Manufacturer: JAMECO KITPRO

Manufacturer No.:   CJKIT-21420

groLEDs Kit User's Manual

Optional Assembly Components, Hookup and Usage, Performance Data and Specifications, Technical Data including Schematics, et al.

Thomas W. Gustin

8/29/2015

This kit was developed by GUSTECH as Club JameCo's Project #21420. The Schematic and Board Layout were developed using EAGLE PRO 6.3.0 tools; these design files are available upon request. The 2-layer printed circuit board measures just 1.95" x 2.60", and the assembly uses all thru-hole components.

This User's Manual for the groLEDs Kit is all of the documentation needed by the kit-builder, beyond that already used to assemble the kit, to understand all of the technical aspects of the design. There are optional components that can be installed, if desired. There are many ways to wire the power to the groLEDs board, and many ways to control it; manually, by computer, or both. The performance data includes plotted data for light output, per color, for a wide range of input voltages, as well as the input current for the same ranges. The technical presentation includes the fully annotated schematic, black and white photoplots of the printed circuit board layers, and board statistics.
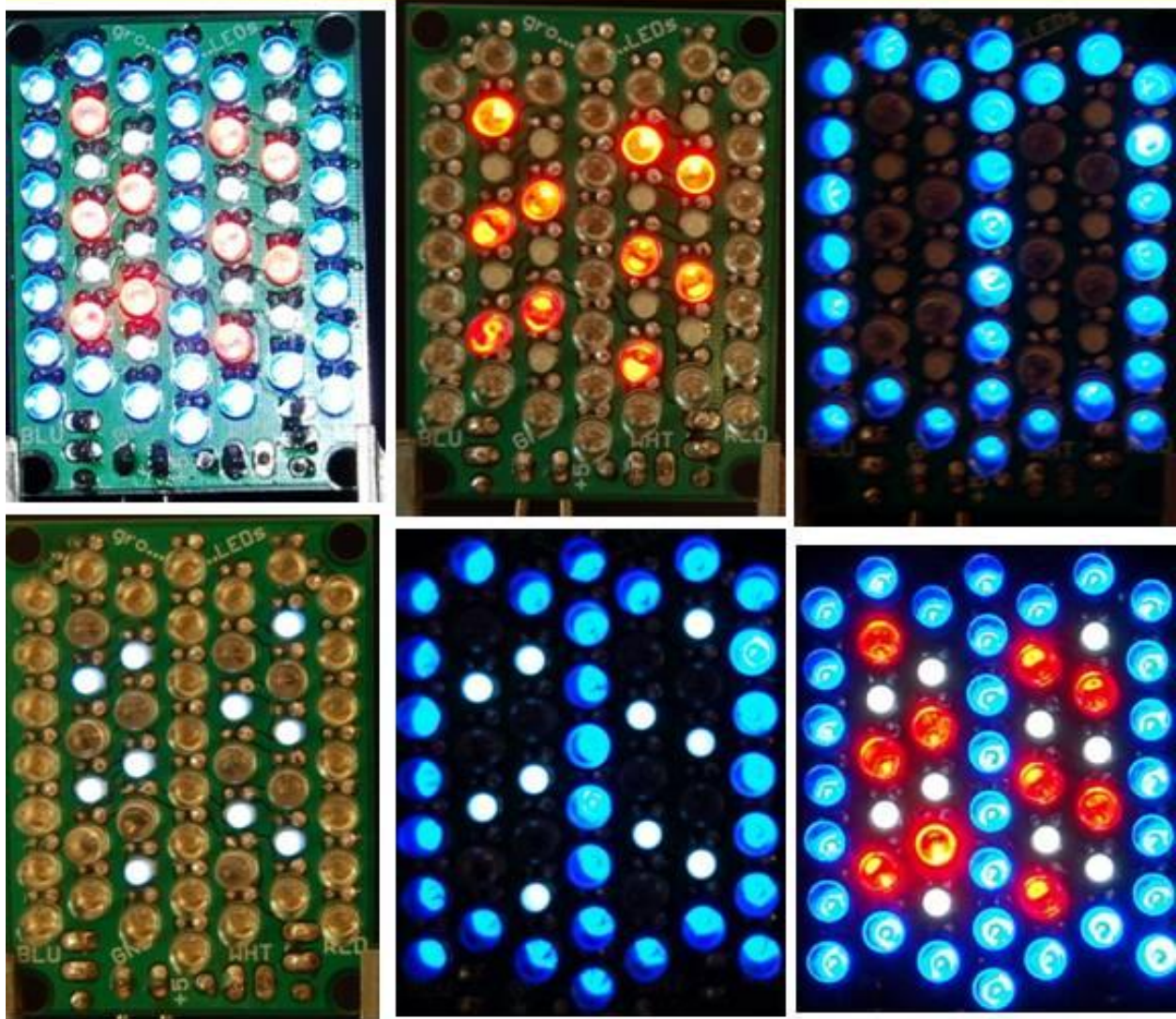
groLEDs 'lit' Photographs

Figure 1: Six views of the dimly lit groLEDs Assemblies

SAFTEY ADVISORY:
Do **NOT** Look directly into these LEDs when they are lit; they are **EXTREMELY BRIGHT**, and can cause temporary diminished sight with 'lots of spots.'

Table of Contents

TABLE OF FIGURES:

TABLE of TABLES

OVERVIEW:

TITLE:

groLEDs: Computer Controllable, Adjustable Broad Spectrum, High Brightness "grow 50-LEDs-lamp" kit

The **groLEDs** kit offers an economical, versatile, safe, efficient, and easy-to-use alternative to traditional and commercial-grade Grow Lamp/Light products.

BRIGHT:

The three different colors of LEDs all include high luminosity intensity ratings[1] measured in candela's (*cd*) instead of 'normal' LED millicandela (*mcd*) ratings. The Blue LEDs emit 57cd (*57,000mcd*), the White LEDs emit 80cd (*80,000mcd*), and the Red LEDs emit 80cd (*80,000mcd*), when they are powered at their specified nominal operating current levels. The equivalent light output is that of (*very bright*) 217 (*standard*) candles when all LEDs are lit. This document presents actual brightness measurement levels.

ADJUSTABLE SPECTRUM:

Unlike many full spectrum Grow Light Products, which attempt to provide some 'additional' red and blue light energy mixed with the standard yellow/white, the **groLEDs** kit is designed to enable the user to specifically select the light color output based upon growing needs. The color combinations include:

1) OFF (emulating night-time darkness)
2) BLUE Only ON, or
3) RED Only ON, or
4) WHITE Only ON, or
5) BLUE and RED Only ON, or
6) BLUE and WHITE Only ON, or
7) RED and WHITE Only ON, or
8) BLUE and RED and WHITE all ON.

This enables the user to emphasize the Blue end of the spectrum when attempting to promote healthy vegetation growth, while the Red end is used when enhancing the budding and flowering phases of growth, depending upon specific growth requirements.

DIRECTIONALLY FOCUSED:

Common Grow Lamps in the shape of (*T5*) Florescent Tubes or common incandescent shaped bulbs broadcast their light in almost all directions, requiring mirror-reflectors to aim the light where it is needed by the plants. LED Lamps with narrow beam widths 'aim' their light like spot lights right where it is needed by the plants.

---

[1] These brightness ratings are based upon the data sheet specifications for a nominal forward current of 20mA each. Actual brightness levels for many different forward current levels are presented in the PERFORMANCE section of this User's Manual.

EASILY CONTROLLED:

Most Grow Lamps, including many 'hi-tech' LED Lamp fixtures, only provide on-off capability. The **groLEDs** kit is designed so that each bank of colors (*Blue, White, and Red*) can be individually controlled, manually, or remotely via (*computer-controlled*) relay contacts, or both. This enables the user to control the spectrum and the time that light is on versus off, changing as the growing cycles change on a per-plant basis, if desired. Adjusting the input (*low level DC*) voltage also controls the brightness level. An example of this might involve using +5.0Vdc for high-brightness growing conditions, while using +3.3Vdc for (just) bright growing conditions[2].

POWER-SAFE:

Mixing water and 115Vac never seemed like a good idea in any kind of growing environment. Nearly every grow light available, including most LED Grow lamps, are powered by 115Vac, whether by a power cord that plugs into a nearby socket, or one that screws into a lamp socket wired for 115Vac. The **groLEDs** kit is designed to be run from +3.0Vdc to +5Vdc, enabling the user to safely use water near the **groLEDs** kit fixture without fear of electrocution. The user places the 115Vac driven power supply in a safe dry location remote from the growing (watering) area. Again, this "User's Manual" lists the light output values and the operating current levels for a broad range of operating voltages, from about +3.0volts up to over +5.0volts.

INEXPENSIVE:

Compared to all other grow light solutions the **groLEDs** kit is very inexpensive. Not including the printed circuit board and optional components, the JameCo catalog list-price for all 50 LEDs and their current limiters is just $21.45.

Multiple **groLEDs** kits can be powered from a single, extremely inexpensive, *($15.00 common)* Computer (*tower*) power supply. Because these power supplies source high current levels for both +3.3volts and +5.0volts, relay control of light levels and colors is very simple to implement.

RELIABLE:

LEDs have a life-cycle measured in tens-of-thousands-of hours, or many years; significantly longer than any other grow-light solution. Many commercially available 115Vac powered LED Grow bulbs include integrated AC-to-DC converters to create the proper power parameters for powering the LEDs within the bulb-fixture. These converters, being active electronics subjected to relatively high-heat conditions are prone to fail long before the actual light-emitting-diodes themselves. The **groLEDs** kit uses only passive components, making it much more dependable for many years of service. Unlike most Christmas LED strings, if and when a LED does fail on the **groLEDs** kit, all the other LEDs remain lit without changing their intensities.

---

[2] +3.3Vdc and +5.0Vdc are both high-current power sources on very inexpensive (*tower*) computer supplies, where a switch or SPDT relay can select between these two voltage rails based upon growing needs. Examples are provided later in this User's Manual.

ADJUSTABLE BRIGHTNESS:

Since the **groLEDs** kit is completely passive, it is possible for the user to vary the light intensity, as needed, by varying the +5volts input (*down to +3.0volts up to about +5.5volts*), to decrease or increase the brightness level, as needed for specific growing requirements. Details about these voltage levels, and the overall power requirements, are included {*later*} in this "User's Manual" for this kit.

