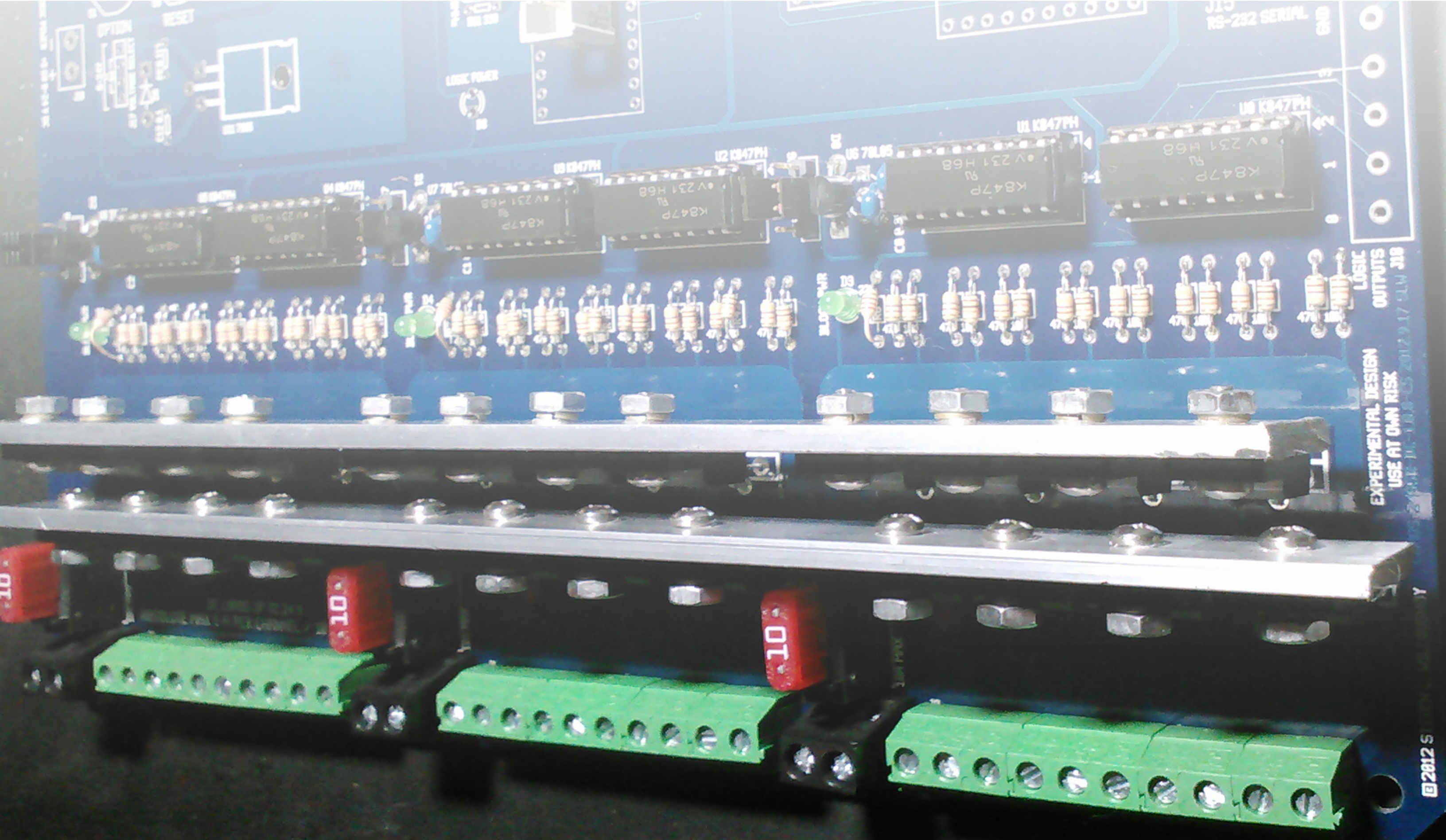
Installing the Lumos™ 24-Channel DC Controller



DANGER

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 1.0.1, for Lumos 24-Channel DC Controller circuit version 1.0.8.

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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™ 24-Channel DC Controller board places 24 such devices under the control of your computer. These outputs are arranged into three blocks of eight channels. Each block is electrically isolated from the logic control circuit and from each other, so each block may be separately powered at different voltages if desired.

