

Troubleshooting ELECTRONIC CIRCUITS

A Guide to Learning Analog Electronics



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RONALD QUAN

Troubleshooting Electronic Circuits

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Troubleshooting Electronic Circuits

*Debugging and Improving
Your DIY Projects
and Experiments*

Ronald Quan



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Contents

Preface	xi
Acknowledgments	xiii
1 Introduction	1
Goals of this Book	2
Quick Notes: Replacing Electrolytic Capacitors and Soldering	2
Soldering Problems (Cold Solder Connections)	3
Summary	5
2 Basic Breadboards	7
Solderless Breadboards	7
Quality	8
Power Buses on Solderless Breadboards ... Look for Breaks in the Power Bus Lines	10
And Now Some Words of Caution	13
Other Breadboards	14
3 Power Sources: Batteries and Battery Holders, Safety Issues, and Voltmeters	17
Batteries	17
Again, a Word of Caution	19
Expected Battery Capacity	21
Safety Considerations	21
Survey of Digital Voltmeters	21
4 Some Basic Electronic Components	27
Capacitors	27
Radial and Axial Electrolytic Capacitors	33
Measure Twice, Install Once: Erroneously Marked Capacitors	35
Resistors	37
Using a DVM to Measure Resistance Values	40
Measuring Low Resistance Values	44

5	Diodes, Rectifiers, and Zener Diodes	49
	Diodes and Rectifiers	49
	Forward Voltage Across Anode to Cathode and Reverse Voltage Effects ..	54
	Testing Diodes and Rectifiers with Digital and Analog Volt Meters	56
	Schottky Diodes	60
	A Brief Look at Zener Diodes	63
	Some General Rules About Diodes	69
6	Light-Emitting Diodes	71
	The LED's Light Output	71
	LED "Minimum Turn On" Voltages	75
	Other Types of Green LEDs	81
	Problems with Paralleling Two LEDs with Different Turn-On Voltages ..	83
	Protecting LEDs from Damage Due to Reverse Voltage	
	Across the Anode and Cathode	86
	Some Keys Points About Light Emitting Diodes	88
7	Bipolar Junction Transistors	89
	Bipolar Junction Transistors	89
	What Happens When a Transistor Is Damaged	94
	Schematic Symbol of NPN and PNP Transistors	95
	Applying a DC Voltage to the Base of the Transistor	
	to Provide a Constant Current Source	96
	Improved Current Source Circuits	101
	What Happens When Things Go Wrong	107
	Insufficient "Headroom Voltage" for the Transistor	112
	Sometimes Even a Correct Circuit Goes Bad	114
	Summary	115
8	Troubleshooting Discrete Circuits (Simple Transistor Amplifiers) ..	117
	Important Practical Transistor Specifications	117
	Simple Transistor Amplifier Circuits	118
	First DC Analysis: Capacitors = Batteries with Self Adjusting Voltages ..	120
	Second DC Analysis: Take Out the Capacitors to Find the	
	DC Currents and DC Voltages	121
	Finding the AC Signal Gain	124
	Limited Input Amplitude Range	130
	Output Swing Determined by IC and $R_L R_2$	133
	Troubleshooting the One-Transistor Amplifier	135
	Using Negative Feedback to Build "Mass Production" Amplifiers	135
	DC Analysis of Self-Biasing Amplifier	136
	AC Analysis of a Self-Biased Amplifier	139
	Output Resistance R_o'	144