THRU-HOLE ONLY:

The small 1.95" x 2.6" 2-layer printed circuit board uses thru-hole components only, making it a kit that can be built by any level of expertise. All 50 LEDs are mounted on one side of the board (*see the pictures on page 2*), and all of the other components, including optional ones, are mounted on the backside of the board. Since this is not a typical assembly process to include thru-hole components on both sides of a printed circuit board, the instructions walk the kit-builder through the process to ensure reliable solder connections and no scorched LEDs (*or fingers*). There are four 0.2" diameter holes in each of the corners of the **groLEDs** kit assembly for mounting, or hanging the fixture for usage.

POWER CONNECTIONS:
WHERE TO:
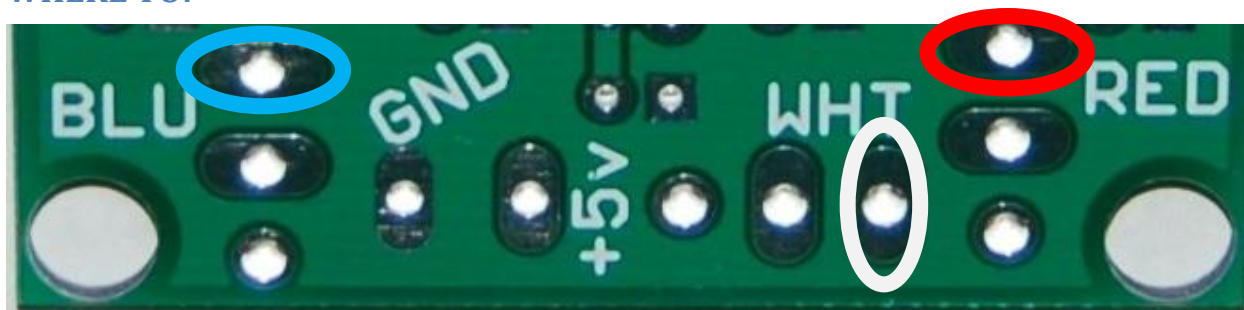
Figure 2: Per LED Color Power Connection Points

Along the bottom edge of the **groLEDs** printed circuit board the optional components of manual slide (*power*) switches and a two-position terminal block for wire-to-board connections can be installed (*on the back side of the board*). The view presented in figure 2 is that of this same area as seen on the top side of the board. The (*added*) three colored ovals, Red, White, and Blue, show the actual wiring holes that really **connect** to the current limiting resistors driving the **LEDs**, by group, respectively.

WIRE-SWITCH-RELAY:

There are several ways to apply power to each of the three banks of LEDs, individually or grouped. On a per power connection point, the following depicts a few possibilities:

This hole connects to the **LEDs**; Power input from wire, switch, or relay contacts

This hole connects to the **Power source** via "**+5v**" by wire, switch, or relay contacts

This hole has no electrical function; used for the switch mounting only

Figure 3: Switch Holes and the Electrical Functions

MANY POWER OPTIONS:
COMMON "+5v":
The hole in Figure 2 labeled "**+5v**" is the **main common power input connection**. It may be wired directly by a wire soldered into this particular hole, and may supply any safe and functional (*positive*) voltage (*referenced to the "GND" hole*) that the kit-user wishes to apply to all three color-banks of LEDs for this particular assembly.

As an alternative to directly soldering the input power wire to the board, the kit-builder may (*optionally*) install the 2-position terminal block (*on the back side of the board*), as discussed later in this document. This enables easier rewiring and reconfigurations, as growing conditions change.

This "+5v" hole also connects to all three center holes of all three triple-hole switch-installation locations, as depicted in Figure 3.

COMMON "GND":
The hole in Figure 2 labeled "GND" is the main common power return or GROUND connection. It may be wired directly by a wire soldered into this particular hole, or the kit-builder may (*optionally*) install the 2-position terminal block (*on the back side of the board*), as discussed later in this document. This enables easier rewiring and reconfigurations, as growing conditions change.

Regardless of the number and voltage levels of power sources used to drive the three different color-banks of LEDs on a per **groLEDs** board basis, ALL of the power sources MUST have the same common GROUND connection. This will be shown clearly in some of the wiring examples that follow.

SEPARATE +V SOURCES:
As mentioned, it is possible to supply different voltages, one each per color-bank of LEDs, per **groLEDs** assembly.

One simple example might be:
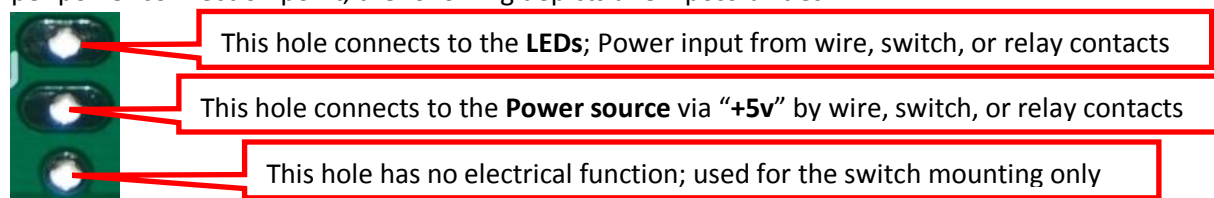- ➢ Connect +4.22volts (*referenced to* "**GND**"), via a wire to the power hole (*top hole with the blue oval in figure 2*) of the "**BLU**" switch hole patterns, to turn on the Blue LEDs (*will need at least 600mA of current driving capacity*).
- ➢ Connect +4.12volts (*referenced to* "**GND**"), via a wire to the power hole (*right hole with the white oval in figure 2*) of the "**WHT**" switch hole patterns, to turn on the White LEDs (*will need at least 200mA of current driving capacity*).
- ➢ Connect +3.99volts (*referenced to* "**GND**"), via a wire to the power hole (*top hole with the red oval in figure 2*) of the "**RED**" switch hole patterns, to turn on the Red LEDs (*will need at least 200mA of current driving capacity*).

These three different voltage levels[3] (*regardless of how they are sourced or controlled*) will drive all 50 LEDs on the **groLEDs** assembly to their nominal 20mA operating current levels, providing (*theoretically*) the light levels depicted in the block diagram for this kit (*see step 1 of the Assembly Instructions, and as listed in the OVERVIEW-BRIGHT text on page 5 of this document*).

---

[3] These three data-sheet theoretical voltage levels of +4.22, +4.12 and +3.99 volts are different from the actual measured values of +4.18, +4.18 and +3.96 volts, respectively, as presented in the PERFORMANCE DATA section on pages 19 to 21.

COMMON CONTROL METHODS:

ALWAYS ON:

This first wiring diagram shows how a bank (*any color*) of LEDs may be configured to be ALWAYS ON whenever there is power supplied to the "+5v" hole (*referenced to the "GND" hole*).

Wire soldered across these two holes
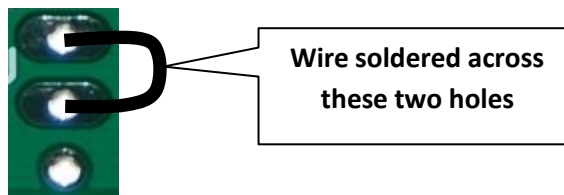
Figure 4: Wiring LEDs to be ALWAYS ON

REMOTELY CONTROLLED:

This second wiring diagram shows how a bank (*any color*) of LEDs may be configured to be remotely controlled whenever there is power supplied to the "+5v" hole (*referenced to the "GND" hole*) by a remotely controlled (*computer, for instance*) relay.

These two wires are connected to a remotely controlled pair of relay contacts
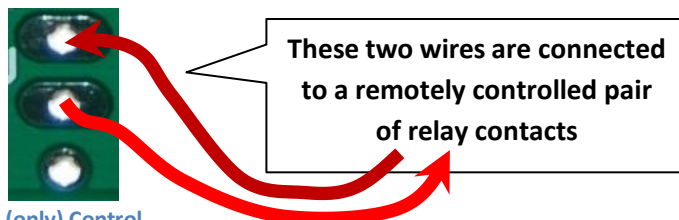
Figure 5: Wiring LEDs for Remote (only) Control

LOCAL & REMOTE CONTROLLED:

This third wiring diagram shows how a bank (*any color*) of LEDs may be configured to be remotely controlled whenever there is power supplied to the "+5v" hole (*referenced to the "GND" hole*) by a remotely controlled (*computer, for instance*) relay, **AND** also locally by the (*wired-in-parallel*) slide switch on the back side of the **groLEDs** assembly.

These two wires are connected to a remotely controlled pair of relay contacts
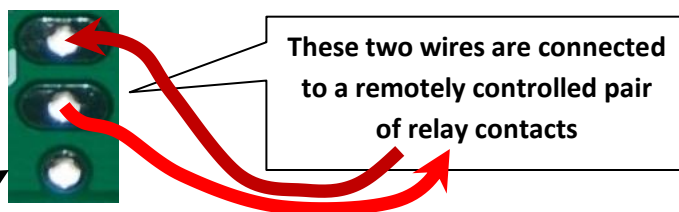
Figure 6: Wiring LEDs for Remote AND Local Control

Not shown in detail here is the fact that the (*optional*) SPDT Slide switch is mounted on the back side of the **groLEDs** assembly. The controlled LEDs will be lit whenever either the slide switch is moved to short the two holes (*shown with wire connections*) or when the relay contacts are closed by the remote control equipment, or both. To turn the LEDs off, therefore, both the manual (*local control*) switch AND the (*remote control*) relay contacts must be open.

LOCAL CONTROL only:

Not explicitly shown here is the final option of using only the back-side-of-the-board mounted slide switches to manually (*locally*) control the ON/OFF state of its associated LEDs. This last option is shown in the next section's OPTIONAL ASSEMBLY topics.

OPTIONAL ASSEMBLY:

POWER SWITCHES:

As mentioned several times, in both this document and that of the Assembly Instructions for this **groLEDs** kit, there are four optional components (*available from JameCo Electronics*) that can be installed on the assembly. The first three components are those of the (*local control, alone, or in parallel with remotely-controlled relay contacts*) SPDT Slide Switches. The footprints on the printed circuit board for the **groLEDs** kit are designed for JameCo Part#109171, SPDT Slide Switches.

