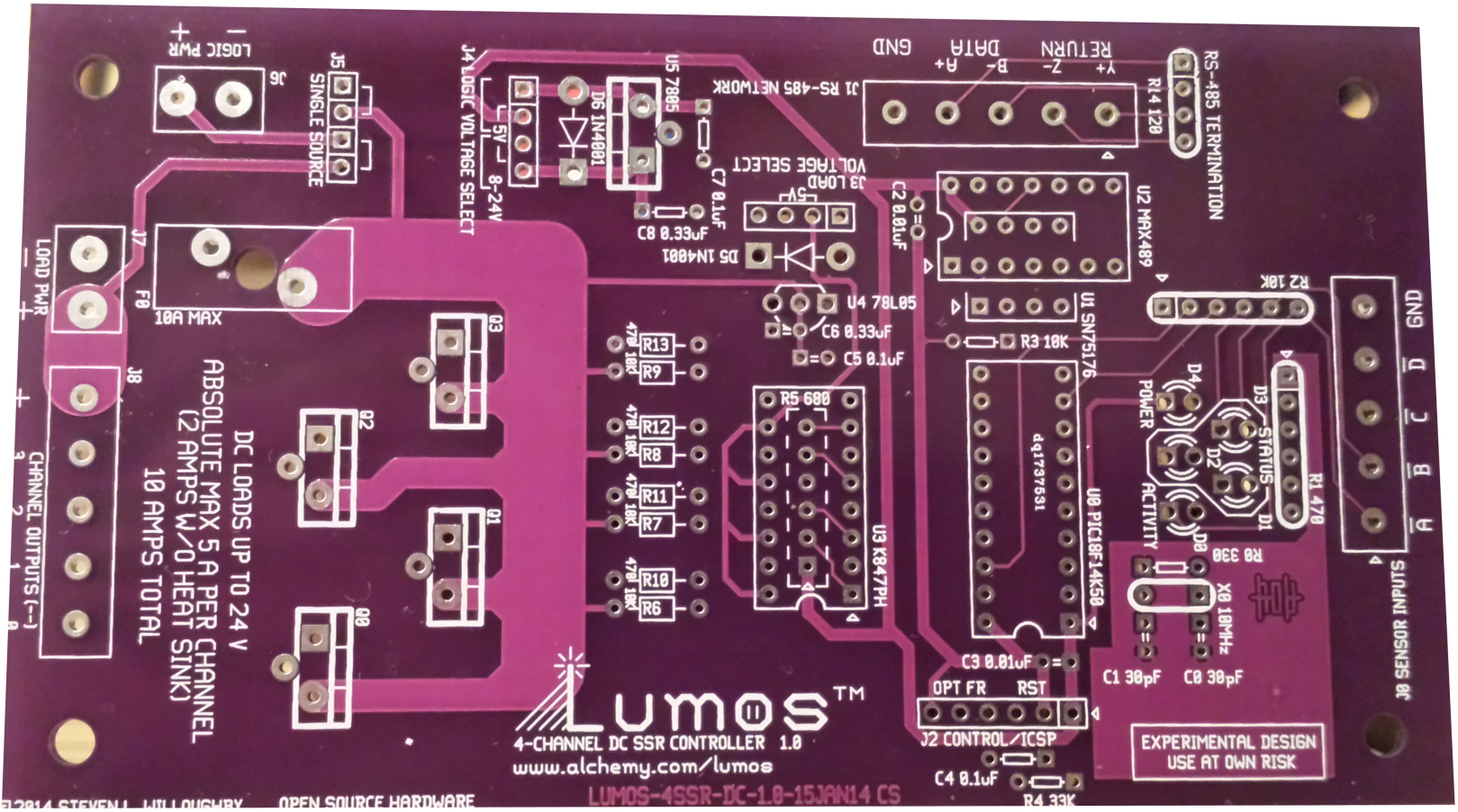
Installing the Lumos™ 4-Channel DC Controller



RISK OF FIRE, ELECTROCUTION, SERIOUS INJURY OR DEATH!

This circuit design, including but not limited to any associated plans, schematics, designs, board layouts, documentation, and/or components, is EXPERIMENTAL and for EDUCATIONAL purposes only. It is not a finished consumer-grade product. It is assumed that you have the necessary understanding and skill to assemble and/or use electronic circuits.

