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Knowm Memristor Discovery Manual

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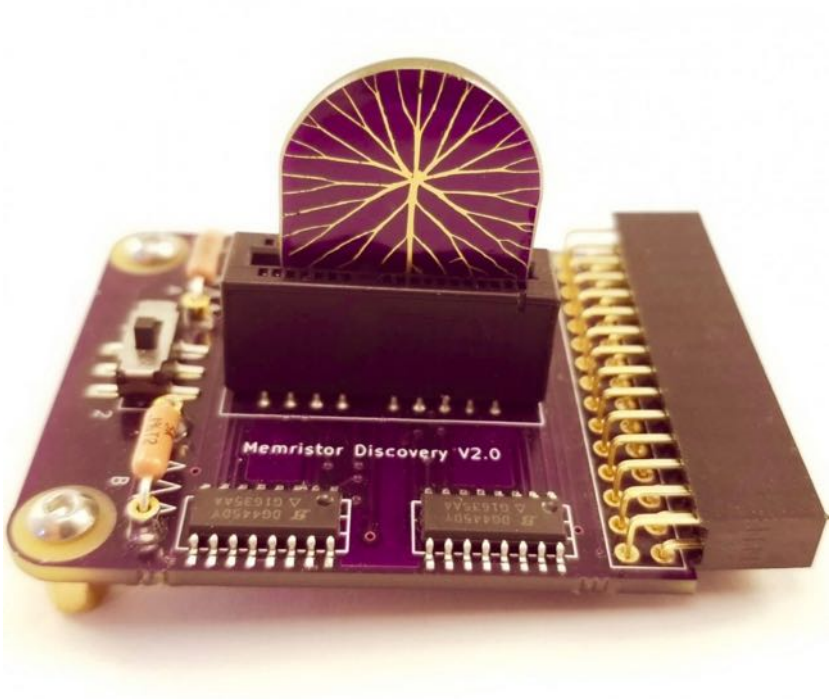

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1 Setup

1.1 Introduction

Welcome to the very new and exciting world of memristors! This guide will help you set up the Memristor Discovery hardware and software on your computer and guide you through some memristor experiments to help you get a better understanding of how memristors work. While the idea of a memristor has been around for many decades and many research labs around the world are constantly testing new memristive materials, Knowm's Metal-doped Self Directed Channel (M-SDC) memristors are the world's first commercially available devices. This Memristor Discovery Kit is the first commercial low-cost memristor introductory platform and currently the only way an average person can get hands-on experience with memristors. This is because Knowm SDC memristors are truly revolutionary. In addition to having many ideal memristor properties, they can be fabricated at high yields and have long shelf-lives. This has enabled us to move the experimental technology out of the laboratory of inventor Dr. Kris Campbell at Boise State University and into your hands. We hope you will help us to further understand this technology and build the adaptive circuits of tomorrow. Indeed, by purchasing this kit you have already helped to move the technology into the world, joining a growing community of researchers, educators, makers and inventors.

1.2 Memristor Discovery History and Purpose

We originally designed the Memristor Discovery board and software as a low cost risk mitigation step to building a Thermodynamic RAM (kT-RAM) core, a differential memristor pair "synaptic processor". Since 2015 we have been selling memristors to researchers around the world, and in a number of cases we got requests to help understand why their particular experimental setup was not working correctly. Given everybody has a unique lab setup with unique equipment, this is simply not possible for us–but we stand by our memristors and wanted to find a way that we could all 'get on the same page'. At the same time we were discouraged by the high price of most laboratory equipment. We realized that we could expand Memristor Discovery to provide a more general introductory platform for others. We decided to open-source the code and started to sell the boards, which we hand-soldered and populated one at a time as the orders came in. To our surprise, we sold more memristors in the kits than without proving the need of the platform. We have since continued to refine the software, fix bugs, add more experiments, make new board generations and write more documentation. The goal of Memristor Discovery is to provide an affordable college or advanced high school hands-on introduction to memristors. It will take you from basic DC response all the way to adaptive synapses and a learning classifier.