Another Common Emitter Amplifier	148
Troubleshooting the Amplifier in Figure 8-31	152
Maximum Output Voltage Swing	155
Amplifier's Emitter AC Grounded via CE	156
Amplifier's Emitter Partially AC Grounded via Series RE2 and CE2	156
Finding an Optimum Bias Point for Maximum Output Swing with Just an Emitter Resistor	158
Summary	159
9 Analog Integrated Circuits Including Amplifiers and Voltage Regulators	161
Operational Amplifiers	161
Maximum Safe Power Supply Voltage	171
Minimum Power Supply Voltage	172
Caution on Providing Supply Voltages	173
Maximum Output Current	174
Output Voltage Range	179
Input Signal Range	179
Non-Inverting Gain Amplifiers	182
Inverting Gain Amplifiers	192
A Short Look at Linear Voltage Regulators	201
Drop-Out Voltage Summary	203
Voltage Selections, Packages, Pin Outs and Schematics	204
Knowing the Pin Out Sequence Is Important	205
Low-Drop-Out Voltage Regulators	206
10 Audio Circuits	213
Preamps and Power Amps	213
A Basic Difference Amplifier	214
Dynaco PAT-5 Low-Level Preamp Section and Power Supply	221
Preamp's DC Bias Point Estimates	227
AC Analysis	229
A High-Fidelity Audio Power Amplifier	231
DC Biasing Conditions in Figure 10-9	234
AC Signal Conditions	236
11 Troubleshooting Analog Integrated Circuits	241
Circuits That Need Fixing or Redesigning	242
Photodiode Circuits	254
Trans-resistance Amplifiers	257
Summary	266
Reference Books	266

12	Some Ham Radio Circuits Related to SDR	267
	Software Defined Radio Circuits	267
	Some Troubleshooting Tips Concerning Figure 12-5 and Figure 12-7	277
	A Common Sample-and-Hold RF Mixer Circuit	279
	A Preferred Implementation with Sample-and-Hold Circuits	284
	A Cool Four-Phase Commutating Mixer	288
	DC Bias Conditions	293
	Testing Circuit with an RF or Function Generator	293
	Improving the “Original Design”	296
	Another View of Op Amp Circuits (Where the Inverting Input Drives a Load)	302
	Suggested System Approach	304
	Crystal Oscillators	304
	Types of Crystals	307
	Low-Frequency Cylindrical Crystals, “Standard” Crystals, and Ceramic Resonators	308
	Standard HC-49 and High-Frequency Cylindrical Crystals	308
	Ceramic Resonators	309
	Be Aware of Overtone Crystals	316
	Gain Bandwidth Product Revisited	318
	Summary	318
13	Timer, CMOS, and Motor Drive Circuits	319
	Types of 555 Timer Chips	319
	Basic Modes of the 555 Timer Chip and Pin Outs	320
	The 555 Pulse Generator (a.k.a., One-Shot or Monostable Mode)	321
	Troubleshooting the 555 One-Shot Monostable Timer	324
	When You Want to AC Couple a Signal to Trigger a Pulse Output Signal	325
	“Strange” Output Signals Observed via an Oscilloscope	328
	Troubleshooting the 555 Oscillator (a.k.a. Astable Mode)	329
	One More Example on Driving Speakers with the 555	332
	Why Again an Output Coupling Capacitor Is Preferable	332
	Using a 555 to Drive Motors via Pulse-Width Modulation	338
	Summary of Troubleshooting Techniques	346
14	Troubleshooting Other Circuits, Including Kits and Projects	347
	Component Kits and Test Equipment	347
	LED and Sensor Kits	349
	A Quick Detour with the LM386 Audio Power Amplifier IC	354
	Photonics: A Light Transceiver System	356
	Thermal Sensing Circuit via Thermistor (Temperature-Dependent Resistor)	361

	A Circuit Using an Electrolytic Capacitor Incorrectly	370
	Identifying and Fixing “Bad” Circuit Designs	375
	An Example of the Missing Ground Connection	378
	Ferrite Beads to Tame Parasitic Oscillations	382
	Summary	386
15	More Tips and Final Thoughts	387
	Deciphering Schematics with Too Many Connection Flags	388
	Troubleshooting with Minimal Test Equipment	393
	Analog Meter Driving Circuits for AC Signals	393
	Troubleshooting an Older Push Pull Audio Amplifier in a 1950s Transistor Radio	396
	Reducing Noise on the Power Supply Bus with Multiple Circuits ..	403
	Bad Connections from Some IC Sockets	405
	Summary and Final Thoughts	406
A	Choosing Test Equipment	411
	Lab Power Supplies (Adjustable)	411
	Signal Generators	414
	Oscilloscopes	415
	Examples of Display Resolution and Number of Memory Points	417
	Oscilloscope Probes	420
	An Inexpensive Lab	422
B	Online Learning Resources	425
C	Components and Parts Suppliers	427
	General Electronic Components	427
	Transistors, FETs, Diodes, LEDs, Photodiodes, and ICs	427
	Low-Noise Transistors and JFETs, Including Matched Pairs	427
	Passive Components, Resistors, Capacitors, Fixed Valued Inductors, Transformers, Tools, Soldering Irons, Breadboards, and Solder	427
	Kit Parts for Transistors, Diodes, Capacitors, Resistors, LEDs, and More	428
	Ham Radio Parts	428
	Crystals, Inductors, Capacitors, Transistors, RF Transistors, Transformers, and ICs	428
	Oscillator Coils, IF Transformers, and Audio Transformers	428
	Antenna Coils	428
	Variable Capacitors	428
	Science Kits, Cool Things, and Everything Else	429
	Index	431