If the kit-builder/user wishes to install these switches, do so from the bottom of the board, as shown in Figure 7 below. If remotely controlled relay contacts are to be wired in, as well, as described on the preceding page under the topic of "local & remote controlled", then connect the relay wires to the top side of the board, sharing the solder from the switch pins mounted from below.

All 3 switches are shown in their OFF positions.

Blue LEDs Manual Power Control Switch
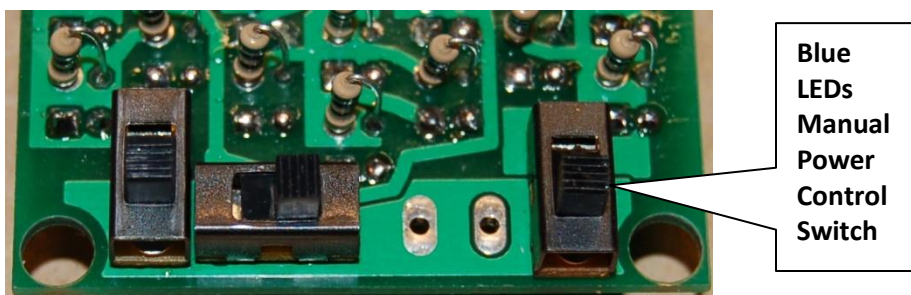
Figure 7: Power Slide Switches Optional Installation

POWER CONNECTOR:

If the kit-builder/user wishes to use a terminal block for wiring in a common power source (*to* **"+5v"** *and* **"GND"** *holes*), then use any 5mm-pitch 2-position terminal block, mounting it on the bottom of the board. The particular unit shown in Figure 8 is JameCo Part#2094506.
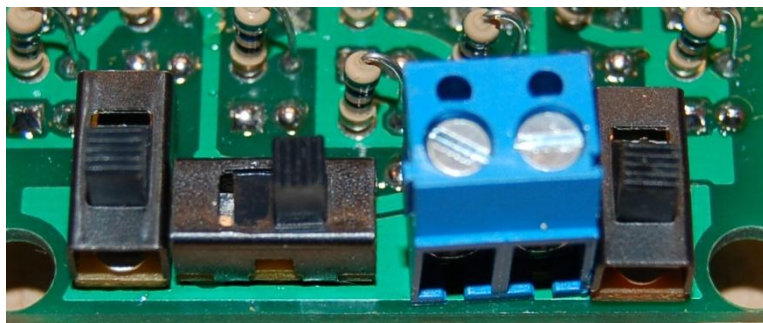
Figure 8: Optional Power Connector Installation

GANG WIRING:

COMPUTER POWER SUPPLY:

The following simplified wiring diagram depicts how multiple **groLEDs** assemblies can be run from a single computer (*tower*) power supply, using switchable very-bright (*at* ≈ +5.0*volts*) and (*just*) bright (*at* ≈ +3.3*volts*) fixed voltages that can be manually controlled or remotely (*computer*) controlled via relay contacts.
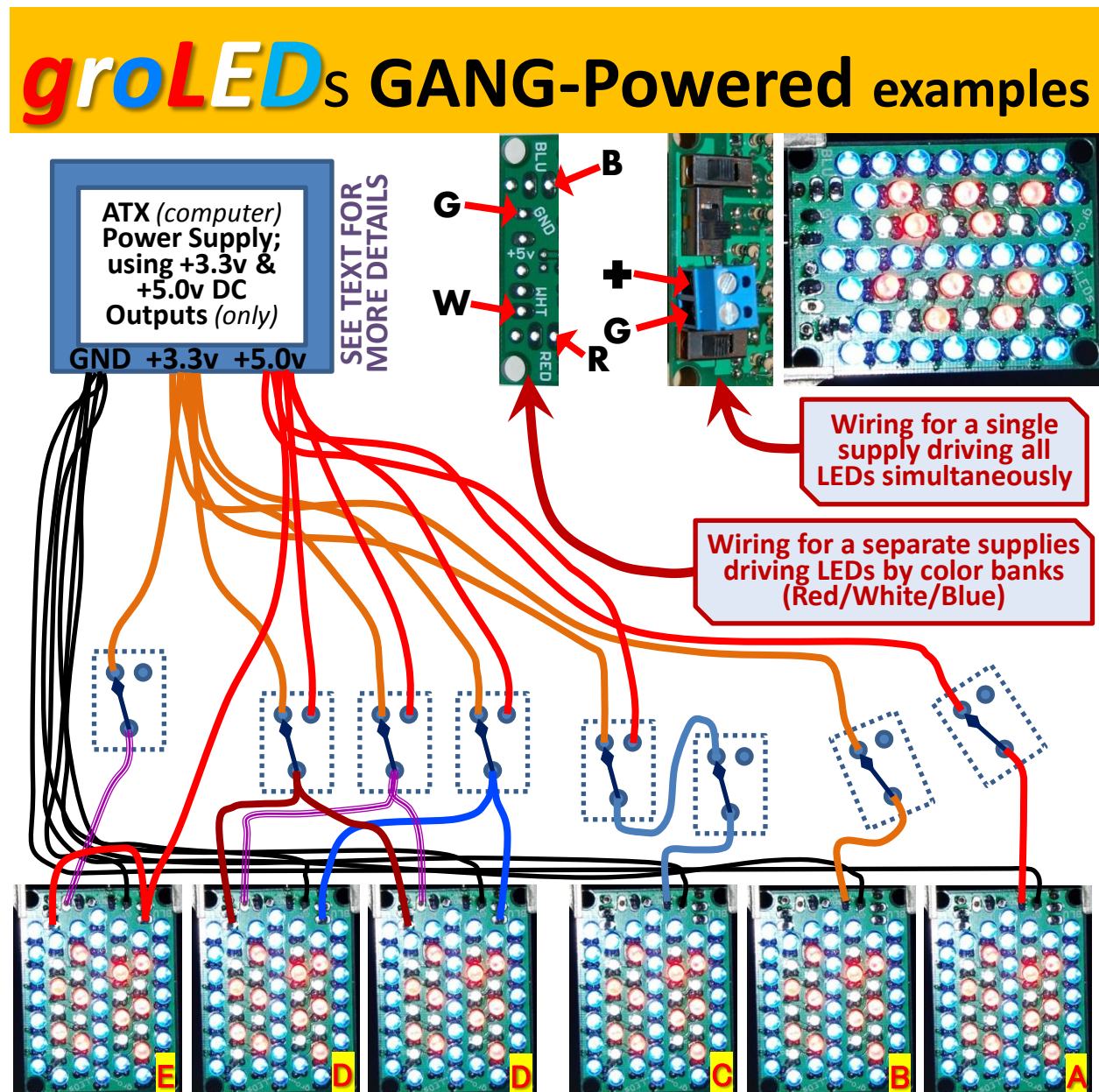
Figure 9: Multiple groLEDs Gang-Powered from Computer Power Supply examples

POWER SUPPLY NOTES:

Supply Voltage	Voltage Range (min-max)	Wire Color	Usage Notes:
+5 Vdc	+4.75↔ +5.25	RED	These Red wires are used to power the **groLEDs** at *(very bright)* 5volt levels
+3.3 Vdc	+3.135↔ +3.465	ORANGE	These Orange wires are used to power the **groLEDs** at *(just bright)* 3.3volt levels
GROUND	Common (0 volts)	BLACK	These Black wires are used to provide the ground path *(power return)* for **groLEDs** assemblies
+12 Vdc	+11.40↔ +12.60	YELLOW	These Yellow wires, though not used by the **groLEDs** assemblies, may be used for small 12volt fans if additional ventilation or heat dissipation is desired
+5 V sb	+4.75↔ +5.25	PURPLE	+5volts standby is present even when rest of the supply lines are turned OFF *(see "Power ON" below)*. **NOT USED**
Power ON	+5 Vsb or GROUND	GREEN	[**MUST**] Connect this Green wire to a Black wire *(always, through a switch, or a computer-controlled pair of relay contacts)* to turn ON the power supply output voltages.
PWR_OK	GROUND or +5 Vsb	GREY	NOT USED
-5 Vdc	-4.50↔ -5.50	White	NOT USED
-12 Vdc	-10.8↔ -13.2	Blue	NOT USED

Table 1: ATX (computer) Power Supply Connections

As depicted in Figure 9 *(on the preceding page)*, the Red Wires are +5volt lines, the Orange Wires are +3.3volt lines, and the Black Wires are the Ground *(power return)* lines. Not shown in Figure 9 are:

1. The GREEN Wire needs to be connected to a BLACK wire to turn ON the power supply; and,
2. The YELLOW Wires *(referenced to the Black wires)* may power small 12-volt computer-type fans if localized air movement is desired, for either cooling the **groLEDs** *(see thermal measurements later in this document)* or for providing some 'ventilation' for the plants themselves.

HOW MANY groLEDs on a POWER SUPPLY:

Since there are many variations of switching power supplies designed to power varying capacities of computers, it is difficult to say with certainty how many **groLEDs** can be powered from a single power supply. The following examples may help understand how the sizing works.

In my own bench stock I have a pair of functional 250watt power supplies; with different current level capacities for the two main voltage rails being used in the example: +5volts and +3.3volts.

1. Power supply #1 can supply +5V at 27amperes (=135Watts) and +3.3volts at 14amperes (=46.2Watts). This is a total of 181.2Watts, with the remaining power (of 250Watts) for the other voltage rails *(see table 1 above)*.
2. Power supply #2 can supply +5V at 25amperes (=125Watts) and +3.3volts at 16amperes (=52.8Watts). This is a total of 177.8Watts, with the remaining power (of 250Watts) for the other voltage rails *(see table 1 above)*.

ALL LEDS at +5VDC:

If all 50 LEDs per **groLEDs** assembly are operated at +5volts, then 1.619Amperes of current is needed, =8.095Watts. This means that 15 or 16 **groLEDs** assemblies can be *(easily)* powered from just one of these two small 250Watt ATX (computer) power supplies using just the +5volts power rail.