If Lumos boards are configured with the RS-485 network option, up to sixteen Lumos boards may be "daisy chained" together (a total of 384 channels) 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

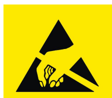
This board contains small parts which could pose a choking hazard to small children. This product is not a toy and is not intended for use by children in any circumstance. The small parts on the product can be swallowed by children under 4 years of age. Keep out of reach of children.

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 (Q0–Q23), voltage regulators (U6–U8 and U11), diodes (D0–D11), and integrated circuits (U0–U5, U9–U10, and U12–U13).

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.

Each block of eight controlled loads may not exceed 10 A total for the block. 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 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.

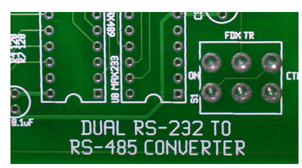
CHAPTER 3

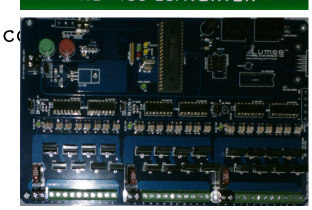
What You Will Need

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).

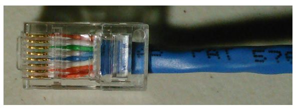
- **An RS-485 converter.** If your Lumos board is an RS-485-compatible model, it will be built for either full-duplex or half-duplex operation. Make sure the RS-485 converter you use matches the Lumos board in this respect. RS-485 converters are available from many vendors, and may plug into your computer's serial port or USB port. We also offer the plans to make your own RS-485 converter from scratch. See `www.alchemy.c`



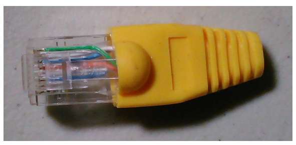


- **One or more Lumos controller boards.** If more than one board will be used together, they need to be RS-485 capable. If your Lumos board uses regular RS-232 serial communications, see the special instructions starting on page **??**.

- **Weather-resistant enclosures for the Lumos boards.** The Cable-Guard® CG1500 is known to work with the Lumos boards, but choose an enclosure which is appropriate for your usage.



- **Data cables.** *(RS-485 models only.)* You will need 8-pin modular cables (8p8c-type, such as Ethernet cables). 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 configuration 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 plug.** *(RS-485 models only.)* 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.

- **RS-232 cable.** *(RS-232 models only.)* A standard 9-pin male-to-female PC serial cable.

- **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.

- **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. One possibility is the CableGuard® CG1500 network demarcation box. This is weather-resistant and has plenty of room inside for the Lumos board and its electrical connections.[1]

To mount the circuit board,

1. Position the board so that the resistor arrays on the bottom side (R0–R5) are not crushed or in the way of anything, and the mounting holes of the PCB are aligned with the enclosure's standoffs.

2. Attach the board to the standoffs using four #6 machine screws. These will self-tap their way into the plastic. **Do not over-tighten.**

[1] We have no connection to the CableGuard company or their products. We just like their boxes.