Proceed ONLY if you know exactly what you are doing, understand the proper procedures for working with the high voltage present on the components and PC boards, and understand that you do so ENTIRELY AT YOUR OWN RISK.

The author makes NO representation as to suitability or fitness for any purpose whatsoever, and disclaims any and all liability or warranty to the full extent permitted by applicable law.

Edition 1.0, for Lumos 4-Channel DC Controller circuit version 1.0.

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CHAPTER 1

INTRODUCTION

CONGRATULATIONS ON JOINING the many computer-controlled Christmas light enthusiasts, theatrical lighting technicians, electronics hobbyists, and home automation innovators who are experimenting with new ways to have computers control lights and other electronic devices.

The Lumos™ 4-Channel DC Controller board places four such devices under the control of your computer. These outputs are electrically isolated from the logic control circuit (although you may opt to forego that isolation and power the logic and loads from the same supply).

Since these Lumos boards use RS-485 for communications, up to sixteen Lumos boards may be "daisy chained" together and controlled from the same PC serial port. By plugging DC-powered Christmas lights into the Lumos controller, your PC can orchestrate a dazzling display of lights synchronized to music.

This manual assumes you have a Lumos controller board built and ready to put into operation. We will describe how to install it in a working circuit.

The operational details involved in getting the controller to work with software is described in *Using Lumos™ SSR Controllers.*

1.1 Intended Audience

This is an "advanced" level do-it-yourself electronic circuit project. It is not an off-the-shelf consumer-ready product. It is only designed for educational and experimental use by experienced hobbyists and professionals who possess the skill to construct electronic circuits, to understand how they function, troubleshoot problems with them, and to use them safely.

1.2 Limitation of Warranty

Since this is a do-it-yourself project, the quality of the final product, and whether it functions as intended, is largely a result of your own efforts in building it. As such, we cannot offer to troubleshoot, repair, or replace a board we did not assemble for you. Accordingly, these instructions, and all accompanying plans, schematics, software, hardware, and other project materials are provided to you "AS-IS" at no cost, as a courtesy between DIY hobbyists with NO WARRANTY of any kind expressed or implied. If you proceed to build and/or use this unit, you do so ENTIRELY AT YOUR OWN RISK.

If you purchased hardware materials from us (such as a PC board or programmed controller chip), we will—at our sole discretion—replace, repair, or refund the cost of those materials if they were defective in manufacture as shipped to you, up to 90 days from the date they were shipped to you, but are not liable for damage caused by your handling or assembly of the unit. Otherwise, we make no representation of suitability or fitness for any particular purpose and disclaim all other warranty or liability of any kind to the full extent permitted by law.

1.3 The Name of the Game

The name "Lumos" is a combination of *lumen*, the Latin word for "light," and the initial letters of "Orchestration System." Hence, "Light Orchestration System" which is the most common application for which the Lumos hardware and software are used—running computerized lighting displays.

CHAPTER 2

SAFETY INFORMATION

BEFORE YOU BEGIN INSTALLING your Lumos controller, please take the time to carefully read the following safety precautions. Failure to follow this advice could result in death or serious injury, damage to the Lumos controller unit, and/or damage to the other devices plugged into the controller.

2.1 Small Part Danger

This board contains small parts which could pose a choking hazard to small children. This product is not a toy and is not intended for use by children in any circumstance. The small parts on the product can be swallowed by children under 4 years of age. Keep out of reach of children.

2.2 Hazardous Voltage

Exercise care when working with any electrical system, including one such as the Lumos DC controllers (even though in theory they deal with low voltages). The power supplies of the loads plugged into the Lumos controller, and even the power loads being controlled, may present a shock hazard if not wired and handled using standard safety protocols. Never touch or work with live circuits. Always disconnect the power source before working on your Lumos controller.

When working with loads outdoors, be sure all supplies are plugged into GFIC-protected circuits.

2.3 Electrostatic Discharge (ESD) Warning

Many of the components used in this project are sensitive to static electricity. Always use a proper ESD-safe work environment when handling them, or these parts may be permanently damaged. If a part is damaged in this way, it is impossible to tell by looking at the part, and you won't necessarily feel the static discharge which caused the damage. Never take the risk of handling sensitive components without ESD protection in place.

These parts include all transistors, voltage regulators, diodes, and integrated circuits.

2.4 Circuit Loading

Always respect the maximum voltage and current capacity of the board and your wiring. Overloading any of these may result serious injury, death, fire, and/or severe damage to any or all of the devices in use.