ALL LEDS at +3.3VDC:

If all 50 LEDs per **groLEDs** assembly are operated at +3.3volts, then 0.424Amperes of current is needed, =1.400Watts. This means that 33 or 37 **groLEDs** assemblies can be *(easily)* powered from just one of these two small 250Watt ATX (computer) power supplies using just the +3.3volts power rail.

CHEAP more-POWER:

OK, let's assume that you don't have a spare computer power supply lying around. A 480Watt ATX Power Supply *(almost double the capacity of the ones noted above)* can be had for just $14.99[4]. This higher wattage power supply can drive up to 66 **groLEDs** assemblies if they all run at +3.3volts or 22 **groLEDs** assemblies if they all run at +5volts. This single power supply, therefore, could theoretically power up to 88 **groLEDs** assemblies before another power supply would be needed for more **groLEDs** assemblies.

FIGURE 9 DETAILS:
SWITCHES or RELAYS:

Figure 9 shows 8 examples of SPDT[5] 'contacts' that can be either mechanical switches or *(computer-controlled)* relay contacts, or a mix of both, as desired. Any of these 'contacts' with three wire connections need to be SPDT, while any with just two wire connections can be either SPDT *(with one position unused)* or SPST.

BOARD "A":

Board "A", in the bottom right corner of Figure 9, is the first **groLEDs** assembly whose wiring will be briefly explored. It is configured to have <u>**all 50 of its LEDs running at +5volts**</u> when the switch or relay contacts are closed *(as shown)*. The 'common' connection on its SPDT 'contacts' connects a single wire to the "+5V" input of the **groLEDs** assembly. The Power supply is bringing in +5volts *(on a <u>**red**</u> wire)* to this set of SPDT 'contacts. The **groLEDs** board itself will need to have three wire-jumpers installed for "always on" as shown in Figure 4, slide switches installed for "local control" as shown in Figure 7, or some other variation *(see figures 5 and 6)*.

BOARD "B":

Board "B" *(next to Board "A" in Figure 9)* is configured to have <u>**all 50 of its LEDs running at +3.3volts**</u> when the switch or relay contacts are closed *(as shown)*. The 'common' connection on its SPDT 'contacts' connects a single wire to the "+5V" input of the **groLEDs** assembly. The Power supply is bringing in +3.3volts *(on an <u>**orange**</u> wire)* to this set of SPDT 'contacts. As with Board "A", Board "B" needs to be configured for local, remote, or some combination of control of the supply to each of its color-banks of LEDs since the whole board is receiving a common power voltage level *(+3.3volts in this example)*.

---

[4] Part# 83-15657, MCM Electronics (www.MCMelectronics.com) 1-800-543-4330; as found on page 132 of their July 2015 (printed) catalog.
[5] SPDT ≡ Single Pole Double Throw; whereas SPST ≡ Single Pole Single Throw

BOARD "C":

Board "C" is the last example of a *(pair of)* **gro**LED**s** boards where all 50 LEDs *(per* **gro**LED**s** *board)* are running at the same voltage that is applied to their "+5V" input connection. In the top right corner of Figure 9, just left of the picture of a **gro**LED**s** board, the bottom side of the board is shown with all four optional components installed *(three power slide switches and a 2-position terminal block)*. For all three board examples discussed so far ("A", "B", and "C") the black *(GROUND)* power supply wire connects to the **gro**LED**s** board where the label "**G**" is depicted, while the input supply voltage is connected where the label "✚" is shown.

Board "C" wiring is just slightly more complex than those of Board "A" and Board "B". There is a pair of SPDT contacts. The right one *(of the pair)* functions as an ON/OFF switch, just as in the two previous examples. The left SPDT 'contact' selects between +5.0volts *(on the red wire from the power supply)* or +3.3volts *(on the orange wire from the power supply)* to be applied to Board "C".

BOARDS "D":

There are two boards in Figure 9 labeled "D" because there are two **gro**LED**s** assemblies wired in parallel; both functioning identically depending upon the three different SPDT 'contact' positions that are supplying power to these **gro**LED**s** assemblies. Unlike the three previous examples, the two **gro**LED**s** "D" assemblies are "always ON" when the power supply is turned on. What makes this example so unique is the fact that all of the Red LEDs can be *(just)* bright running at +3.3volts or they can be very bright running at +5volts; AND, all of the Blue LEDs can be *(just)* bright running at +3.3volts or they can be very bright running at +5volts; AND, all of the White LEDs can be *(just)* bright running at +3.3volts or they can be very bright running at +5volts.

The SPDT 'contact' common connections depicted in Figure 9 for this example ("D") uses the wire connections shown at the top of Figure 9 in the center. The switch or relay contacts that supply power to all of the Red LEDs connects to the hole labeled "R" for both **gro**LED**s** boards. The switch or relay contacts that supply power to all of the White LEDs connects to the hole labeled "W" for both **gro**LED**s** boards. The switch or relay contacts that supply power to all of the Blue LEDs connects to the hole labeled "B" for both **gro**LED**s** boards. Don't forget to connect power supply GROUND *(power return)* Black Wires to the holes labeled "G" for both **gro**LED**s** boards.

BOARD "E":

There is just one board in Figure 9 labeled "E" *(bottom left corner)* that is configured for special growing needs. Following the wires from the power supply down to the circuit connections for board "E" one finds that the Red and Blue LEDs are always ON at a very-bright level *(driven by +5volts-red wire)*, since there are no intervening switches or relay contacts for controlling these connections. The White LEDs on board "E" are controlled by the one switch or relay contacts that are powered by the +3.3volts source from the power supply. So, board "E" lights up very-bright Red and Blue LEDs whenever the power supply is on, and dimmer White LEDs are turned on and off as needed.

NOTE: The general terms of <u>dim</u> and <u>just-bright</u> and <u>very-bright</u> are only relative adjectives since, in reality, all of these LEDs are <u>too bright to look at</u> *(safely)* even when they are powered at +3.0volts. Absolute brightness levels are presented in the PERFORMANCE section of this document.

TECHNICAL:

BLOCK DIAGRAM:

*gro*LEDs kit
Block Diagram

30 *different* **Blue LEDs: 1900mcd each; 468nm; ±15° Viewing angle**
Bright Blue, clear lens
Narrow Beam 'spot'
57,000mcd total

+5Vdc Input

Power Connect
Current Limiters

10 *different* **White LEDs: 8000mcd each; (dominant) 650nm; ±120° Viewing angle**
'Broad' White,
diffused lens,
Wide Beam 'flood'
80,000mcd total

Power Connect Options: Always ON, Manual ON/OFF Switch, Relay Control, et.al

Power Connect
Current Limiters

10 *different* **Red LEDs: 8000mcd each; 635nm; ±20° Viewing angle**
Bright Red, clear lens
Narrow Beam 'spot'
80,000mcd total

Power Connect
Current Limiters

As noted earlier, the brightness levels cited in this block diagram are the data sheet specifications for LEDs operating at their nominal current levels of 20mA each.

All of the topics covered so far in this document are primarily concerned with the application and distribution of power inputs to the groLEDs, and less with their actual brightness levels and the power required under various operating conditions. These latter topics are discussed in greater detail in the PERFORMANCE section of this document.

Figure 10: groLEDs Assembly Block Diagram

SCHEMATIC:
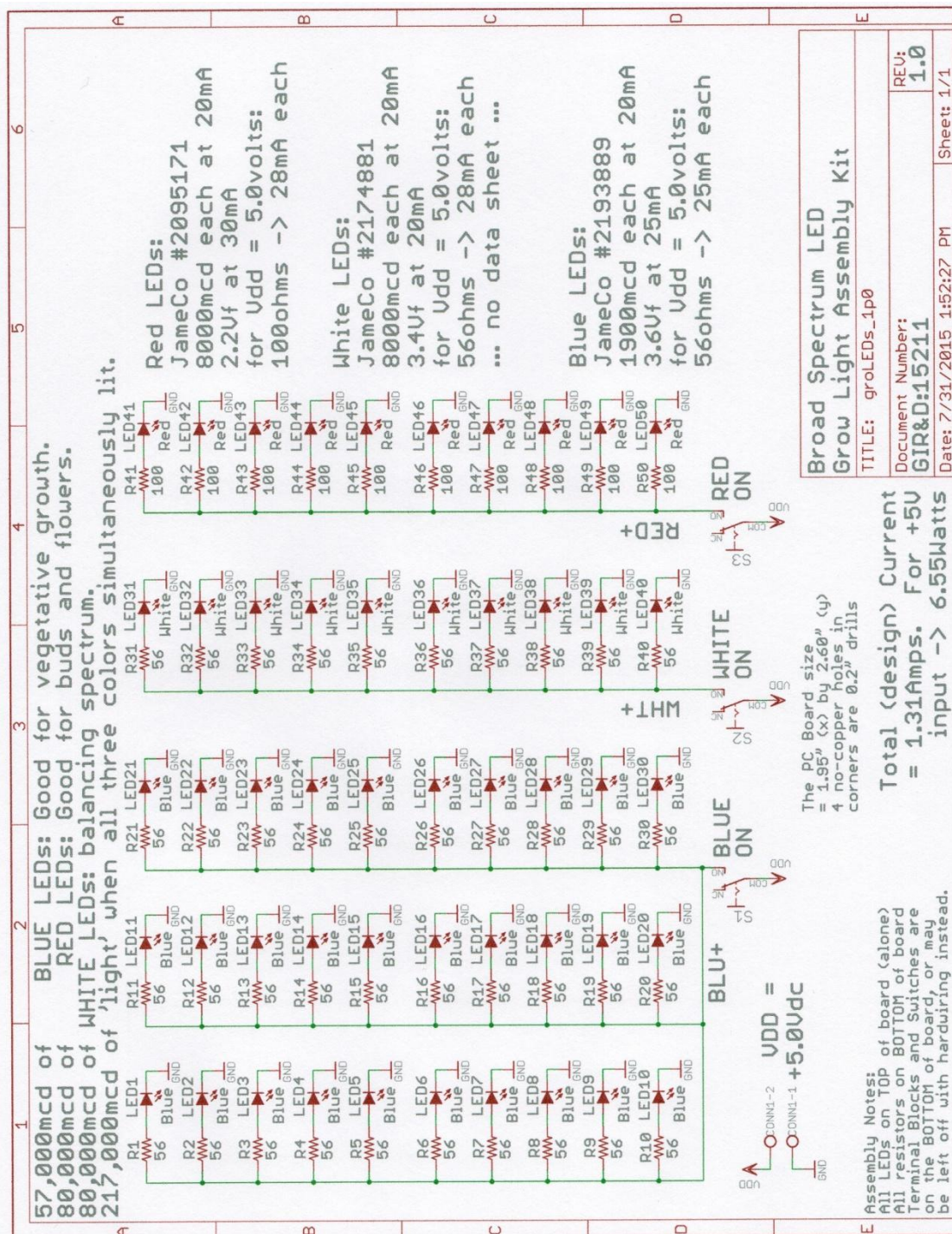
Figure 11: groLEDs annotated Schematic