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1.3 Unboxing

Depending on which kit you purchased, you should see items as in Figure 1. This guide can be used for all versions of the kit, which differ only slightly. The version 0.0 board contains a hard-wired memristor-resistor circuit with selectable memristors. The version 1.0 board has 1-4 Mux chips capable of dynamic routing of waveform generators and oscilloscopes as well as selectable memristors. The version 2.0 board accepts our new encapsulated chip-on-board chips with 16 memristors. The version 1.0 and 2.0 boards allow for adaptive synaptic and neuron experiments, although the version 1.0 board has been superseded with the more stable and reliable version 2.0 'common grounded anode' circuit. This manual was introduced concurrently with the release of the V2.0 boards.

(a) V0 (b) V1 (c) V2

Figure 1: Memristor Discovery Kit versions with contents. Packaging has been omitted from picture.

Each V2.0 Kit should contain the following items, as seen in Figure 2

1. Analog Discovery 2 Multi Instrument Tool
2. Memristor Discovery Board V2.0
3. Knowm SDC Memristor 1X16 Linear Array Chip
4. Female-Female wire jumpers
5. 30 pin connector dongle
6. USB Cable Magnetic Choke
7. USB Cable
8. Male-male pin headers

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9. PCI-E 36 Breakout Board

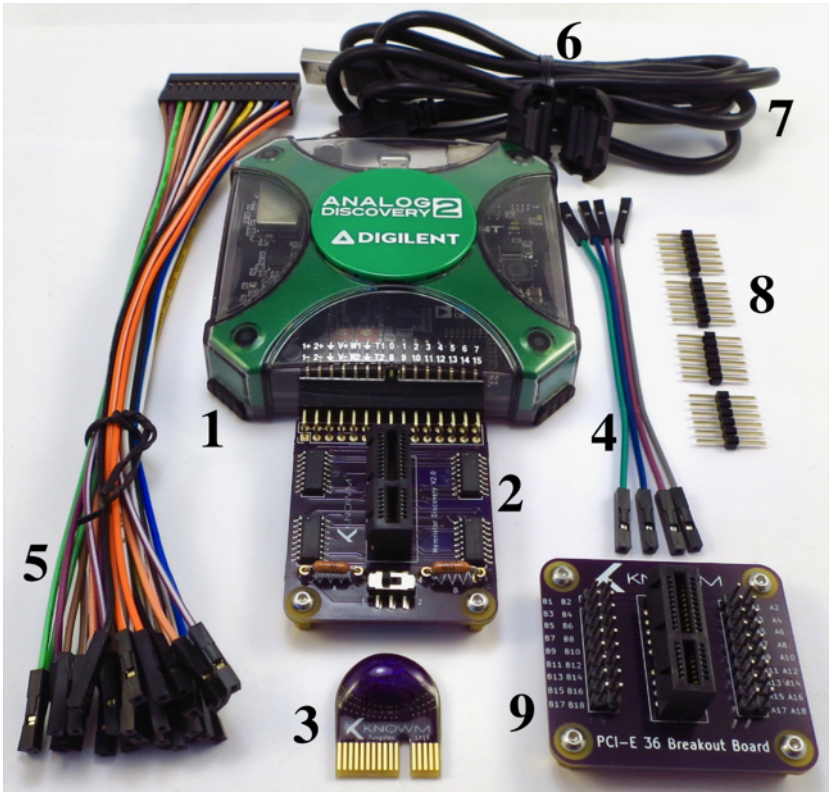

Figure 2: Memristor Discovery V2.0 Kit Contents

In addition to the above listed items, each kits contains a plastic box that comes with the Analog Discovery 2 that fits all the components.

WARNING: Do not directly touch or remove memristors from their packaging foam until your work station has been set up and you understand the basics of Electrostatic Discharge (ESD) and how to mitigate it.

1.4 Workstation Setup

You can use Memristor Discovery almost anywhere so long as you observe and understand a few things. The best location will be free from distraction, desk clutter, and electromagnetic interference. Your two main concerns are (1) Electro-Static Discharge (ESD) and (2) Electromagnetic interference. ESD is much more serious and has the potential to end the life of your memristors in a nanosecond. Electromagnetic interference can prevent your equipment from

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working properly, especially during capture of fast pulses, and is more of a frustration.