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Preface

This book on troubleshooting analog circuits is intended for the hobbyist, student, educator, or engineer. Because the subject is more into debugging or improving circuits, the book does not require the reader to have an engineering background.

Students who take electronics classes at the technician or engineering level may find this book useful. Some chapters will include basic electronics theory (with some high school algebra). However, we will not be looking for exact calculations when troubleshooting. Instead, approximations will be presented.

Hobbyists who read this book will not only learn troubleshooting techniques. They will also gain insight into why some circuits perform badly. Suggested circuit modifications will be offered to improve the performance of these types of circuits.

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Some material in this book pertaining to building circuits and entry-level electronics came from working with many students and Professor Robert W. Dutton at Stanford University. I give my greatest thanks to Bob Dutton for inviting me into the Electrical Engineering Department as a mentor and as a lecturer for his classes.

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Another person who inspired me is Professor Robert G. Meyer at the University of California, Berkeley. His class notes, books, and lectures played an important role for me in writing about distortion analysis. So thank you, Bob Meyer!

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During this whole process I have been indebted to the following friends for encouraging and supporting me: Alexis DiFirenzi Swale, Germano Belli, Jeri Ellsworth, Phil Sittner, Edison Fong, and Amy Herndon.

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William K. Schwarze, who was my best teacher at Galileo High School, also deserves thanks for his ability to convey mathematical concepts in a very clear manner to me. Also, my friend James D. Lee continues to be an inspiration to me.

Finally, I acknowledge a big debt of gratitude to members of my family: William, George, Thomas, and Frances, for their support.

And, of course, I dedicate this third book to my parents, Nee and Lai.

Troubleshooting Electronic Circuits

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CHAPTER 1

Introduction

This book will cover mostly analog circuits and will include a few timer and logic circuits.

Troubleshooting electronic circuits takes a great deal of detective work. We must have a good idea of how the circuit should work. For example, in an amplifier, we would expect that the amplifier's output provides a larger voltage or current compared to the input signal.

When a circuit does not work as expected, we should check the wiring and solder connections, then double-check the components' value (e.g., correct value resistors and capacitors) along with confirming that the power supply is connected properly. With other test equipment such as a voltmeter or oscilloscope, we begin to trace parts of the circuit for direct current (DC) voltages and alternating current (AC) signals. Eventually we may find where the AC signal disappears, which then allows us to replace a part or confirm whether the original part was connected correctly.

I am writing this book based on observations from my students and colleagues. In most cases, you do not have to be an electrical engineer to troubleshoot circuits. As a matter of fact, many fresh-out-of-school graduates will have limited skill in troubleshooting if they did not have electronics as a hobby most of their lives.

For the hobbyist, just a basic knowledge of using electronic components and test equipment goes a long way. It is more likely that sometimes a hobbyist or a technician will be a better troubleshooter than a young engineering graduate. The reason is that troubleshooting is more of an experience-based skill. If you have been working with many different circuits by building them and probing them (e.g., with a voltmeter and oscilloscope) you will have learned some essential practical knowledge. And if you start learning some electronics theory combined with practical electronics knowledge that includes understanding how to use volt-ohm-meters, oscilloscopes, and signal generators, then you will be able to troubleshoot circuits even better.

To troubleshoot analog circuits, we need to understand components very well via their data sheets (e.g., maximum voltage or power ratings), know how to use test equipment, and understand signals.