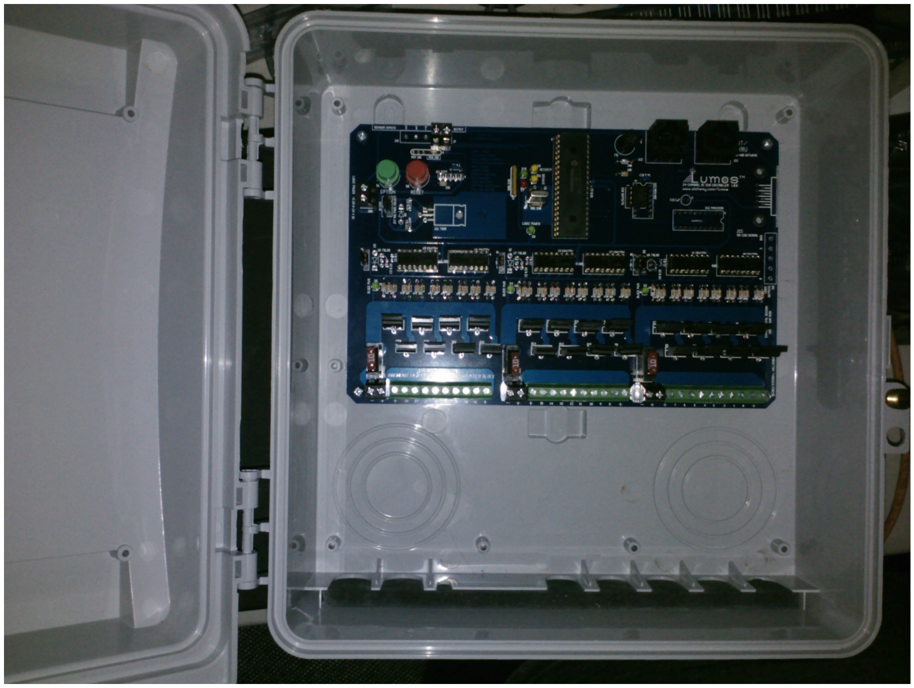


Figure 4.1: Example Enclosure with Lumos Controller Installed

3. Attach the box to the wall, structure, or other suitable support at the location where it will be used.

4.2 Connecting the Lumos Controller to a Computer

The standard configuraiton 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 **??**.

If your Lumos controller uses a regular serial port (“RS-232”) instead, see the instructions starting on page **??**.

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. Plug the free end of that cable into the connector labeled “IN” (J12) on the first Lumos board. **Note:** If you’re using a weather-tight en-

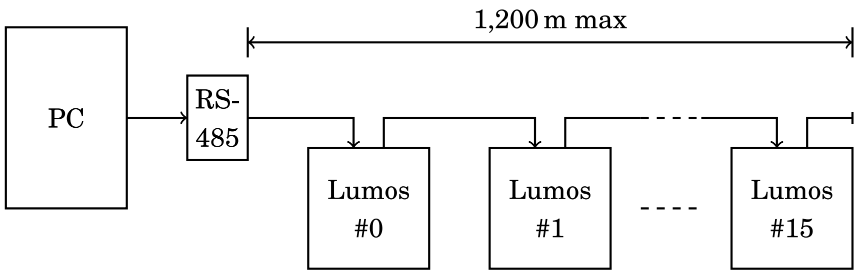


Figure 4.2: Network Connection Diagram

closure, you will need to route the cable through the foam grommets at the bottom of the enclosure.

4. If there is more than one Lumos controller in the chain, connect one end of another cable from the first Lumos controller's "OUT/THRU" (J13) connector.

5. Plug the other end of this cable into the next Lumos controller's "IN" (J12) connector.

6. Repeat steps **??**–**??** until up to 16 Lumos controllers have been connected together.

7. Insert a special "terminator plug" into the last Lumos controller's "OUT/THRU" (J13) connector.

8. Refer to Figure **??** to see how the serial network cables look when connected. The unit on the left has two cables attached. The blue cable is the incoming data line from the PC's RS-485 converter. The orange cable is going out from this Lumos controller to the next one in the chain, which is shown on the right of Figure **??**. Note that on the second unit, the orange cable from the first unit is plugged in to the "IN" jack, and a terminator plug is placed in the "OUT" jack, ending the chain at that point.

4.3 Special Instructions for RS-232 Serial Boards

If your Lumos controller is built for RS-232 communications, this means it can plug directly into your PC's standard serial port using a 9-pin serial cable. The limitations of this kind of serial port mean that the cable must be shielded, and not longer than 25 ft. Only one Lumos board may be attached to a PC's serial port (you will need more serial ports or USB serial adaptors to attach more Lumos boards).

The serial cable is a standard straight-through 9-pin male-to-female configuration such as would be used to connect a modem to your PC.

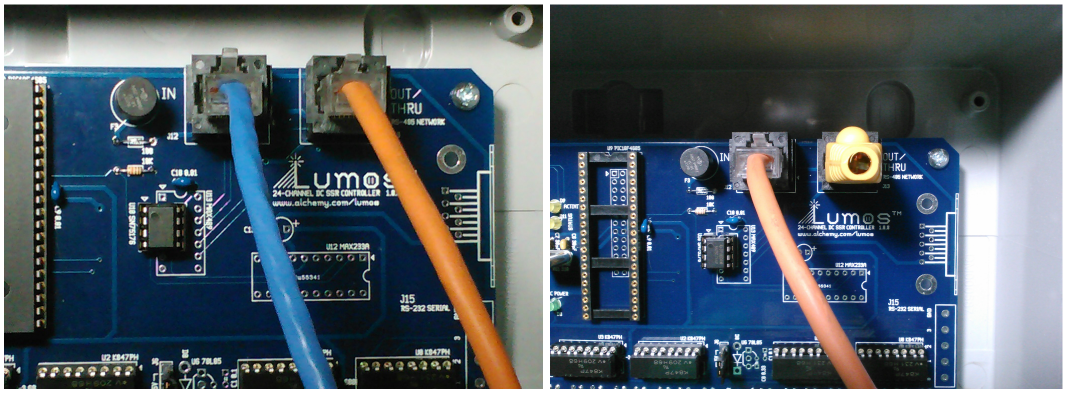


Figure 4.3: Connected Network Cables (terminated unit on right)