The combined total of all four channels must not exceed 10 A. Each single output channel may not exceed 5 A. These should be considered *absolute maximum* tolerances. The board was designed to operate at sustained levels below those limits.

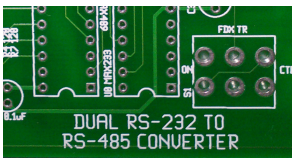
Also note that the Lumos output circuits were designed to control simple resistive loads such as LEDs and incandescent lights. They are not appropriate for all kinds of loads. Some inductive loads (for example, electromagnetic relays and motors) may require a protective "snubber" circuit which is not included in the Lumos product. Adding snubber components to a Lumos board would be a custom modification to the Lumos circuit and should not be attempted except by qualified engineers.

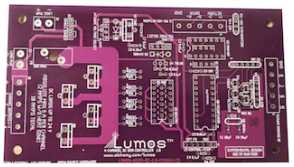
CHAPTER 3

What You Will Need

Before you begin installing your Lumos controller, please ensure you have the following materials and tools on hand, so you don't get caught part-way into the procedure and are unable to complete it.

- **A PC running the Lumos software.** This may be nearly any semi-modern PC. Lumos has successfully been run on systems as small as a laptop with 256 Mb of memory to large, high-performance servers. It may be run on Microsoft Windows, Linux, BSD UNIX, and Mac OSX. See the software manual *Using the Lumos Software* for full details. You may also use other software with Lumos controllers, such as the popular Vixen program (assuming compatible drivers are available and loaded), or a program which uses the DMX512 protocol (assuming the Lumos controller is configured for DMX512 operation).





- **An RS-485 converter.** Make sure the RS-485 converter you use matches the Lumos board's duplex mode (full or half). RS-485 converters are available from many vendors, and may plug into your computer's serial port or USB port. We also offer the plans to make your own RS-485 converter from scratch. See `www.alchemy.com/lumos/fp`.
- **One or more Lumos controller boards.** If more than one board will be used together, they all need to be RS-485 capable.
- **Weather-resistant enclosures for the Lumos boards if applicable to your application.**
- **Data cables.** You will need unshielded twisted-pair cables to carry the communication signals between the PC and Lumos board(s). The

wire may be CAT3, CAT5, or CAT6 type, with twisted pairs on pins 1–2, 3–6, 4–5, and 7–8. (This is the standard configuraiton for Ethernet cable—if you just use that kind of cable it will work just fine.) You will need one cable to connect the RS-485 converter to the first Lumos board, another cable from that Lumos board to the next, and so forth.

- **RS-485 terminator.** Both ends of the RS-485 "chain" must end in a terminator. Usually, your RS-485 converter will have a terminator built into it, so it can form one end of the chain by itself. If a 4-channel Lumos board is at one end of the chain, install resistor network R14 to terminate the chain at that point. Do *not* install R14 in any other Lumos board other than those at either end of the chain.

- **Power supplies** for the Lumos boards and the loads you want to control. ATX-style power supplies used in PC computers may work well for many common types of DC loads you wish to control, but choose a supply appropriate to your application and environment.
- **Small Phillips screwdriver.**
- **Small slotted screwdriver.**

CHAPTER 4

INSTALLATION

NOW THAT YOUR LUMOS CONTROLLER has been built, it is time to install it and put it fully into operation. This chapter will guide you through the hardware installation procedure. After that is accomplished, see the separate manuals *Using Lumos SSR Controllers* and *Using the Lumos Software* for details on how to program the board and apply computer control software to operate it.

4.1 Installing the Lumos Controller Into an Enclosure

Install the Lumos circuit board into some kind of protective enclosure before attempting to use it. Any suitable container will work.

4.2 Connecting the Lumos Controller to a Computer

The standard configuration for Lumos controllers is a "daisy chain" of up to 16 of them on an RS-485 serial line. One end of the chain is connected to a PC via an RS-485 converter. A diagram of the RS-485 connection is shown in Figure **??**.