Goals of this Book

We will start with components because understanding their specifications and limitations is key to troubleshooting. For example, if you are using a 12-volt circuit but your component is rated at 10 volts, then most likely that component will fail at some point. Also, in some cases, which are rare, an integrated circuit's (IC's) pinouts may be different between its through-hole version (e.g., 8-pin DIP, dual inline package) and its surface mount SO-8 (small outline, 8-pin) counterpart, such as the AD633 analog multiplier chip.

Therefore, the first six chapters are devoted to passive devices, breadboards, and volt ohm milliamp meters. We show how to test these types of components, which is really essential these days because a 10 pf capacitor and a 1 μ f capacitor may look nearly identical (e.g., in size) with really small print that is hard to read and easy to mistake one for the other.

When building circuits, we should verify the components' value by inspection and sometimes by measuring them (e.g., for resistance, capacitance, and polarity or confirming NPN or PNP transistors) before soldering or placing them into a circuit board. A variation of the old saying of "measure twice and cut once" can be readapted to "measure twice and solder once."

From Chapters 7 to 15, amplifying devices, integrated circuits, and some electronic systems are presented as examples for troubleshooting audio, RF (radio frequency), timer, and power supply circuits. Some of these circuits come from older hobbyist magazines, books, or postings on the web. We will explore circuits that "kind of work," which can be improved, debugged, or modified for better performance.

Quick Notes: Replacing Electrolytic Capacitors and Soldering

For now, here's a short summary on troubleshooting techniques for the experienced hobbyist concerning (aluminum) electrolytic capacitors.

If you are restoring older electronic devices such as radios, tape recorders, stereos, power supplies, signal generators, etc., you should most likely replace all the electrolytic capacitors with the same (or sometimes larger) capacitance and voltage rating. For example, if there is a 100 μ f, 10-volt electrolytic capacitor that has lost its capacitance or became leaky, you can replace it with a new 100 μ f, 16-volt version. Of course, make sure that the replacement capacitor is installed correctly in terms of

polarity. Also, if the device runs off the power outlet (e.g., 110 volts AC or 220 volts AC), then make sure you completely disconnect its 110v/220v power cord from the wall (or mains) outlet before repairing the device.

Even in many newer devices, you can spot a bad electrolytic capacitor by noticing if the case is bulging. For example, normally the top of an aluminum electrolytic capacitor is flat, but a bad one might be curved up like having a mound added on top of the capacitor. Also, if there are chemical residues near the leads (e.g., white or blue powder, gel, or liquid), these are telltale signs of a bad electrolytic capacitor. See Figure 1-1 that shows a residue leak.



FIGURE 1-1 A bad capacitor on the left side (A), and a good capacitor on the right side (B).

Should you decide to repair or restore older electronic devices from the 1950s to 1980s, keep in mind that aluminum capacitors have about a 15-year life. However, if they are in a warmer environment such as in a TV camera, electrolytic capacitors can fail within 5 years.

Soldering Problems (Cold Solder Connections)

If you are starting out in electronics, then you can build circuits with solderless breadboards, solder your own circuits, or purchase preassembled soldered boards. For troubleshooting, sometimes you will be required to solder when working with new circuits, replacing components, or repairing/modifying printed circuit assemblies. When soldering connections, we must avoid making cold solder joints where the solder may have been “tacked” or “dabbed” onto the circuit, or the solder had not melted sufficiently. See Figure 1-2.

In Figure 1-2, we see that all connections can be improved by just reheating and adding a little more solder until the connections create a smooth mound of solder. If your connections have a “spiky” look similar to number 3 in Figure 1-2, then you may only have a temporary connection that can easily be disconnected with a slight pull on the wire. Generally, spend an extra few seconds on the solder joint to allow the solder to flow all around the connection. See Figure 1-3.



FIGURE 1-2 Bad solder connection examples.



FIGURE 1-3 A good connection where the solder has been heated sufficiently to flow properly.

Summary

Throughout this book we will include basic electronics circuit theory such as Ohm's Law applied to the associated circuits that are discussed.

Finally, do not forget to read Appendix A, which covers choosing test equipment (e.g., power supplies, oscilloscopes, and generators) and shows some of their limitations.

