PROJECTOR CONNECTIONS

Need some kind of sub-heading like "Making the right connections for perfect laser images".

Note that text in blue is a good candidate for a longer version of the article, which might appear on the web as opposed to print. Text in black is the main article text, which of course may be edited as needed for space or style.

During the 22 years that I've been a part of the laser display industry, I have offered my knowledge and assistance freely. One of the things that I am known for is helping people with their scanners. Laserists and scanner manufacturers alike have been sending scanners to me for years, so that I can tune them for optimal performance and make other modifications when necessary. Most often, I do this as a free service for ILDA members.

One thing that I have noticed in recent years is that people are having more difficulty with connecting the various components together to make a complete laser projector. Incorrect connections can lead to distorted images and other problems, which are then mistakenly blamed on poor scanner tuning or poor component performance. Incorrect connections can also lead to a dangerous projector – for example, one which will output a beam even when it is not connected. For this reason, it is quite often that when I receive a projector or scanning system to tune, I wind up re-wiring the components so that the projector can produce perfect images. Since so many people seem to have difficulty in this area, I decided to write an article that shows the proper way to connect the components together.

This article is intended to be a guide for projector manufacturers, on the best way to assemble components to create a laser projector conforming to the ILDA Standard Projector (ISP) specification. This article may also be interesting to persons who are not projector manufacturers, as it provides a good insight into how projectors work and the components involved.

When discussing the connections inside a laser projector, it is best to conceptually separate these connections into two categories: Connections that are related to power supplies (referred to as "Power Connections"); and connections that are related to the ILDA DB-25 signals (referred to as "Signal Connections"). We will discuss the power connections first.

POWER CONNECTIONS

Figure 1 shows the general manor in which power connections should be made between the various components. We will discuss the connections for the scanner power supplies first, because they are at the top of the page, and also because once that foundation is laid, the other power connections can be easily understood.

Power enters the projector from the AC Mains Supply. An integrated switch and fuse assembly is often used as shown. The international color standard specifies the brown wire as the LINE (or "Hot") lead, and the blue wire as the NEUTRAL lead. These are connected to the power supply LINE and NEUTRAL connections respectively. If you look closely at the power supply, you should see the words "Line" and "Neutral", or letters "L" and "N" that designate which wire goes where.

Note that there are AC power cords that do not have polarized plugs, and these two may become swapped at the point that the projector plugs into the wall. However, you should still maintain a sense of "Line" and "Neutral" throughout the laser projector, always connecting the "Line" terminals of all power supplies to the same (preferably brown) wire, and "Neutral" terminals to the other (preferably blue) wire. The most important difference between the "Line" and "Neutral" connections, is that the "Line" connection is the one that you use when connecting a switch and fuse in line with power supplies.

For laser projectors whose optical output power is relatively low (for example, a few hundred milliwatts) and projectors that have a plastic enclosure, there may only be two AC power wires (Line and Neutral) and the Ground wire may or may not be used. For projectors that have a metal enclosure, a Ground wire (international color code is green as shown) must always be used and connected as shown.

The Power Connections diagram shows two separate power supplies used to generate +24V and –24V for the scanner amplifiers, but this could be embodied as a single power supply that generates both voltages as indicated by the light gray box. In either case, the +24V and –24V power wires are connected from these power supplies to the scanner amplifiers. As with the power supplies, the scanner amplifiers may also be embodied as two separate single-axis amplifiers, or as one dual-axis amplifier as indicated by the light gray box around them.

The most important part of Figure 1 is the "Central Grounding Point". This is really the single most important connections concept inside the laser projector, and the thing that many people do not initially understand. Basically, any component inside the laser projector that requires a ground connection should make a "home-run" to the "Central Grounding Point". This connection scheme is called a "Single-Point Grounding Scheme" which is also known as a "Star Grounding Scheme". The "Central Grounding Point" should be located close to the power supplies.

Unlike the +24V and –24V, which can simply be connected to the scanner amplifiers in a daisy-chain fashion as shown, the ground connections (designated

PG in the diagram for "Power Ground") require more careful consideration, and must each make a "home run" type connection to the "Central Grounding Point".

When an AC ground connection is used (green wire on the diagram), it should be connected to the "Central Grounding Point" as well. When an AC ground is not used, then ILDA DB-25 pin 25 should be connected to the "Central Grounding Point". However, the ILDA DB-25 pin 25 should NOT be connected to the "Central Grounding Point" if the AC ground connection is already connected there, otherwise there will be a ground loop formed external to the projector, which is undesirable.

WHY USE A SINGLE-POINT GROUNDING SCHEME

To understand why it is best to use a single-point grounding scheme, take a look at Figure 2, which shows a power supply connected to a single-axis scanner amplifier. Each of the wires that connect the scanner amplifier to the power supply will have some finite amount of resistance. As an easy-to-understand example, lets assume that each wire has a resistance of 1 ohm. During hard accelerations that occur when the beam is commanded to jump from one side of the projection area to the other, the scanner amplifier will momentarily require high peak currents from the power supply. Typically these peak currents could reach up to 4 amps. If the wires that connect the power supply to the scanner amplifier are 1 ohm, this will momentarily raise the voltage on the "Power Ground" connection to 4 volts! (This is referred to as "Ground Bounce".) If this "Power Ground" signal is then daisy-chain connected to another scanner amplifier, or to other components inside the projector, then those other projector components will also momentarily experience a voltage of 4 volts, thus corrupting the signal integrity of the other components.