To connect the controllers to your PC, follow these steps:

1. Connect the RS-485 converter to your PC's serial port using the serial cable which came with the converter unit.
2. Connect one end of an Ethernet-style cable to the RS-485 converter.
3. The four-channel Lumos controller is designed to connect bare-wire ends of the communication cables to terminal block J1. If connecting

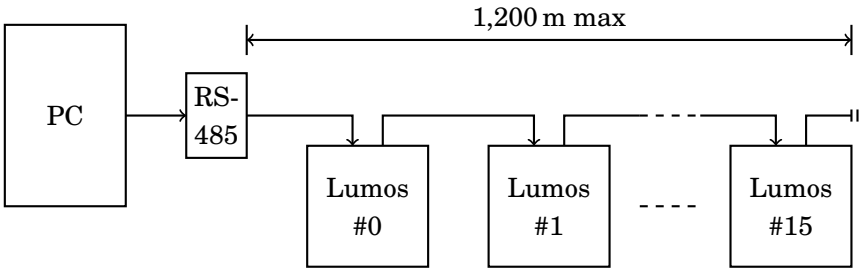


Figure 4.1: Network Connection Diagram

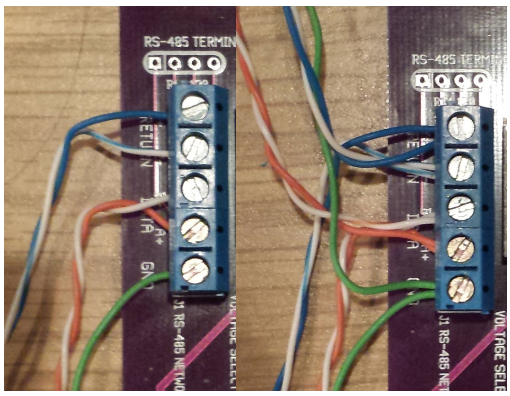


Figure 4.2: Connected Network Cables: Single (left), Daisy-Chained (right)

multiple Lumos boards directly to these terminal blocks, connect the incoming and outgoing segments of cable together to J1 as shown in Figure **??**. If you are wiring a connector such as an 8-pin modular jack to the board, make sure to wire *both* incoming and outgoing jacks to J1. Do not connect them to each other with a single bit of cable from the jacks to J1.

4. Insert a 120 Ω resistor pack R14 on the last Lumos board in the chain (as well as the first if the PC is connected in the middle of the chain), so that each end of the chain is terminated.

4.3 Attaching Power Loads to the Lumos Controller

The block of output channels is electrically isolated from the logic portion of the board, allowing them to have separate power supplies in case the load is a different voltage than the logic supply. You must supply power to the Lumos controller itself (at connector J6) as well as to the block of output channels you will be controlling at J7.

Also note that the Lumos output circuits were designed to control simple resistive loads such as incandescent lights. They are not appropriate for all kinds of loads. Some inductive loads (for example, electromagnetic relays and motors) may require a protective "snubber" circuit which is not included in the Lumos product. Adding snubber components to a Lumos board would be a custom modification to the Lumos circuit and should not be attempted except by qualified engineers.

For these instructions, we will guide you through attaching an ATX-style power supply to a Lumos board, to supply +5 V power to run the Lumos board itself, and +12 V to run a string of RGB LED Christmas lights. Figure **??** shows how the wires are connected, using typical wire colors employed by this style of power supply.

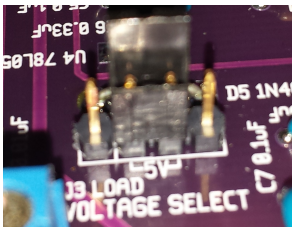
Caution: The colors used here are typical for ATX power supplies, however not all supplies use the same color codes to mark wires. Connecting the wrong wires to the terminals of the Lumos board may have catastrophic consequences, including serious injury, death, fire, and severe damage to the controller and all devices connected to it. Check your power supply until you are *certain* you know exactly which wires carry which signals and voltages. Be sure your power supply has the capacity to provide the power needed for the loads you will plug into it and is appropriate for the environment where it will be used..

Make the main power connections to the board by following these steps:

1. Many ATX-style power supplies have a wire which is used by the computer's motherboard to tell it when to start up or go to sleep (this is done to save power). The Lumos board supports this feature. If this power supply has such a wire, connect it to pin 4 of header J2 using a matching wire-to-board connector. Typically, this is the **green wire** from the power supply.

2. We need to make sure the Lumos board is powered even if the power supply is in "sleep" mode. The power supply provides a special +5 V supply called the "standby power" line, on a **violet wire**. Connect the violet wire to the "+" terminal of J6.