1.4.1 Electrostatic Discharge

Electrostatic discharge (ESD) is the flow of electricity between two electrically charged objects caused by contact–usually *you* and *the chip you just fried*. A buildup of static electricity can be caused by number of processes, for example walking across a floor, opening a plastic bag or using equipment such as spray cleaners, heat guns, etc. To be safe you should assume that everything around you has some sort of charge on it that is waiting to equalize with other objects when they come into contact.

Static Generation Method	Volts Generated (Humidity 15%)
Walking across a carpet	35,000 V
Walking on a vinyl floor	12,000 V
Pulling paper from vinyl bag	7,000 V
Worker at bench	6,000 V

Table 1: Electrostatic generation methods and voltages.

ESD becomes especially serious if you live in a dry climate. Just take a look at Figure 1 and realize that your memristors can be fried if you apply just 1 volt without proper current limiting (to be discussed). Take ESD seriously.

The best solution is to buy or build an ESD safe workstation. This involves insuring that the surface you are working on (your desk), the thing you are working with (the chip) and yourself are wired all to the same (ground) electrical potential. You can buy dedicated equipment for this, called an anti-static mat and a wrist strap, or you can create your own solution if you know what you are doing.

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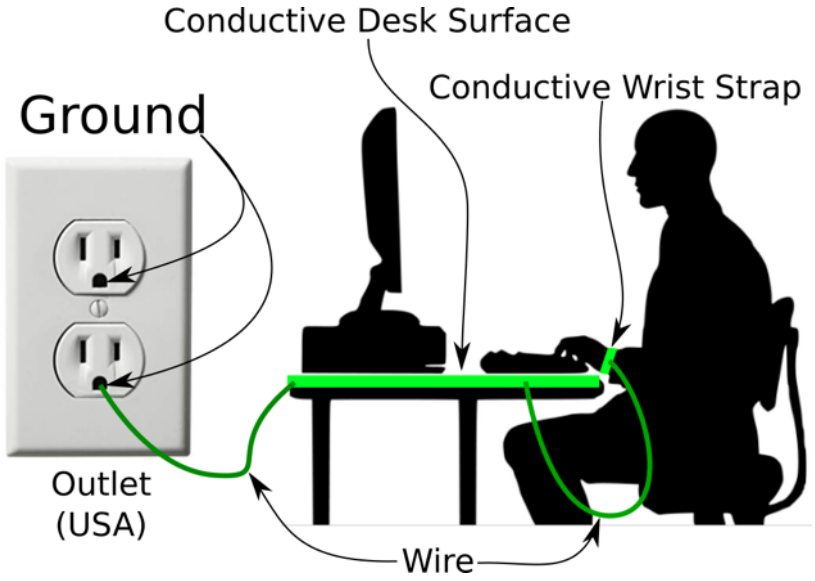

Figure 3: ESD Safe Workstation

The basics of an ESD safe workstation are shown in Figure 3. If your desk is metal and does not have paint or other coating that prevents electrical conductivity then you are almost all set–you simply need to wire yourself to your table and then wire your table to electrical ground. We will leave the details of this up to you. If you do not have an ESD safe workstation but really want to get started and are aware of the risks, we recommend the following:

1. Plug Memristor Discovery Board into the Analog Discovery 2
2. Plug the Analog Discovery 2 into your computer.
3. Make sure your computer is on.
4. Touch your finger to the left three pins between the board and the AD2 (the 1+, 2+, and Ground pins). Your are now at ground potential with all the electronics.
5. Remove the conductive black foam with Memristor chips from the bag and touch the foam against the three left pins of the AD2 as you did with your finger previously. The foam is now at ground potential.
6. Carefully place the chip into the board socket.

Anytime you are handling the memristor chips, even if at a ESD safe workstation, it is best to take care not to touch the pins as in Figure 4. When finished with the memristor chips, be sure to store them in an ESD safe configuration such as pressed (front side down) into the black conductive foam or otherwise all pins electrically shorted together.