4.4 Attaching Power Loads to the Lumos Controller

Each block of 8 output channels is electrically isolated from the others, allowing them to have separate power supplies to distribute load appropriately, or to control different voltage devices. You must supply power to the Lumos controller itself (at connector J10) as well as to each block of output channels you will be controlling.

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 two strings of 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.

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 com-

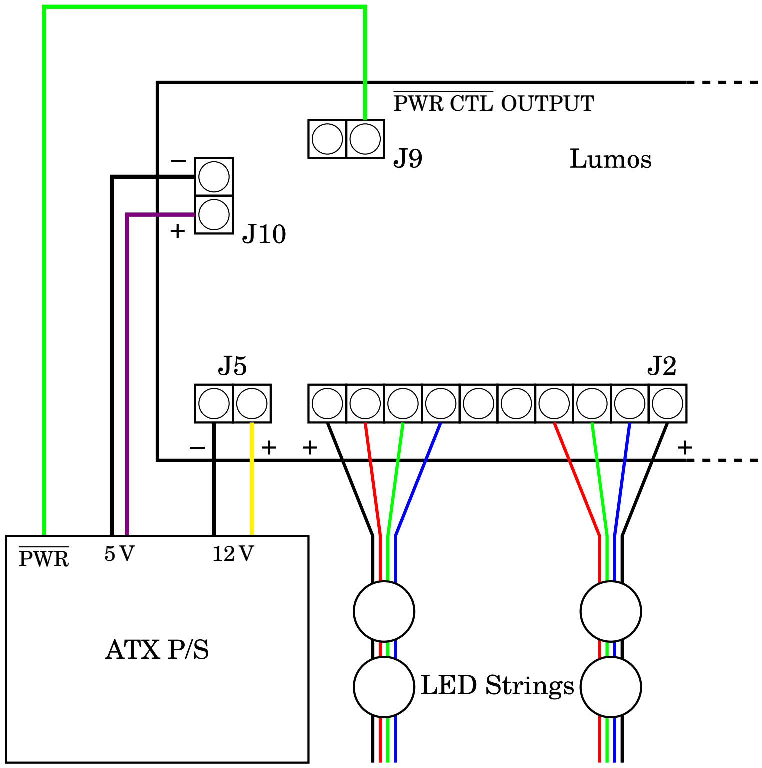
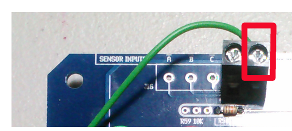
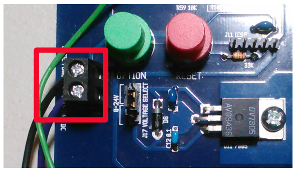
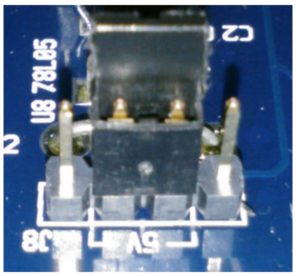


Figure 4.4: Example Wiring of Two 12 V RGB LED Strings

puter'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 the "$\overline{\text{PWR CTL}}$ OUTPUT" terminal J9. 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 J10.

3. Connect a ground wire (typically **black**) to the “–” terminal of J10.

4. Configure the input voltage jumper J17. If the board will be provided with a regulated +5 V DC supply, place a single jumper across the middle 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, 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 J17, J6, J7, and J8 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.**

   ☞ **Advanced Tip:** When the voltage select jumper J17 (and the three voltage select jumpers J6–J8 for the output channel blocks) 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 blocks. There are three separate blocks of 8 channels. Each block is independently powered via its input power terminal block (J3–J5). When attaching power to these terminals, 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 eight outputs in each block are negative (–), and available at terminal blocks J0–J2. For your convenience, two positive (+) supply terminals are provided on the outer two positions of each of those terminal blocks.

Follow these steps to attach the two +12 V light strings 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 J5 on the Lumos board.