3. Connect a ground wire (typically **black**) to the "–" terminal of J6.



4. Configure the input voltage jumper J4. If the board's logic circuits will be provided with a regulated +5 V DC supply to J6, place a single jumper across the middle pins of J4 (pins 2–3). Otherwise, for input supply voltages from +8 V to +24 V DC, place two jumpers on pins 1–2 and 3–4 of J4, as shown in Figure **??**. In the example being described here, we are getting +5 V so place a jumper across pins 2–3.

   ☞ **Warning! Be certain that the voltage select jumpers J3 and J4 are correctly configured for the power you supply to the board. If they are placed in the "5 V" position but more than 5 V is supplied, it will destroy the Lumos board.**

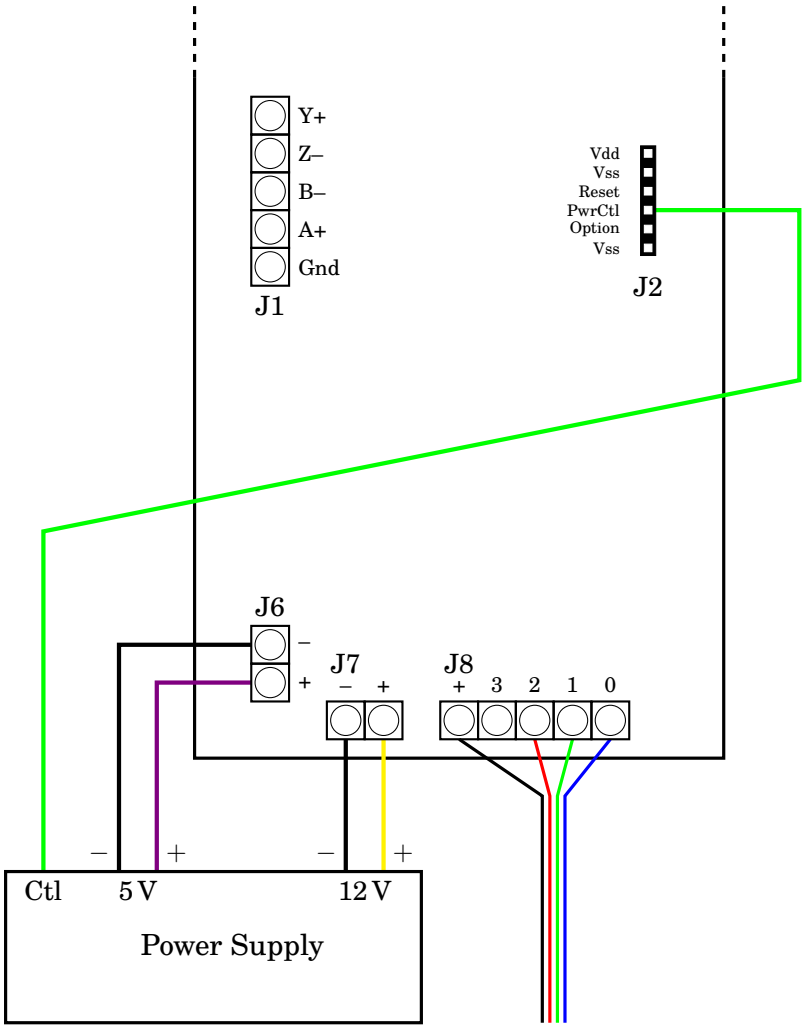


Figure 4.3: Example Wiring of a 12 V RGB LED String

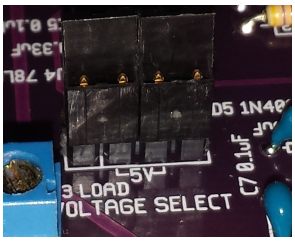
☞ **Advanced Tip:** When the voltage select jumpers J3 and/or J4 are in the middle position (pins 2–3 shorted), the on-board voltage regulator is bypassed so the input power is sent directly into the circuit which is expecting +5 V. This is necessary because the on-board +5 V regulator needs at least +8 V input to function. If you select this, you must supply a clean, regulated +5 V source.

When the voltage select jumpers are in the other position (pins 1–2 are shorted together, and 3–4 are shorted together), the input power is routed through the on-board regulator. The input voltage in this case must be between +8 and +24 V DC, but need not be perfectly regulated.

Attach loads to the Lumos board by connecting them to the output channel block. The output block is independently powered via its input power terminal block (J7). When attaching power to this terminal, watch for the polarity as marked on the board. The negative supply is attached to the left terminal, while the positive terminal is on the right.