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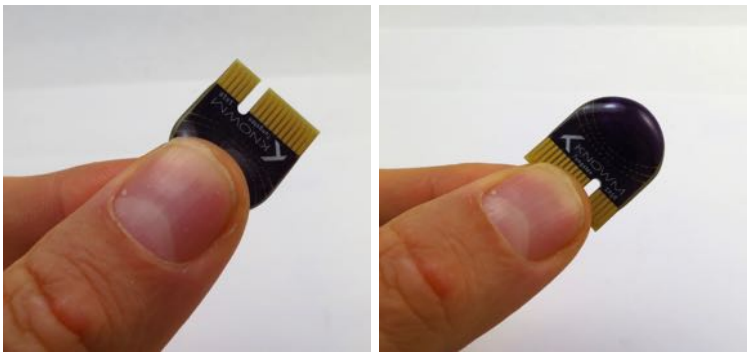

(a) Proper Way (b) Improper Way

Figure 4: Proper and improper way to handle the memristor chips. In other-words, try not to touch the pins.

1.4.2 Electromagnetic Interference

Electromagnetic interference is less of a concern than ESD, but it can and does cause problems. Electromagnetic radiation will induce voltage noise on metal wires that act as antennas. In all case but antennas, this is a problem. In our case it may cause a problem by introducing noise on the USB Cable. This makes it hard or impossible for the Analog Discovery 2 to communicate with your computer. There are only a few things you can do to mitigate electromagnetic interference.

1. Install the magnetic ferrite choke around your USB cable. See item 6 of Figure 2.
2. Use a shorter USB cable (also with a magnetic choke).
3. Change your work location.
4. Find the source of electromagnetic radiation and remove it.

1.4.3 Do Not Measure Resistance With A Multi-Meter!!!

A multi-meter can apply a voltage above the memristors threshold's without adequate current limiting. At best the memristor will change its conductance in response, making your measurments useless and very confusing. At worse, it will irreparably damage it via current overloading. Only apply voltages less than .1V with current limiting when measuring the resistance of a memristor.

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1.5 Software Installation

1.5.1 Digilent Waveforms

Download waveforms software suitable for your operating system and computer from the Digilent website: https://reference.digilentinc.com/reference/software/waveforms/waveforms-3/start

Follow the instructions dependent on your specific OS:

Mac OSX Move the dwf.framework to /Library/Frameworks and Waveforms to Applications, as indicated during the install of Waveforms from the DMG.

Windows Download and run the installer.

Linux Download Waveforms .deb file. Open up the terminal and type the following commands:

```
sudo mv ~/Downloads/digilent.waveforms_3.9.1_amd64.deb /var/cache/apt/archives
cd /var/cache/apt/archives
sudo dpkg -i digilent.waveforms_3.9.1_amd64.deb

sudo mv ~/Downloads/digilent.adept.runtime_2.19.2-amd64.deb /var/cache/apt/archives
cd /var/cache/apt/archives
sudo dpkg -i digilent.adept.runtime_2.19.2-amd64.deb
```

1.5.2 Analog Discovery Test and Calibration

Once Waveforms software has been installed, open the program and verify it is functional and communicating with the AD2. We suggest you take some time to learn how to use Waveforms as it is both flexible and extensive.

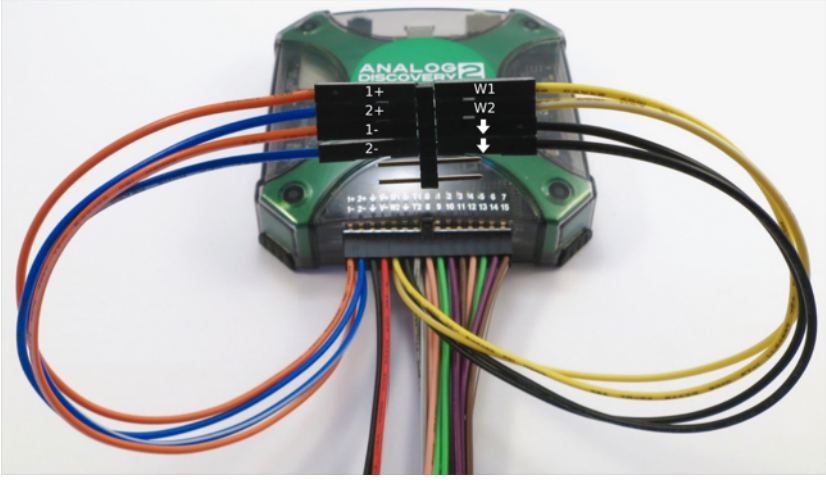

Figure 5: Waveform generator and scope self-test.