And now let's proceed to Chapter 2.

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CHAPTER 2

Basic Breadboards

This chapter will examine various breadboards for constructing circuits. We will cover solderless breadboards, copper clad bare printed circuit boards, and perforated or vector boards.

Let's first look at solderless breadboards, which can vary in size and quality.

Solderless Breadboards

In Figures 2-1 and 2-2, we see two different types of solderless breadboards. Note that each of them has tabs (e.g., Tab1, Tab2, and Tab3) that allow multiple boards of the same type/size to be expanded.

Let's start with Figure 2-1's solderless breadboard. In each column, there is a column number (e.g., 1 to 30) and five rows (a to f and g to l).

Each column (e.g., column 1 to 30) is connected from rows a to f in the upper portion of the breadboard. And on the lower portion each column (e.g., column 1 to 30) from rows g to l is connected.

The columns 1 to 30 from the upper portions with rows a to f are independent and not connected to any of the columns in the lower portion, such as columns 1 to 30 and row g to l.

Stated in other words, each column is independent and not connected to any other column, even if they are on the upper or lower portion of the breadboard. For example, column 1 is insulated and not connected to any other column such as column 2.

For the example in Figure 2-2, each column from 0 to 60 on the top rows, and on the lower rows the five locations in rows A to E and F to J are connected together. For example, the hole in column 1 row A is only connected to column 1 rows B, C, D, and E. The same connections apply to the other columns, for example, column 3 row F is only connected to column 3 rows G, H, I, and J.

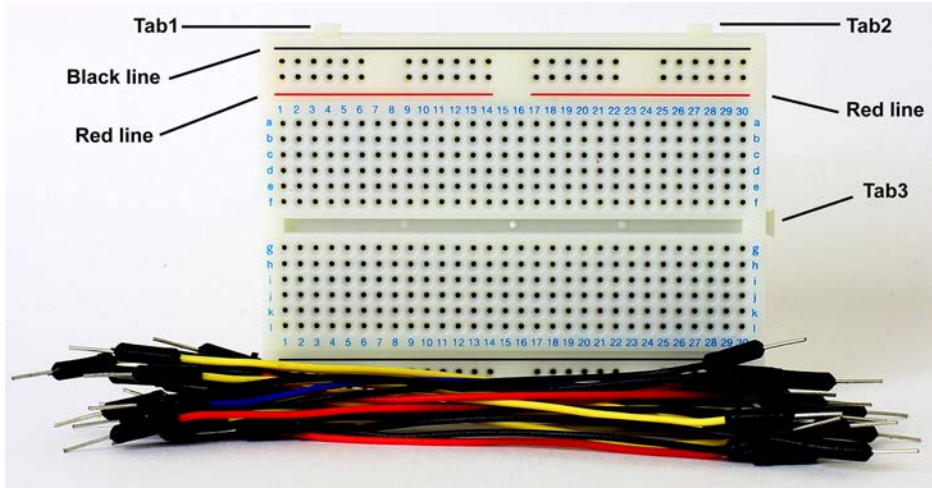


FIGURE 2-1 A small 30-column solderless breadboard with wire jumper connectors.

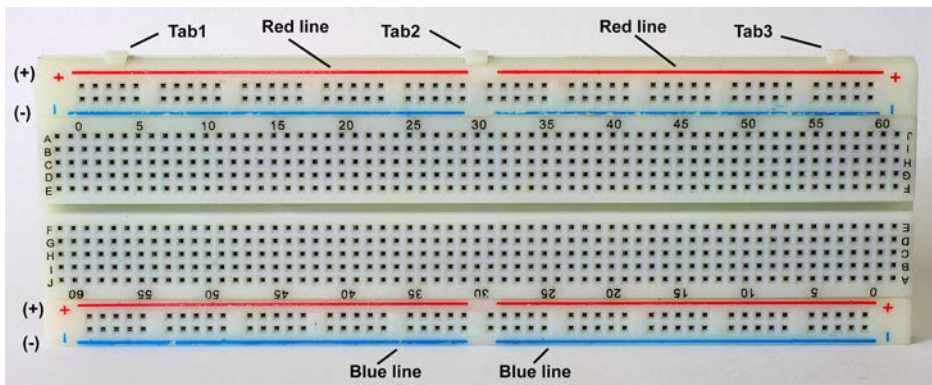


FIGURE 2-2 A larger-sized solderless jumper board with 60 columns. The power buses are denoted by the red and blue lines running across the solderless breadboard.