The four outputs are negative (–), and available at terminal block J8. A common positive (+) output is also available there to power the controlled loads.

Follow these steps to attach the +12 V light string for our example installation:



1. Connect +12 V to the block by attaching a **yellow** wire from the power supply to the "+" (right) terminal of J7 on the Lumos board.

2. Attach another **black** ground wire to the "–" (left) terminal of J7.

3. Configure the block's input voltage by putting jumpers on J3 as described in step **??** on page **??**. In this example, we're using +12 V so we place two jumpers onto pins 1–2 and 3–4 of J3.

4. Attach the string of LED lights by attaching its **white** common wire to the "+" terminal of J8.

5. Attach the light string's **red** wire to the "2" terminal of J8.

6. Repeat the previous step to attach the remaining color wires to terminals "1" and "0" on J8.

7. Plug the power supply into an AC outlet.

The board is now fully plugged in, connected, and ready to be controlled by the PC's software.

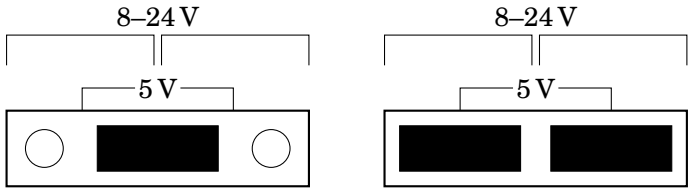


Figure 4.4: Input Voltage Select Jumpers for +5 V (left) and +8–24 V (right)

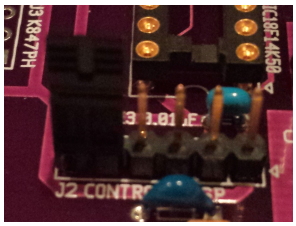
4.4 Using a Common Supply

If you wish to use a single power supply to power both the logic and controlled loads, simply attach that supply to J7, and install jumpers onto J5 such that pins 1–2 and 3–4 are shorted. Also be sure that the voltage select jumpers J3 and J4 are correctly configured for the input voltage.

Note that if you do this, the loads and logic circuits will no longer be electrically isolated from one another, but will all be part of one operating circuit.

4.5 Checking Your Work

You may test the connections you made before going all the way to the PC and running a sequencing program. This verifies that everything is working and that the lights are plugged into the correct output channels.



1. Power on the board. **Caution:** Exercise care when working with the live board. Don't touch anything other than the jumper blocks as instructed here. Even when used for low-voltage loads such as LED lights, your application may involve hazardous current levels which may cause personal injury or death if not handled properly.

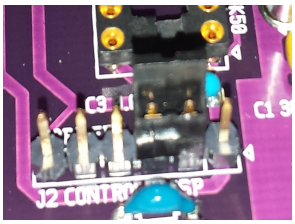
2. Check that the green LED on the Lumos controller is slowly fading on and off. This indicates that the controller is in its normal operating mode and is functioning correctly.

3. Insert a jumper onto pins 5–6 of J2 until the Lumos board's diagnostic lights all start flashing rapidly.

4. Remove the jumper and wait a second or two for the lights to change to just the green light flashing rapidly (the others will be off). The Lumos board is now in "configuration mode."

5. Insert the jumper onto pins 5–6 again for at least 2 seconds.

6. Remove the jumper again. The green light will turn off, and the red light will pulse rapidly. The Lumos board is now in "field test mode."



This mode is designed to help you check your connections before closing up the units and starting your show. The controller will cycle each output channel on for one second, then off again, starting with channel 0. Each second, the next channel in order from 0–3 will turn on, then will restart with channel 0 again.

When you're finished with this test, insert a jumper between pins 2–3 of J2 and then remove it again to reset the controller back to normal operating mode.

☞ **Tip:** You can "freeze" the cycle, holding the currently-lit output channel on indefinitely, by inserting briefly and removing the jumper on pins 5–6 of J2. Insert and remove it again to resume the test cycle.

CHAPTER 5

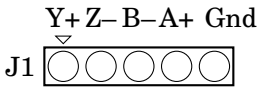
Going On From Here

Now that your controller is installed and ready to use, refer to the separate manual, *Using Lumos SSR Controllers* for full instructions on how to program and use your controller with your computer or in stand-alone operation.

