reflowing solder on high-density integrated circuit chips.

### **Chapter 13, “That’s a Wrap: Reverse-Order Reassembly”**

- Common reassembly errors.
- Ensuring good ground connections on boards and chassis.
- Lead dress: placement of wires and cables, physical and thermal risks, electromagnetic interference.
- Reconnecting ribbon cables.
- Repairing damaged ribbon sockets.
- Reversing layer and cup order.
- Rejoining plastic snaps.
- Reinserting screws: tension and correct placement.
- Final test.

## Chapter 14, “Aces Up Your Sleeve: Tips and Tricks for Specific Products”

- How they work, what can go wrong, when repair is worth doing, dangers within, and how to fix them.
- Switching power supplies, receivers, disc players and recorders, flat-panel displays, hard drives, laptop computers, MP3 players, VCRs, camcorders and video projectors.

Whether or not you've already had your hands inside some electronic devices, this book will guide you from the “maybe it's the fuse” level to the “ah, the biasing diode on the output stage is open” point. It will help hone your sleuthing skills with logic and a solid foundation in how things work, until you feel like an ace detective of electrons. At the very least, it'll leave you fascinated with everything that goes on inside your favorite gadgets and eager to tackle everything that comes your way. *Everything*...maybe it's not such a scary word after all.

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# Chapter 1

## Prepare for Blastoff: Fixing Is Fun!

Electronics is a lifelong love affair. Once its mysteries and thrills get in your blood, they never leave you. I became fascinated with circuits and gadgets when I was about 5 years old, not long after I started playing the piano. There may have been something of a connection between the two interests—both involved inanimate objects springing to life by the guidance of my mind and hands. Building and repairing radios, amplifiers and record players always felt a little like playing God, or perhaps Dr. Frankenstein: “Live, I command thee!” A yank on the switch, just like in the movies, and, if I had figured out the puzzle correctly (which was far from certain at that age), live it would! Pilot lights would glow, speakers would crackle with music and faraway voices, and motors would turn, spinning records that filled my room with Haydn, Berlioz and The Beatles. It was quite a power trip (okay, a little pun intended) for a kid and kept me hankering for more such adventures.

By age 8, I was running my own neighborhood fix-it business, documented in an article by *The Miami News* titled “Little Engineer Keeps Plugging Toward Goal.” Repairs usually ran about 25 cents, and I had customers! Neighborhood pals, their families and my dad’s insurance business clients kept me busy with malfunctioning radios and tape recorders. I even fixed my pediatrician’s hearing tester for 50 cents. If only I’d known what *he* was charging....

My progression from such intuitive tinkering to the understanding required for serious technician work at the employable level involved many years of hands-on learning, poking around and deducing which components did what, and tracing signals through radio stages by touching solder joints with a screwdriver while listening for the crackling it caused in the speaker. Later came meters, signal tracers and, finally, the eye-opening magic window of the oscilloscope.

Ah, how I treasure all the hours spent building useful devices like intercoms and fanciful ones like the Electroquadrastatic Litholator (don’t ask), fixing every broken gadget I could get my hands on, and devouring *Popular Electronics*, *Electronics Illustrated* and *Radio-Electronics*—great magazines crammed with construction articles and repair advice columns. Only one issue a month? What were they waiting for??

C'mon, guys, I just have to see the last part of that series on building your own color TV camera, even though I'll never attempt it. But now I know how a vidicon tube works! And, thanks to my parents' wise and strict rule that I experiment only on battery-powered items, I survived my early years to share my enthusiastically earned expertise with you, the budding tech.

After graduating from the Boston Conservatory of Music, I did what any highly trained, newly certified composer/conductor does: I completely abandoned my field of study and started working in electronics! I was a tech in repair shops, I programmed computers, and I developed circuitry and software for several companies around Boston and New York, while building my own inventions and running a little mail-order company to sell them. All of those experiences integrated into the approach I will present in this book, which includes inductive and deductive reasoning, concepts of signal flow and device organization, taking measurements, practical skills and tips for successful repair, a little bit of art, and even a touch of whimsy here and there.

No book can make you an expert at anything; that takes years of experience and squirreling away countless nuggets of wisdom gleaned from what did and didn't work for you. My hope is that this distillation of my own hard-won understanding will infect you with the love of circuits and their sometimes odd behaviors, and start you on the very enjoyable path of developing your skills at the wonderful, wacky world of electronic repair.

So, warm up your soldering iron, wrap your fingers around the knobs of that oscilloscope and crank up the sweep rate, 'cause here we go!

## Repair: Why Do It?

When I was a kid, there were radio and TV servicemen in many neighborhoods. If something broke, you dropped it off at your local electronics repair shop, which was as much a part of ordinary life as the corner automotive service garage. These days, those shops have all but disappeared as rising labor costs and device complexity have driven consumer electronics into the age of the disposable machine. When it stops working, you toss it out and get a new one. So why fix something yourself? Isn't it cheaper and easier just to go out to your local discount store and plunk down the ol' credit card?

It might be easier, but it's usually not cheaper! Sans the cost of labor, repair can be quite cost effective. There are lots of other good reasons to become a proficient technician, too:

- *It's fun.* You'll get a strong sense of satisfaction when your efforts yield a properly working gadget. It feels a bit like you're a detective solving a murder case, and it's more fun to use your noodle than your wallet.
- *It's absorbing.* Learning to repair things is a great hobby to which you can devote many fruitful hours. It's good for your brain, and it beats watching TV any day (unless you fixed that TV yourself!).

- *It's economical.* Why pay retail for new electronics when you can get great stuff cheap or even free? Especially if you live in or near a city, resources like craigslist.org will provide all the tech toys you want, often for nothing. Lots of broken gadgets are given away, since bringing them in for repair costs so much. They're yours for the taking. All you have to do is fix 'em!
- *It can be profitable.* Some of the broken items people nonchalantly discard are surprisingly valuable. When your tech skills become well developed, you'll be able to repair a wide variety of devices and sell what you don't want for yourself.
- *It can preserve rare or obsolete technology.* Obsolete isn't always a negative term! Some older technologies were quite nice and have not been replaced by newer devices offering the same features, utility or quality. The continued zeal of analog audio devotees painstakingly tweaking their turntables offers a prime example of the enduring value of a technology no longer widely available.
- *It's green.* Every product kept out of the landfill is worth two in ecological terms: the one that doesn't get thrown away and the one that isn't purchased to replace it. The wastefulness of tossing out, say, a video projector with a single capacitor is staggering. To rip off an old song, "Nothing saves the green'ry like repairing the machin'ry in the morning...."
- *Your friends and family will drive you crazy.* Being a good tech is like being a doctor: everyone will come to you for advice and help. Okay, maybe this one isn't such an incentive, but it feels great to be able to help your friends and loved ones, doesn't it? Being admired as an expert isn't such a terrible thing either.

## Is It Always Worth It?

While it's often sensible to repair malfunctioning machines, sometimes the endeavor can be a big waste of time and effort, either because the device is so damaged that any repair attempt will be futile or the cost or time required is overwhelming. Part of a technician's expertise, like a doctor's, lies in recognizing when the patient can be saved and when it's time for last rites and pulling the plug—in this case, literally! Luckily, in our silicon and copper realm, those destined for the hereafter can be recycled as parts. A stack of old circuit boards loaded with capacitors, transistors, connectors and other components is as essential as your soldering iron, and you'll amass a collection before you know it.



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