PC BOARD TOP COPPER:
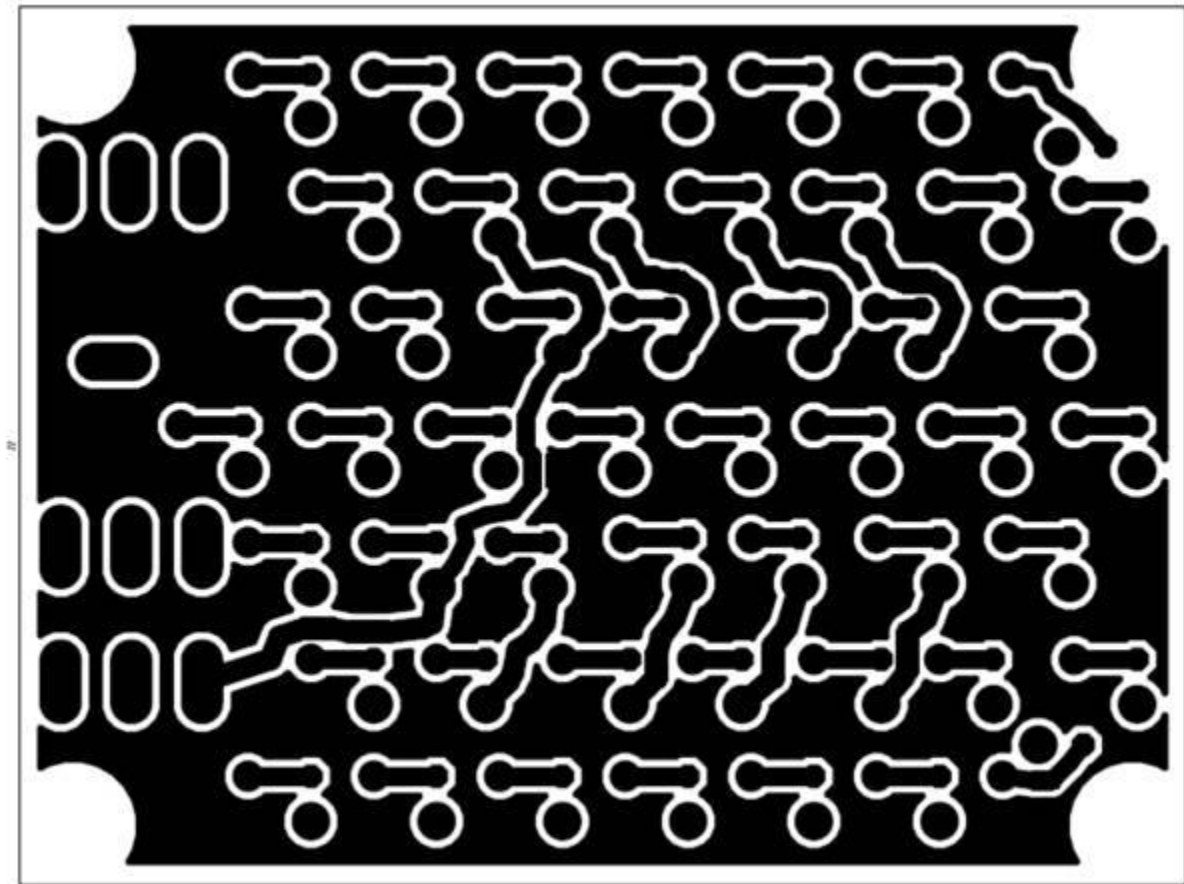
Figure 12: groLEDs PC Board Top Copper Layer

PC BOARD BOTTOM COPPER:
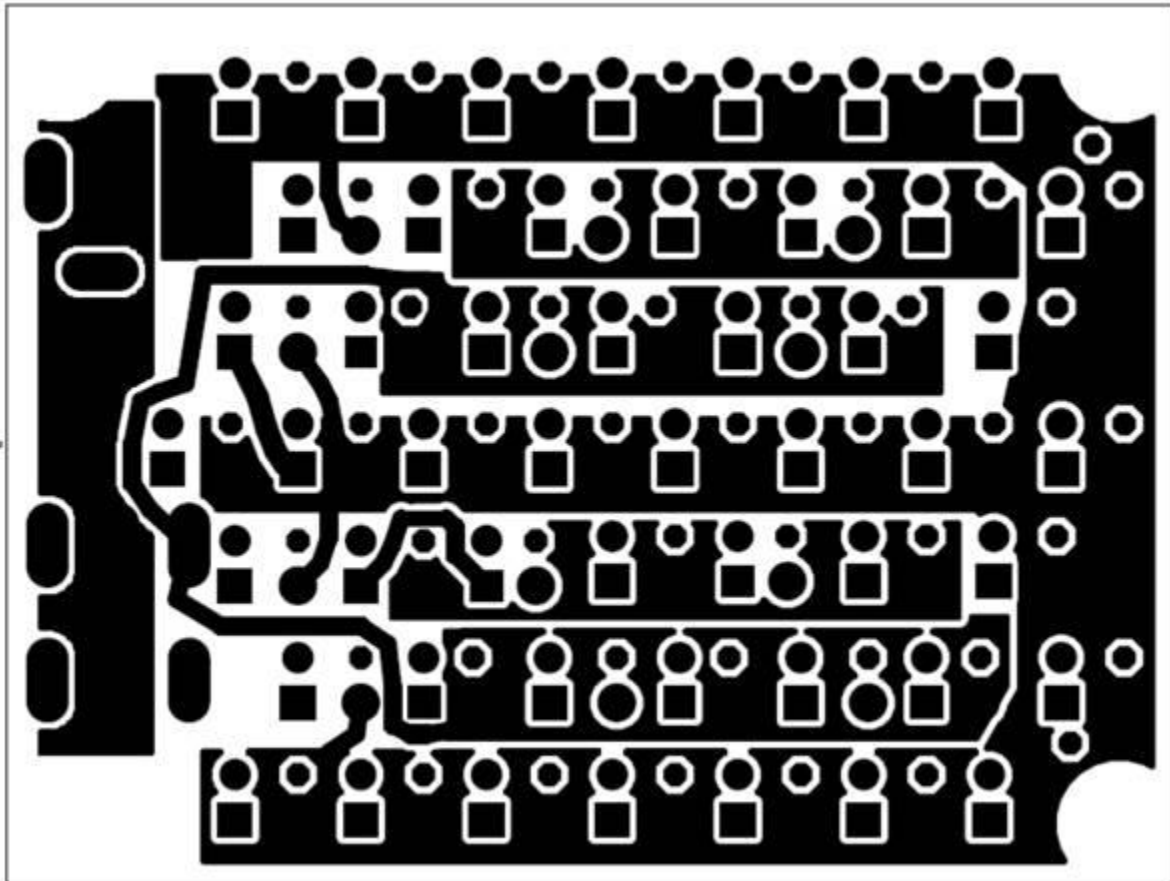
Figure 13: groLEDs PC Board Bottom Copper Layer

BOARD STATISTICS:

Board Size = 1.95" (49.53mm) 'x' by 2.60" (66.04mm) 'y'.

This 2-layer board has 55 signals connecting 211 pads using 183 wires and 7 polygons. The top layer is 72.2% copper *(see figure 12)* while the bottom layer is only 60.5% copper *(see figure 13 above)*. The majority of the 'wires=traces' are 0.040" wide, with the minimum width being 0.032". The isolation regions on all *(copper-pour)* polygons is 0.016". The four [pad] 'drill' sizes are 0.032" (0.8128mm), 0.051" (1.3mm), and 0.063" (1.6mm) for copper-filled pads; and the largest drill size of 0.199" (5.08mm) are for the four corner holes lacking copper for mounting the board in various ways. There are soldermask layers for both top and bottom; but, there is only a top layer *(minimal text)* silkscreen.

PERFORMANCE DATA:

POWER per VOLTAGE:

Red LEDs POWER:

ALL RED LEDS: Total Power Input (y axis) per Voltage Input (x axis)

$$y = 104.81x^2 - 247.93x + 124.19$$
$$R^2 = 1$$

Figure 14: Red LEDs Total Power per Input Voltage Plot

The Red LEDs, with their lower forward voltage drop, include 100Ω series current limiting resistors. They 'turn ON' at a lower voltage at the minimum of 1.69volts in this plot, compared to the Blue and White LEDs.

As the input voltage increases, the forward voltage drop across the Red LEDs increases slightly, from 1.59volts to 2.10volts, with the majority of the total voltage drop occurring across the resistors. Therefore, as the input voltage increases, the total efficiency drops because proportionally more of the power is lost as heat across the resistors.

The equation *(for the trend line)* can be used to determine the total power for any given input voltage. When added to the trend line equations for the Blue and White LEDs, total power for the entire **groLEDs** assembly can be predicted for any given input voltage(s).