The product website at `www.alchemy.com/lumos` contains additional documentation, pointers, hints, and tips to assist you further. If that doesn't answer all your questions, there is an online forum where you may submit questions for help.

Connector Pinouts

RS-485 Connection (terminal block J1)

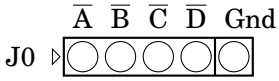


Note that RS-485 works best if the signal bus is a single line from one end to the other, with very short "taps" in the line for each Lumos board. In other words, if this is one unit in a chain, both the input and output lines should be tied to the terminal block. Do not "tap in" to the communication line and run a single jumper out to the Lumos board.

If this is the last device in the chain, install a terminator at R14.

The main data line carrying PC commands to the Lumos boards connects at "A+" and "B–" (the positive and negative signals respectively). The return channel (for full-duplex networks) is on "Y+" and "Z–".

Sensor Input Terminals (J0)



If the Lumos controller is built to accommodate one or more sensor inputs, a set of terminals will be installed at J0.

It is important to note that the board's circuitry must be configured for certain inputs to be enabled at the time the board is built, and that the board must be configured (using software) to recognize those inputs, before they will be usable.

Each input accepts a TTL-level signal. The lines are pulled up to +5 V internally. The board can be configured in software to react to the inputs as active-high or active-low.

Control/ICSP Header (J2)

1 V_{DD} (+5 V)
2 V_{SS} (Ground)
3 $V_{PP}/\overline{\text{MCLR}}/\overline{\text{RESET}}$
4 PGD/$\overline{\text{PWR CTL}}$
5 PGC/$\overline{\text{OPTION}}$
6 Ground

This header is used for reprogramming a new firmware image onto the microcontroller chip. Be sure to check the pinout used by your programmer before connecting it to this port. It may be different!

During normal operations, this header may also be used to connect off-board buttons for the reset and option functions. These buttons should be normally open, but connect their respective pins to ground when pushed. Note that the $\overline{\text{PWR CTL}}$ output is only available on this header. If the board is to be used with a controlled power supply, a connector will need to be used to obtain this signal from J2.

Voltage Select Headers (J3, J4)

+I: Positive voltage in from power supply
+O: Positive voltage out to circuit
VRI: Input to voltage regulator
VRO: Output from voltage regulator

J3 and J4 are used to select the input voltage supplied to the load power control and the logic portion of the board. The square pin on the board corresponds to the VCO pin in the diagram above. If a regulated +5 V supply is employed, there is no need for the on-board regulator (and in fact it can't function properly unless its input is at least +8 V), so a jumper is placed across the middle two pins (connecting +I and +O), bypassing the voltage regulator entirely. *In this case, it is critically important that the input voltage be a clean, regulated +5 V supply. If this voltage is exceeded, permanent damage to the Lumos board will result!*

If +8 V to +24 V is attached to an input, the corresponding jumper block needs jumpers installed into the outer two pins, connecting +I to VRI and +O to VRO. This routes the incoming power through the voltage regulator.

Troubleshooting

While we anticipate the Lumos board will provide many hours of worry-free operation, as with any device (particularly one built as a DIY project), sometimes things don't go quite as planned. Here are a few common problems and their solutions.

Symptom	Likely Cause(s)	Solution
The entire block of outputs does not turn on	No power to the block	Check the fuse, the connection from the power supply to the block, and that the power supply is powered on.
	Power supply not told to wake up (ATX-style supplies only).	Check that the power supply's green wire is attached to the $\overline{\text{PWR CTL}}$ output (J2, pin 4).
Some outputs don't work, or are erratic.	Loose chip.	Lightly press chip U3 back into its socket.
	Bad solder connection or loose chip.	Re-check all solder connections on the board, re-solder any which are cold, broken, or incomplete.
No units in serial network respond to commands.	Missing terminator	Replace terminators on both ends of the daisy chain (note the PC's RS485 converter may include a built-in terminator for that position).
One unit does not respond to commands.	Wrong address.	Use the `lumosctl` program to reconfigure the board to have the correct address.

Glossary

Active High: A logic signal which is considered "on" when the signal is "high" (binary 1 or +5 V), and "off" when the signal is "low" (binary 0 or 0 V). Lumos relay circuits are triggered with active-low signals.

Active Low: A logic signal which is considered "on" and "off" at the opposite signal levels to an "active high" signal (q.v.).

Daisy Chain: The arrangement of wiring a number of devices together by connecting the first to the second, then adding another connection from the second to the third, and so forth. The network connection diagram in Figure **??** shows an example of a daisy chain.