2. Attach another **black** ground wire to the “–” (left) terminal of J5.

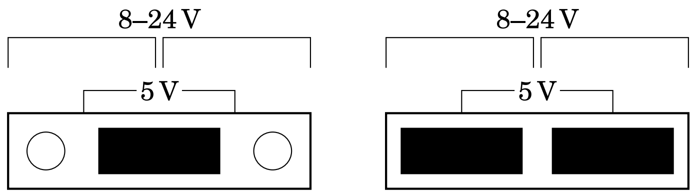
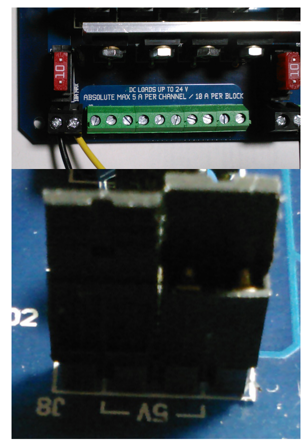


Figure 4.5: Input Voltage Select Jumpers for +5 V (left) and +8–24 V (right)



3. Configure the block's input voltage by putting jumpers on J8 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 J8.
4. Attach one string of LED lights by attaching its **white** common wire to the "+" terminal of J2.
5. Attach the light string's **red** wire to the "23" terminal of J2.
6. Repeat the previous step to attach the remaining color wires to terminals "22" and "21" on J2.
7. Repeat steps **??**–**??** again to attach the second string of lights to three more output channels (such as "18," "17," and "16") and one of the "+" terminals on J2.
8. Close the enclosure and secure it.
9. 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.

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 but leave the cover open, allowing access to the control buttons. **Caution:** Exercise care when working with the live board. Don't touch anything other than the control buttons. Even when used to control low-voltage loads such as LED lights, your specific application may involve hazardous current levels, which can result in personal injury or death if not handled appropriately.

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. Press and hold the green "OPTION" button until the Lumos board's diagnostic lights all start flashing rapidly.

4. Release the button 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. Press the green "OPTION" button again for at least 2 seconds.

6. Release the button. 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 0–23 will turn on, then wll restart with channel 0 again.

When you're finished with this test, simply press the red "RESET" button to reset the controller back to normal operating mode.

☞ **Tip:** You can "freeze" the cycle, holding the currently-lit output channel on indefinitely, by pressing the green "OPTION" button briefly. Press it again to resume the test cycle.

CHAPTER 5

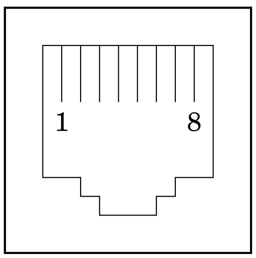
Going On From Here

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 (8p8c Female Modular Jacks)



1 Return Data (+); *[Full-duplex models only]*
2 Return Data (−); *[Full-duplex models only]*
3 Cable Check
4 Data (−)
5 Data (+)
6 Cable Check
7 Data Ground
8 Return Data Ground

Note that the jacks are labeled "IN" and "OUT/THRU" on the board. This is intended to remind the user that these are daisy-chained connections with a signal coming "in" to the board on one wire, and on "through" to the next board in the circuit.These names also mirror the naming conventions used with DMX equipment.

Electrically, however, the RS-485 serial "network" is a single bus running from the host PC to the last Lumos controller. Each controller "taps" into the line as it goes by. This means that, labeling notwithstanding, the "IN" and "OUT/THRU" jacks are in fact completely identical and interchangeable.

The "cable check" lines are simply passed through the Lumos board from input to output, with the expectation that the terminator will connect them together. These lines are not used by Lumos boards at all. They are provided as a convenient way for the host PC interface to verify cable continuity by sending a voltage down one pin all the way to the terminator and back on the other pin. This helps warn the user if a cable becomes disconnected. The Lumos front panel circuit board is one example of a circuit which makes use of this feature.

The two grounds on pins 7 and 8 are actually shorted together and connected to the common signal ground on the Lumos board.

If connecting a Lumos board to a DMX controller, an adapter cable is needed to connect the DMX DIN plug to the 8-pin modular plug used on the Lumos board. A typical adapter is wired as shown in Table **??**, but check your equipment in case it is different.