The data tabulated *(in Table 2)* are just a few samples from extensive bench testing conducted on the first **groLEDs** assembly. Since this is NOT a large statistically significant population, use the data as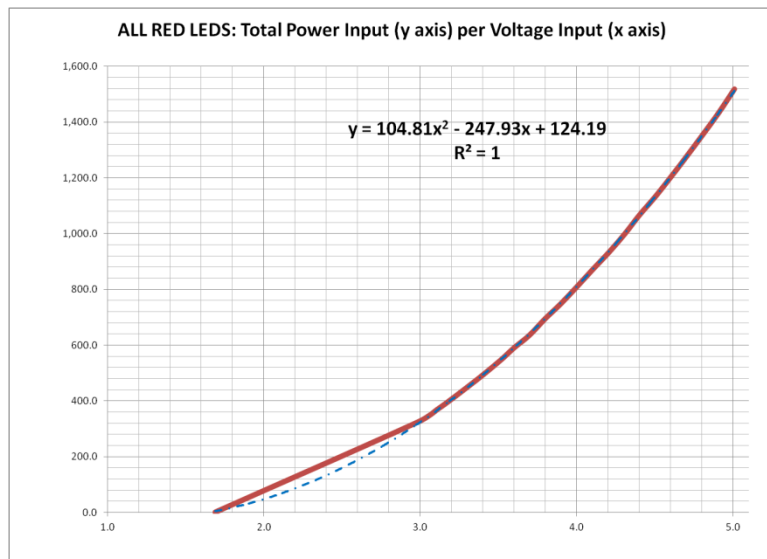 approximations only. The Yellow Highlighted data is that where the input voltage causes the nominal 20mA per LED operating point to occur. The two **BOLD BLUE Data** points are those that occur when using an ATX Computer Power Supply as the power source, as

Voltage Input	Total Current Input	Total Power	PWR Efficiency %
1.69Vdc	1mA	1.7mW	99.24%
2.99Vdc	109mA	325.9mW	63.69%
3.31Vdc	**137mA**	**453.5mW**	**60.13%**
3.52Vdc	156mA	549.1mW	56.94%
3.80Vdc	183mA	695.4mW	53.30%
3.96Vdc	200mA	792mW	50.12%
4.31Vdc	232mA	999.9mW	47.91%
4.51Vdc	252mA	1,136.5mW	45.58%
4.70Vdc	271mA	1,273.7mW	44.04%
5.01Vdc	**303mA**	**1,518.0mW**	**41.63%**
5.31Vdc	335mA	1,778.9mW	39.55%

Table 2: Red LEDs Power and Efficiency per Input Voltages

discussed previously in this document. Note: the 5.31Vdc sampling was NOT included in the Plot of Figure 14. A high end light test at +5.50Vdc needed 353mA of current for 1.9415Watts of Power usage.

White LEDs POWER:

The White LEDs, with their higher *(than the Red LEDs)* forward voltage drop, include 56Ω series current limiting resistors. They 'turn ON' at a minimum voltage of 2.59volts in this plot, compared to the Red and Blue LEDs.

As the input voltage increases, the forward voltage drop across the White LEDs increases slightly, from a low of 2.43volts to a high of 3.22volts, with the majority of the total voltage drop occurring across the resistors. Therefore, as the input voltage increases, the total efficiency drops because proportionally more of the power is lost as heat across the

ALL WHITE LEDS: Total Power Input (y axis) per Voltage Input (x axis)

$$y = 198.17x^2 - 794.13x + 719.56$$
$$R^2 = 0.9999$$

Figure 15: White LEDs Total Power per Input Voltage Plot

resistors. They are still more efficient than the Red LEDs examples cited previously.

The equation *(for the trend line)* can be used to determine the total power for any given input voltage. When added to the trend line equations for the Blue and Red LEDs, total power for the entire **groLEDs** assembly can be predicted for any given input voltage(s).

The data tabulated *(in Table 3)* are just a few samples from extensive bench testing conducted on the first **groLEDs** assembly. Since this is NOT a large statistically significant population, use the data as approximations only. The Yellow Highlighted data is that where the input voltage causes the nominal 20mA per LED operating point to occur. The two **BOLD BLUE Data**

Voltage Input	Total Current Input	Total Power	PWR Efficiency %
2.59Vdc	1mA	2.6mW	99.61%
2.99Vdc	38mA	113.6mW	93.02%
3.31Vdc	**78mA**	**258.2mW**	**87.13%**
3.51Vdc	106mA	372.1mW	83.69%
3.80Vdc	147mA	558.6mW	78.09%
4.18Vdc	200mA	836mW	73.68%
4.31Vdc	228mA	982.7mW	71.73%
4.51Vdc	260mA	1,172.6mW	69.56%
4.70Vdc	291mA	1,367.7mW	67.02%
5.00Vdc	**340mA**	**1,700.0mW**	**63.8%**
5.30Vdc	375mA	1,987.5mW	60.75%

Table 3: White LEDs Power and Efficiency per Input Voltages

points are those that occur when using an ATX Computer Power Supply as the power source, as discussed previously in this document. Note: the 5.30Vdc sampling was NOT included in the Plot of Figure 15. A high end light test at +5.50Vdc needed 419mA of current for 2.305Watts of Power usage. The **groLEDs** user is reminded that the White LEDs are going to 'flood' the area with white light; they are NOT narrow beam spot *(light)* LEDs like the Red and Blue LEDs used on the **groLEDs**.

Blue LEDs POWER:

ALL BLUE LEDS: Total Power Input (y axis) per Voltage Input (x axis)

$$y = 608.2x^2 - 2586.1x + 2603.6$$
$$R^2 = 0.9998$$

Figure 16: Blue LEDs Total Power per Input Voltage Plot

The Blue LEDs, with their higher *(similar to the White LEDs)* forward voltage drop, include 56Ω series current limiting resistors. They 'turn ON' at a minimum voltage of 2.52volts in this plot.

As the input voltage increases, the forward voltage drop across the Blue LEDs increases slightly, from a low of 2.40volts to a high of 3.21volts, with the majority of the total voltage drop occurring across the resistors. Therefore, as the input voltage increases, the total efficiency drops because proportionally more of the power is lost as heat across the resistors. They are still more efficient than the Red LEDs examples cited previously.
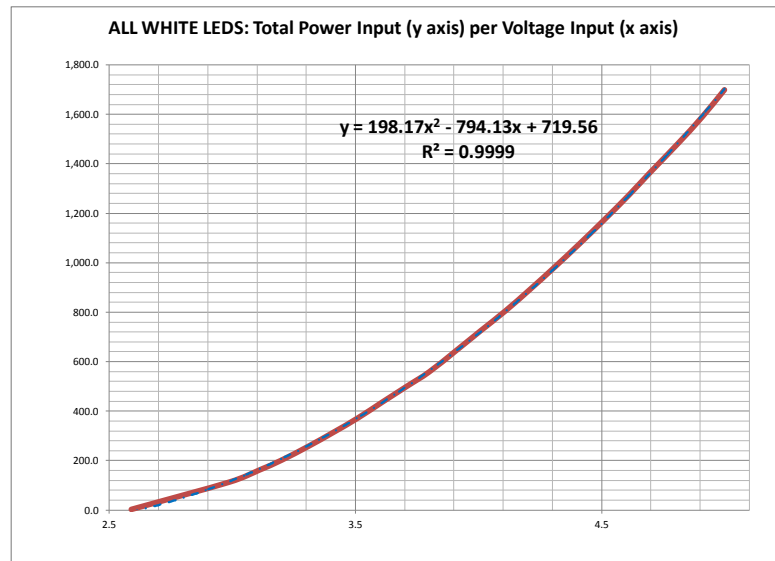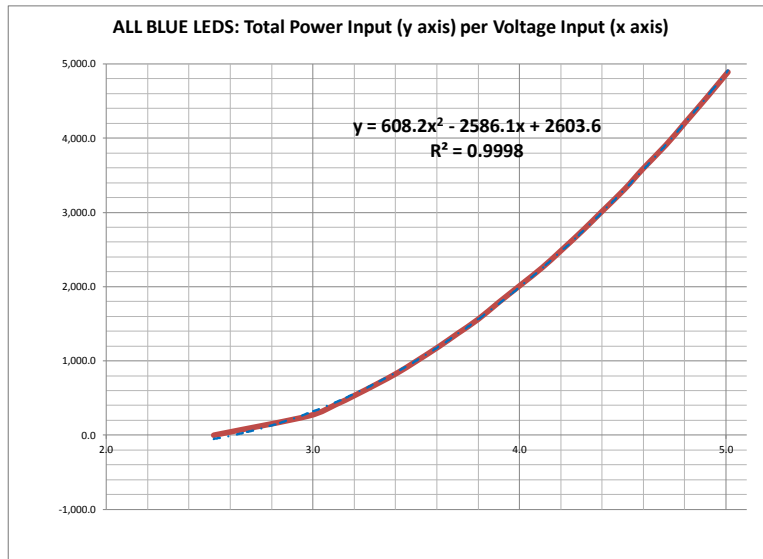
Voltage Input	Total Current Input	Total Power	PWR Efficiency %
2.52Vdc	1mA	2.5mW	99.61%
2.98Vdc	88mA	262.2mW	94.24%
3.31Vdc	**209mA**	**691.8mW**	**86.83%**
3.50Vdc	285mA	997.5mW	84.11%
3.80Vdc	411mA	1,561.8mW	78.96%
4.18Vdc	600mA	2,508.0mW	73.21%
4.31Vdc	642mA	2,767.0mW	71.63%
4.51Vdc	735mA	3,314.9mW	69.11%
4.71Vdc	830mA	3,909.3mW	66.51%
5.01Vdc	**976mA**	**4,889.8mW**	**63.40%**
5.31Vdc	1,140mA	6,053.4mW	60.45%

Table 4: Blue LEDs Power and Efficiency per Input Voltages

The data tabulated *(in Table 4)* are just a few samples from extensive bench testing conducted on the first **groLEDs** assembly. Since this is NOT a large statistically significant population, use the data as approximations only. The Yellow Highlighted data is that where the input voltage causes the nominal 20mA per LED operating point to occur. The two **BOLD BLUE Data** points are those that occur when using an ATX Computer Power Supply as the power source, as discussed previously in this document. Note: the 5.31Vdc sampling was NOT included in the Plot of Figure 16. A high end light test at +5.51Vdc needed 1.213Amperes of current for 6.683Watts of Power usage.

It is recommended that the **groLEDs** user does NOT operate the **groLEDs** above +5.0volts input without also using some kind of air-movement scheme to cool down the board. Later, temperature data will be provided showing how the board heats up *(above ambient temperatures)* in still air. With just a small amount of air moving over the **groLEDs** assembly, the **groLEDs** assembly was operated at 5.3volts and at 5.5volts inputs for an extended period of time with no thermal issues.