DCE (Data Communications Equipment): In the realm of RS-232 devices, this is the peripheral device plugged into the main "terminal" (DTE) device. Examples include Lumos controllers and modems.

DIY: "Do-It-Yourself."

DTE (Data Terminal Equipment): In the realm of RS-232 devices, this is the main "terminal" device such as a PC or teletype.

Duplex: a feature of a serial line. On a full-duplex connection, separate data wires are present to carry data in both directions, so one device can send and receive data at the same time. On a half-duplex connection, only a single set of data wires is present, so devices must take turns transmitting over them.

ESD (Electro-Static Discharge): static electricity which builds on your skin and is then discharged into sensitive components when you touch them. Invisible to the eye, this can punch microscopic holes in the inside of the components, severely damaging them.

Jumper Block: A series of pins mounted to the PCB. Different options are configured for the circuit by placing a jumper over certain pairs of pins, shorting them together.

LED (Light Emitting Diode): A special kind of diode which emits light when current passes from its anode to its cathode.

PCB (Printed Circuit Board): The board where electronic components are mounted to form a complete circuit. Metal traces are "printed" (actually etched) onto the surface of the board itself to make the connections between components.

RS-485: A standard hardware protocol for sending serial data between multiple devices on a single cable length (electrically it is a single cable which each device "taps into" along the line; physically it is typically a "daisy chain" arrangement where a short cable connects one device to the next, another cable to the next, and so on). Unshielded twisted-pair cable is used (like Ethernet cable), and the cable lengths should not exceed a total of 4,000 ft (1,200 m).

Terminator Plug: An RS-485 network requires a terminator at each end. This is a small plug which plugs into the last unit in the daisy chain.

TTL (Transistor-Transistor Logic): One of the ways digital logic circuits can be constructed. For our purposes here, we consider a "TTL-level" signal to be a logic input or output where a voltage near +5 V is "high" (binary 1 or "true") and a voltage near 0 V is "low" (binary 0 or "false"). The inputs should never be above +5 nor below 0 volts.

Acknowledgements

Kickstarter Project

We launched a Kickstarter project to build a test network of Lumos DC boards for final testing and debugging before releasing the final designs and firmware as an open source DIY project.

Thank you to all our Kickstarter backers who made the final testing of the Lumos DC controllers possible!

Fan Level

Amanda Allen

Supporter Level

Casey Adams
Sue Allen
Andrej Čibej
Betsy Fernley
Beth Gordon
Sara Jacobson
Tanya Spackman

Backer Level

DC

Silver Level

David Johnston
Melf

Gold Level

Rob Beasley
Phil Willoughby

Patron Level

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Jama Scaggs
Doug Van Camp
Matthew Wentworth

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Technical Legacy

The do-it-yourself computerized Christmas light hobby thrives as a community of enthusiasts who contribute their ideas and designs for others to build, enjoy, and improve upon with new designs of their own. This journey began for me years ago with the discovery of Hill Robertson's Computer Christmas website (`www.computerchristmas.com`). It continues on sites such as Chuck Smith's Planet Christmas (`www.planetchristmas.com`), `doityourselfchristmas.com`, and many others.

Over the years the users of these forums have produced some great designs which have become *de facto* standards as others adopt them and refine them in their own designs. The Lumos boards' TRIAC and MOSFET relay circuits (the final few components at the controlled outputs) are a continuation of the standard circuits used by those communities, inspired most by Robert Stark's TRIAC design and the DC MOSFET circuits by John Wilson (from Computer Christmas and Do It Yourself Christmas, respectively). I am pleased to contribute my own innovations on these common design themes back to the same community (the remainder of the Lumos circuits other than the TRIAC and MOSFET output sections are entirely my own original design).

Colophon

This manual was composed and typeset by the author using LaTeX with Memoir layout macros, augmented by wrapfig, lettrine, bytefield, wallpaper, Ti*k*Z, and a host of miscellaneous behind-the-scenes working packages.

It was set 10/12 pt using the TeX Gyre Schola font family created by GUST, the Polish TeX User Group. This typeface is based on URW Century Schoolbook L, originally designed by Morris Fuller Benton in 1919, for the American Type Founders.

Schematics were generated using the gEDA tool `gschem`. The PCB layout illustrations were created by `pcb` on Linux. All of the above are free and open-source tools.

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