There are two power buses denoted by red and blue lines toward the edge of the board. We will discuss power buses in more detail later; some are broken into “sectors” within the board, and others are not.

Quality

Figure 2-3 shows a high-quality solderless breadboard where the connectors inside the wells or holes do not cause wire or leads from electronic parts to be jammed.

As we can see in Figure 2-4, the holes or wells labeled “Bad” are closed off, leaving less area to insert wire leads from components. The metal connector clips inside the holes should be expanded outward to allow a larger hole or well size for easier lead or wire insertion.

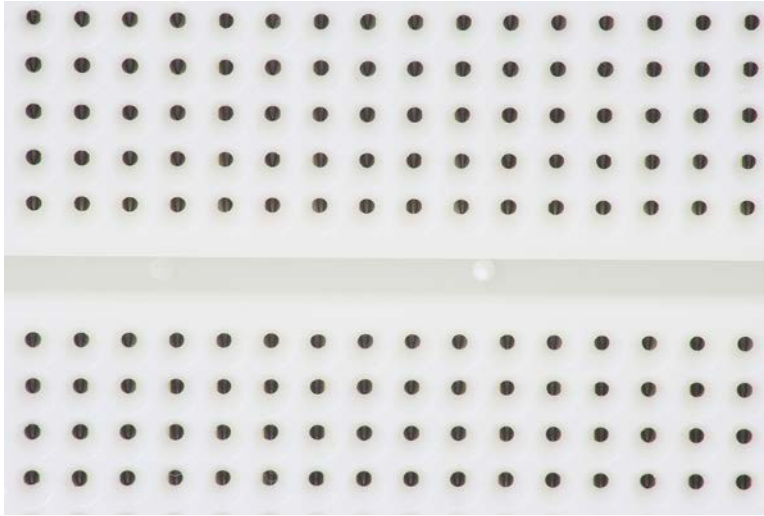


FIGURE 2-3 A high-quality solderless breadboard where the wells or holes are clear and allow for easy insertion of wire leads from electronics components such as resistors, capacitors, etc.

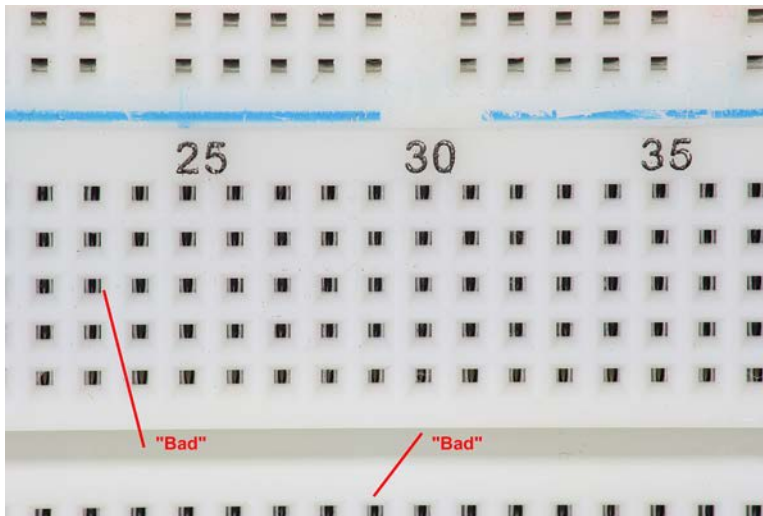


FIGURE 2-4 A lower-quality solderless breadboard with internal connectors or "blades" narrowing the pathways for inserting wires or electronic components.

So be on the lookout for these and avoid them because plugging in resistors, capacitors, and wires will be difficult. One possible workaround on this is to order parts (e.g., resistors and capacitors) with thinner leads. However, you may find that the standard solderless jumper wires may have difficulty plugging in with these partially blocked or narrowed wells.