Signal	DMX DIN Connector	Lumos Modular Connector
Ground	1	7, 8
Data (−)	2	4
Data (+)	3	5

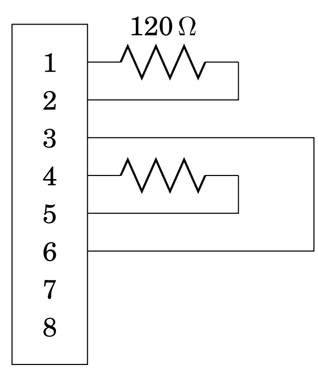
Table A.1: Typical Wiring Arrangement to Adapt DMX to Lumos

RS-485 Terminator (8p8c Male Plug)

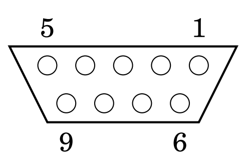
The terminator plug consists of a pair of 120 Ω resistors. One is connected across pins 1–2, and the other across pins 4–5. This provides the proper line termination at the end of the RS-485 chain. A terminator must be plugged in to each end of the chain (but note that often the PC's RS-485 adaptor contains a built-in terminator).

To enable the cable check feature to work, pins 3 and 6 must also be shorted together.

The schematic diagram for the terminator is included below. Often, the resistors are mounted to a small circuit board which fits inside the modular plug, making a self-contained terminator plug.



RS-232 Serial Connection (9-pin Female DE-9 Jack)



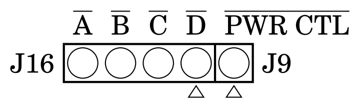
2 Receive Data
3 Transmit Data
4 Data Terminal Ready
5 Signal Ground
6 Data Set Ready
7 Request to Send
8 Clear to Send

For Lumos boards configured to use RS-232 serial connections to a host PC, a standard 9-pin connector is used, with the Lumos board wired as a DCE device.

On the Lumos board, Data Terminal Ready (DTR) and Data Set Ready (DSR) on pins 4 and 6 are shorted together, as are Request to Send (RTS) and Clear to Send (CTS) on pins 7 and 8. This should satisfy most communications software which expects to see these signals present, although the Lumos board itself does not perform any hardware or software handshaking.

Receive Data (RxD) and Transmit Data (TxD) are named from the point of view of the DTE (host PC), so TxD is the wire which carries data from the host PC to the Lumos board.

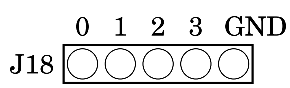
Sensor Input Terminals (J16)



If the Lumos controller is built to accommodate one or more sensor inputs, a set of terminals will be installed at J16, next to the $\overline{\text{PWR CTL}}$ output at J9. These are labeled from left to right (as the board is viewed right-side-up from the front) as $\overline{A}$, $\overline{B}$, $\overline{C}$, and $\overline{D}$. 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.

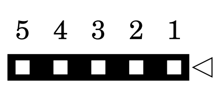
Each input accepts a TTL-level signal. The lines are pulled up to +5 V internally. The board can be configured in software to react to the inputs as active-high or active-low.

Logic Output Terminals (J18)



For experimental use, TTL-level outputs for the first four channels are available on J18. These are active-low outputs, where a "low" (0) state indicates that the output should be on, and a "high" (1) state means that the output should be off. Note that if an output is at a dimmer level other than fully on or fully off, the signal will pulse with a duty cycle corresponding to the dimmer level as illustrated in Figure **??**.

ICSP Header (J11)