AMBIENT SUNLIGHT:

On 20 August 2015, at 1355 hrs, with no clouds in the sky[6], several light measurements[7] were made for establishing a comparison light-level, where many plants around the house attempt to 'grow'. NOTE: there is no direct sunlight here in the woods; three tiers of canopy *(the maximum at about 150feet)* maintain a <u>mostly-shaded growing environment</u>. The average ambient light level was:

<div align="center">

1209 Lux ≈ 112.4 Fc

</div>

LIGHT OUTPUT per VOLTAGE:
Red LEDs LIGHT:

Measured with Tenma Light Meter #72-9195 at a distance of 12.0". NOTE: The meter is calibrated to a standard incandescent lamp at color temperature 2856 K (which is NOT peak for these 635nm LEDs).

$y = 369.65x - 595.32$
$R^2 = 0.9971$
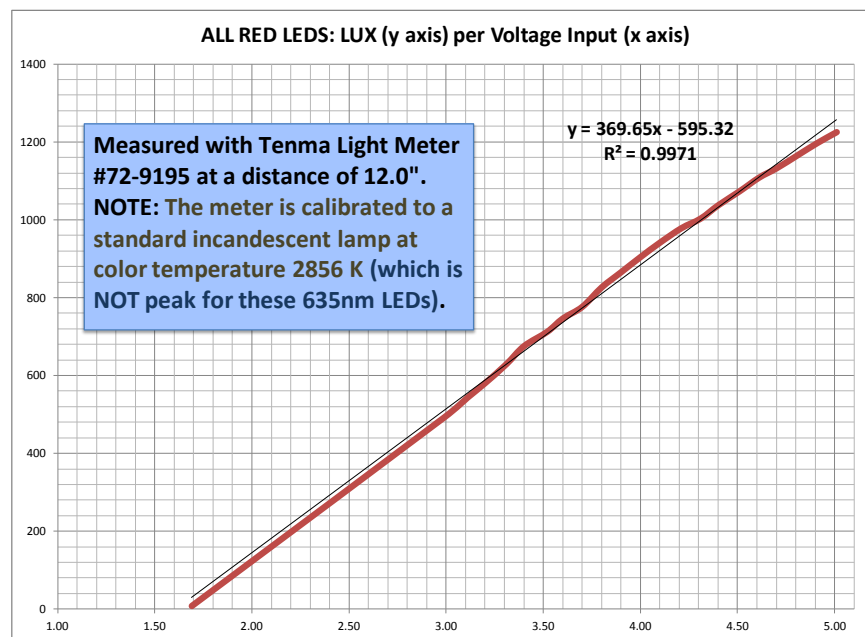
Figure 17: Red LEDs Luminous (incident) Power [Lux] per Input Voltages Plot

Input Voltage	Lux	Notes	Input Voltage	Lux	Notes
3.31Vdc	629	ATX Power Supply Voltage Level	4.00Vdc	904	Near the nominal operating point of 20mA per Led
5.01Vdc	**1225**	ATX Power Supply Voltage Level	5.50Vdc	**1333**	Voltages higher than +4.94Vdc resulted in light BRIGHTER than the ambient shaded sunlight conditions.

Table 5: Red LEDs Lux levels at a few key Input Voltages

---

[6] Rare occurrence in Ohio; bright, mid-summer, mid-day, peak-growing time light level measurement.
[7] All light measurements were made using a Tenma model 72-9195 Light Meter that provides both FootCandles (Fc) and Lux readouts *(where they define* 1 FootCandle = 10.76 Lux*)*. Except for the Ambient Light Measurements, the Light Meter was exactly 12inches (one foot) from the Light Meter's sensor.

White LEDs LIGHT:

ALL WHITE LEDS: LUX (y axis) per Voltage Input (x axis)

Measured with Tenma Light Meter #72-9195 at a distance of 12.0".
NOTE: The meter is calibrated to a standard incandescent lamp at color temperature 2856 K (which is NOT peak for these White LEDs).

$y = 143.88x - 354.77$
$R^2 = 0.9911$
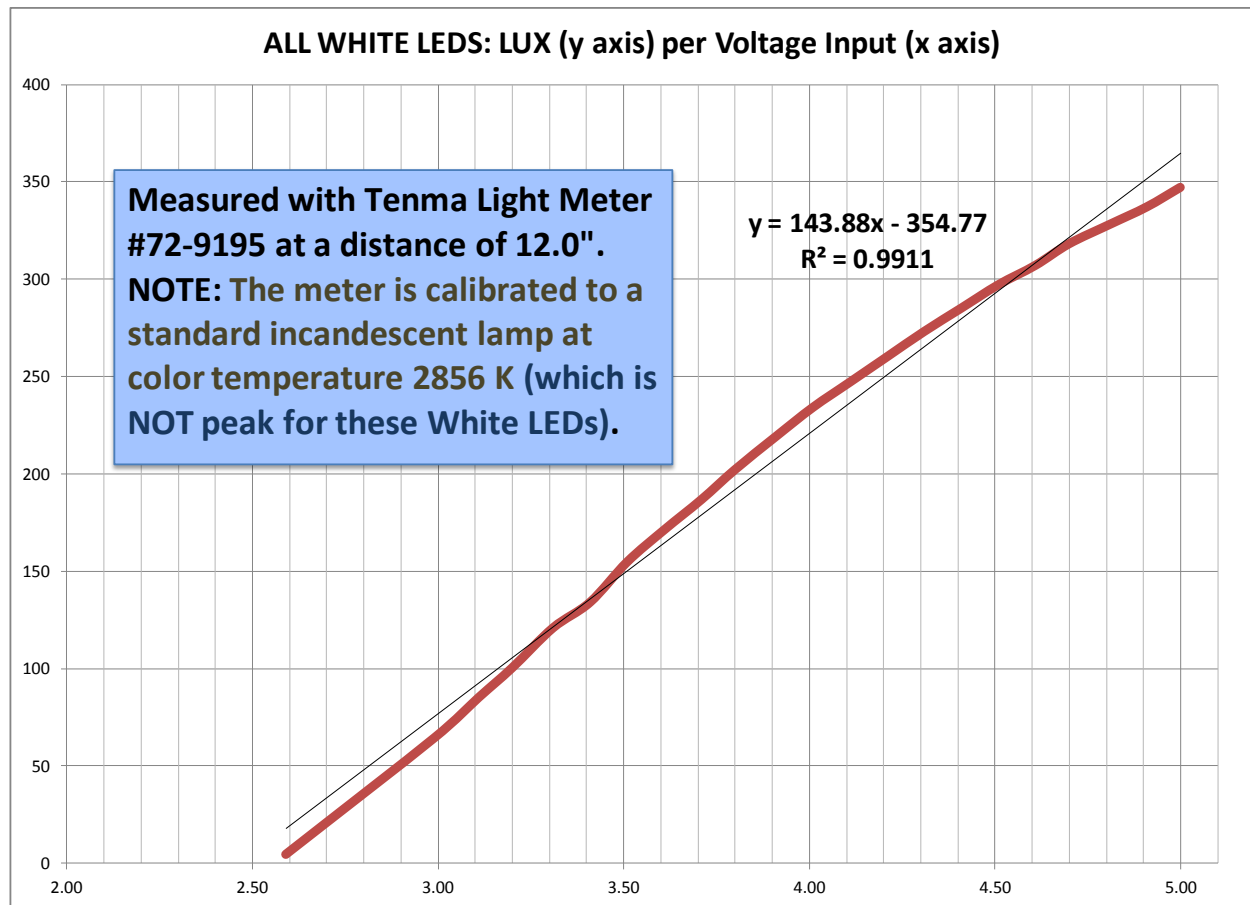
Figure 18: White LEDs Luminous (Incident) Power [Lux] per Input Voltages Plot

Input Voltage	Lux	Notes	Input Voltage	Lux	Notes
3.31Vdc	120.8	ATX Power Supply Voltage Level	4.11Vdc	247	Near the nominal operating point of 20mA per Led
5.00Vdc	347	ATX Power Supply Voltage Level	5.50Vdc	393	Highest voltage used for testing

Table 6: White LEDs Lux Levels at a few key Input Voltages

Note that none of the White LEDs Lux readings were very high *(compared to the Red and Blue LEDs)* because of the angle of dispersion. The White LEDs are FLOOD *(lamps)* LEDs with a very wide viewing angle; not SPOT *(lamps)* LEDs like the Red and Blue LEDs used on the **groLEDs** assembly.

Blue LEDs Light:

ALL BLUE LEDS: LUX (y axis) per Voltage Input (x axis)

Measured with Tenma Light Meter #72-9195 at a distance of 12.0". NOTE: The meter is calibrated to a standard incandescent lamp at color temperature 2856 K (which is NOT peak for these 468nm LEDs).