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/$\overline{\text{OPTION}}$

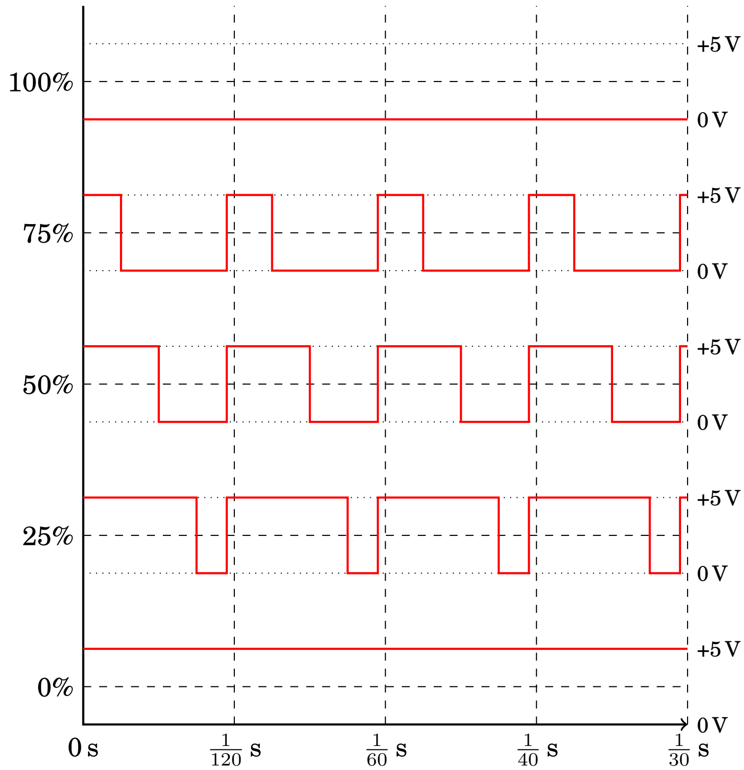
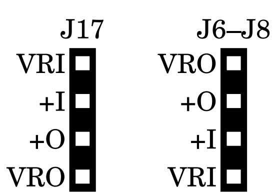


Figure A.1: Duty Cycles of Channel Logic Drive Outputs

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 also present on pin 4 of J11 in addition to its normal terminal at J9.

Voltage Select Headers (J6–J8, J17)

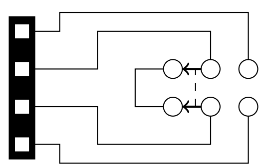


+I: Positive voltage in from power supply
+O: Positive voltage out to circuit
VRI: Input to voltage regulator
VRO: Output from voltage regulator

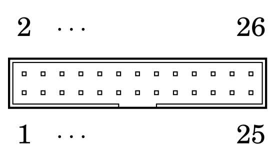
J6–J8 are used to select the input voltage supplied to the power control blocks for channels 0–7, 8–15, and 16–23 respectively. Likewise, J17 selects the input voltage supplied to the logic portion of the board. Although the pinouts are mirrored between J17 and the others, their operation is the same. 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.

If it is necessary to move this selection to a front panel switch, this can be accomplished simply by attaching a DPDT switch to each jumper block header like this:



Relay Control Connection (26-pin Male IDC Header)



For Lumos controllers built as "dumb" relay boards with no built-in logic control of their own, a 26-pin IDC ribbon cable header is installed at J14. This is used to connect the relays to the controlling circuit (e.g., a Lumos 48-channel controller). The pinout of this header is:

1	$\overline{\text{SSR23}}$	8	$\overline{\text{SSR3}}$	15	Gnd	22	$\overline{\text{SSR9}}$
2	$\overline{\text{SSR0}}$	9	$\overline{\text{SSR19}}$	16	+5 V	23	$\overline{\text{SSR13}}$
3	$\overline{\text{SSR22}}$	10	$\overline{\text{SSR4}}$	17	$\overline{\text{SSR16}}$	24	$\overline{\text{SSR10}}$
4	$\overline{\text{SSR1}}$	11	$\overline{\text{SSR18}}$	18	$\overline{\text{SSR7}}$	25	$\overline{\text{SSR12}}$
5	$\overline{\text{SSR21}}$	12	$\overline{\text{SSR5}}$	19	$\overline{\text{SSR15}}$	26	$\overline{\text{SSR11}}$
6	$\overline{\text{SSR2}}$	13	$\overline{\text{SSR17}}$	20	$\overline{\text{SSR8}}$		
7	$\overline{\text{SSR20}}$	14	$\overline{\text{SSR6}}$	21	$\overline{\text{SSR14}}$		

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
An entire block of outputs does not turn on	No power to the block	If the BLOCK PWR light is off, check the fuse for that block, 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 $\overline{\text{PWR CTL}}$ terminal on J9.
Some outputs don't work, or are erratic.	Loose chip.	Lightly press chips U0–U5 back into their sockets.
	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.
	Blown communication fuse.	Replace fuse F3.

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-232: A standard hardware protocol for sending serial data between two devices (such as a computer and a modem or a single Lumos board). Shielded cable should be used for best results, and the cable length should not exceed 25 ft.

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

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David Johnston
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Gold Level

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Patron Level

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We also wish to thank Darren Bliss who has been a great supporter of the Lumos project since the very first prototype was being experimented with, and the other Kickstarter backers and friends who offered moral support, other contributions, or who wished to contribute anonymously.

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, TikZ, 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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