$y = 753.92x - 1881$
$R^2 = 0.996$
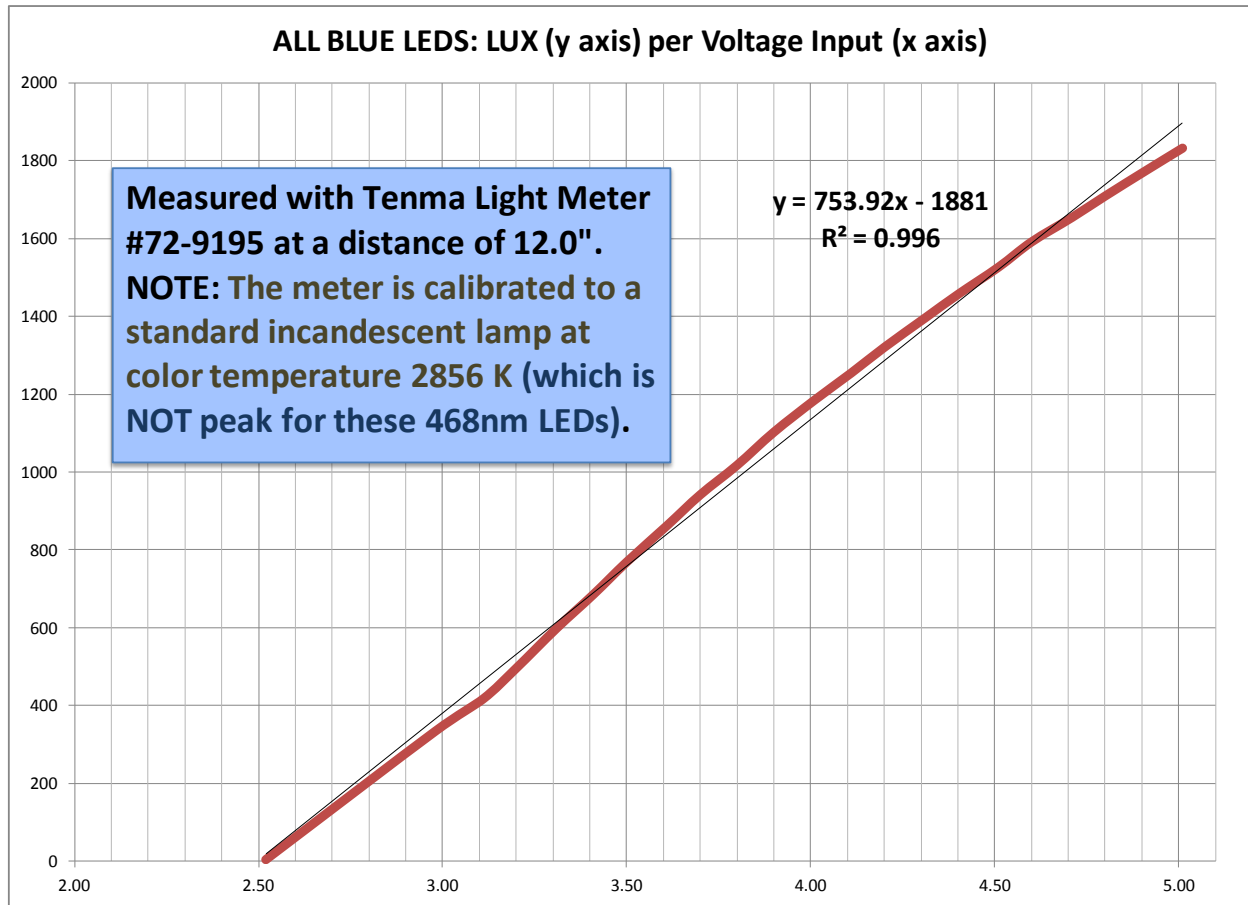
Figure 19: Blue LEDs Luminous (Incident) Power [Lux] per Input Voltages Plot

Input Voltage	Lux	Notes	Input Voltage	Lux	Notes
3.31Vdc	598	ATX Power Supply Voltage Level	4.18Vdc	1320	Near the nominal operating point of 20mA per Led
5.01Vdc	1832	ATX Power Supply Voltage Level	5.51Vdc	2150	Voltages higher than +4.05Vdc resulted in light BRIGHTER than the ambient shaded sunlight conditions.

Table 7: Blue LEDs Lux Levels at a few key Input Voltages

VERY BRIGHT @ 3.31Vdc:

Adding the Lux value for Red LEDs = **629** *(see Table 5)* to the Lux value for White LEDs = **120.8** *(see Table 6)* to the Lux value for Blue LEDs = **598** *(see Table 7)*, all operating at just 3.31Vdc, creates a combined light Luminous Power value that is much higher than the "ambient sunlight" (in the shade) measurements. The **groLEDs** assembly is VERY BRIGHT even at low operating voltage levels. Hence the need for repeating…

> # SAFTEY ADVISORY:
> ## Do NOT Look directly into these LEDs when they are lit; they are EXTREMELY BRIGHT, and can cause temporary diminished sight with 'lots of spots.'

OTHER LUX VALUES:

It may be helpful, for relative comparison[8] purposes, to compare the Lux levels of the **groLEDs** assembly to a few *(more)* common light sources, where some familiarity may be beneficial:

Lux Level @ 12"	Light Source	Notes
283	5Watts CFL	Not open spiral; enclosed in incandescent-style globe
450	15Watts FL	Cool White 2-foot Florescent Tube Desk Lamp
810	60Watts	'standard' (bare) Incandescent Light Bulb
1200	19Watts CFL	Open spiral; 900Lumens rating @ 2700K (color)
1590	80Watts FL	Pair of 4feet 40Watts Cool White Florescent Tubes in a hanging "workshop" open fixture
3810	100Watts	'standard' (bare) Incandescent Light Bulb
6000	50Watts H	115Vac Halogen Spot Light (track lighting)
19720	Vehicle	Truck's headlamp (at a very close 12") at unknown ratings

Table 8: Some Common Light Sources Lux Values

Obviously, the **groLEDs** assembly can't compete against my truck's headlamps; but, it is interesting.

---

[8] Very un-scientific; simple samplings at 12" distances

HEAT:

The **groLEDs** assembly, due to its totally passive design, converts some of the input power to heat across the 50 current-limiting resistors *(one per LED)*. As shown in previous discussions, the efficiency drops as the input voltage goes up because the voltage drop across the *(diodes)* LEDs is not linear. Therefore, the heat-losses increase as the input voltage goes up.

While the **groLEDs** assembly is much more efficient than incandescent bulbs, halogen lamps, and the very high power grow lamp technologies of metal halide and high pressure sodium lamps, and even some florescent bulb systems if you also consider the ballast power losses, they still generate some heat that may become an issue in some growing environments.

Three simple thermal-rise experiments were conducted, summarized as:

1. Dead-air – no airflow with the **groLEDs** assembly <u>vertical</u>
2. Dead-air – no airflow with the **groLEDs** assembly <u>horizontal</u>
3. Light air flow *(from a small desk fan 5 feet away)* with the **groLEDs** assembly <u>horizontal</u>

For experiments #1 *(see Table 9 below)* and #2 *(see Table 10 below)* each voltage setting included a two minute delay to permit the heat level to rise and stabilize, before the highest[9] temperature reading was acquired on the back *(resistor)* side using the Infrared Thermometer of an Extech Model EX210T. The first tabulated value, at Vin= 0.00Vdc, is the baseline 'ambient' unpowered board temperature used for the 'rise' values tabulated.

VERTICAL HEAT RISE:

Vin	Temperature	Rise above Ambient	$\approx$ Input Power[10]
0.00Vdc	76.2°F	Baseline	0mW
2.58Vdc	77.3°F	+1.1°F	182.19mW
2.74Vdc	79.5°F	+3.3°F	346.97mW
3.00Vdc	82.2°F	+6.0°F	763.49mW
3.30Vdc	89.9°F	+13.7°F	1.397Watts
3.75Vdc	107.7°F	+31.5°F	2.655Watts
4.02Vdc	122.1°F	+45.9°F	3.587Watts
4.30Vdc	138.0°F	+61.8°F	4.694Watts
4.71Vdc	161.6°F	+85.4°F	6.572Watts
5.03Vdc	183.5°F	+107.3°F	8.251Watts

Table 9: Vertical groLEDs Assembly Heat Measurements for various Input Voltages

As mentioned in footnote 10, the total power tabulated is equation-derived, and very closely matches samples acquired during testing.

All 50 LEDs were 'on', except for when the "Vin" value was too low for the Blue and White LEDs *(2.58Vdc in table 9)*. The 'hottest' spot was consistently found on the top edge of the (vertical) board, usually midway.

The 'high' heat values for the high input voltage values were a bit of a surprise until the total Power Input Values were added. 8.251Watts being dissipated by a single large power resistor would be very warm to the touch. And, it must be stressed again that this was an unrealistic, still-air experiment, where real growing environments would have some airflow to lower these temperature values.

---

[9] The Infrared (laser-pointer-guided) Thermometer was scanned over the whole back side of the **groLEDs** board 'holding' on the maximum reading found.

[10] Total Power is calculated from the sum of the three different trend line equations presented in Figures 15, 16, and 17 for the Red, White, and Blue LEDs, respectively, except for the lowest non-zero reading which only included power for the Red LEDs, since the input voltage was not yet high enough to turn on the Blue and White LEDs.

HORIZONTAL HEAT RISE:

Vin	Temperature	Rise above Ambient	≈ Input Power[11]
0.00Vdc	73.9°F	Baseline	0mW
2.55Vdc	74.8°F	+0.9°F	173.50mW
2.76Vdc	76.8°F	+2.9°F	374.63mW
3.00Vdc	81.5°F	+7.6°F	763.49mW
3.30Vdc	88.3°F	+14.4°F	1.397Watts
3.75Vdc	112.6°F	+38.7°F	2.655Watts
4.01Vdc	124.5°F	+50.6°F	3.550Watts
4.32Vdc	138.2°F	+64.3°F	4.778Watts
4.70Vdc	161.9°F	+88.0°F	6.523Watts
5.00Vdc	185.5°F	+111.6°F	8.086Watts

Table 10: Horizontal groLEDs Assembly Heat Measurements for various Input Voltages

The same notes presented in Table 9 apply here in Table 10.

LIGHT AIRFLOW:

With the **groLEDs** assembly still powered (at Vin = 5.00Vdc) from the last sample acquired in Table 10, a small desk fan about 5 feet away was turned on low *(I realize this is not very scientific)* to see what would happen with the temperatures.

After two minutes of 'pause' a scan-for-the-highest temperature found that the hot spot *(right in the middle of the board)* was now at a much lower 155.6°F, a 29.9°F drop in temperature.

After another two minutes of 'pause' a scan-for-the-highest temperature found that the hot spot *(still right in the middle of the board)* was now at an even lower 132.4°F, another 23.2°F drop in temperature.

After another two minutes of 'pause' another scan-for-the-highest temperature found that the hot spot *(still right in the middle of the board)* was now at an even lower 131.7°F.

After another two minutes of 'pause' a final scan-for-the-highest temperature found that the hot spot *(still right in the middle of the board)* was now at a slightly lower 130.4°F.

Some, even a little, airflow helps significantly when running the **groLEDs** assembly at high input voltages.

the end

---

[11] Total Power is calculated from the sum of the three different trend line equations presented in Figures 15, 16, and 17 for the Red, White, and Blue LEDs, respectively, except for the lowest non-zero reading which only included power for the Red LEDs, since the input voltage was not yet high enough to turn on the Blue and White LEDs.