When a single-point grounding scheme is used, the "Ground Bounce" stays localized to the particular projector component that generated it (in this case, the X scanner amplifier), thus preventing the "ground bounce" from corrupting other projector signals. And since the scanner amplifier has differential inputs, the amplifier itself will be able to subtract out the "ground bounce", thus maintaining it's own signal integrity.

This illustrates why a single-point grounding scheme is the best way to connect projector components. Without this scheme, images often appear distorted, as shown in Figure 3.

A scan fail monitor may also be connected to the scanner amplifiers as shown on the diagram. This is required for audience-scanning projectors, and might also be advisable for graphics projectors as well. Most scan fail monitors connect to the same power supply that operates the scanner amplifiers. In any event, the ground connection of the scan fail monitor must make a "home run" connection to the "Central Grounding Point" as shown on the diagram.

POWER CONNECTIONS FOR THE LASERS

In addition to showing the connections for the scanner power supply, Figure 1 also shows the connections for the lasers. However, unlike the connections for the scanner amplifiers, the connections shown for the lasers are intended to be more conceptual than literal. The reason is because, although scanner amplifiers are highly standardized and generally all require the same kind of power supplies and connections, the lasers themselves may have integrated AC power supplies and laser diode drivers, or may each operate on a separate power supply and driver.

The diagram shows a single power supply operating three solid-state laser diode drivers, but there may be only a single laser, or in fact the laser may be an ION laser with completely separate power supply. Nevertheless, the diagram shows conceptually what must be accomplished for best results. If the laser power supply is small enough to fit within the projector, then the "Power Ground" from the power supply, as well as the "Power Ground" from the laser diode driver should each be routed to the "Central Grounding Point". If an ION laser were used, then a PCAOM would be used to modulate the beam. In this case, you would connect the Power Supply of the PCAOM driver, as well as the PCAOM driver each to the "Central Grounding Point" using a "home-run" type connection.

PROJECTOR INTERLOCK (required by the ISP standard)

The diagram also shows a relay placed in series with the laser power supplies. This relay is intended to facilitate the "interlock" feature of the ILDA Standard Projector. When connected as shown, the laser diode drivers (and optionally, the shutter driver) will only receive power when the interlock loop is closed.

The interlock facilitates an additional layer of safety for laser projectors, and is required by the ISP standard. The interlock signals form a "loop" that starts at the laser projector, goes through all of the cabling that connects the projector to the signal source (often a computer), and goes right back to the laser projector. If this loop is broken somehow, for example by someone tripping over the signal cable, the projector should not output light. It is also possible for users to place a "Red Mushroom Switch" in series with the ILDA cable and connected to the interlock lines. This provides an easy mechanism for laser operators to prevent laser output when needed. And lastly, since the connector on an ILDA Standard Projector is a DB-25, which is the same connector used by desktop computers for SCSI, Printer, and Serial connections, it is possible that someone might mistakenly plug the laser projector into one of these connectors. The SCSI, Printer, and Serial DB-25 connectors all output some kind of signals, and thus, might cause light to be emitted from the laser projector. The interlock portion of the ISP standard is intended to help prevent light from coming out of the projector if the projector is mistakenly connected to a non-laser signal source.

The ISP specification allows for voltages up to 25 volts, and currents up to around 160 milliamps to exist on the DB-25 pins. Thus, the projector interlock must be facilitated in such a way that these values are not exceeded. However, it is recommended by the author of this article to try to implement an interlock that uses far less voltage and current – for example 5 volts and 5 milliamps. This could be done using an electronic relay instead of an electro-mechanical relay. The interlock may also be implemented in other manors that might provide an increased level of safety – for example, by outputting a small sine-wave signal on pin 4, and comparing it to the voltage received on pin 17.

SIGNAL CONNECTIONS

We will now discuss the connections that are related to the ILDA DB-25 signals, starting with a discussion of the scanner amplifiers.

The ILDA DB-25 connector primarily contains signals that control the motion of the beam (i.e. X-Y scanning), and the color and brightness of the beam (i.e. R, G, B beam power). There are other signals on the DB-25, such as the projector interlock mentioned above, a shutter signal, and some multi-propose "user" signals, but this article only discusses motion and color related signals, as well as the shutter and projector interlock.

The motion- and color-related signals are arranged as differential pairs. For the purpose of the laser projector, the word "differential" means that the laser projector must derive the actual signal level by taking the difference between two signals (i.e. by subtracting). For example, ILDA DB-25 pin 1 contains the X+ signal, and pin 14 contains the X- signal. Often times, when pin 1 is going from 0V to +5V, pin 14 will be going from 0V to –5V. The actual signal level is found by subtracting; thus +5V minus –5V = +10V. This means that the voltage level that the X scanner amp should sense is +10V.

Note that I used the term "often times" above. The reality is that there is no strict requirement for the X- signal to be "equal but opposite" when compared to the X+ signal. As far as the projector is concerned, the same X position could be commanded if the X+ signal goes to +10V and the X- signal stays at 0V, because +10V minus 0V = +10V. Likewise, the same result could be generated if the X+ signal goes to +20V and the X- signal goes to +10V, because +20V minus +10V = +10V. This is an important concept, because the ISP standard absolutely requires projectors to derive all motion and color signals by taking the difference between two signals. No motion or color signal should be assumed to be referenced to ground, and – at the projector – no motion or color signal should be connected to ground.

With that in mind, you will notice that we connect ILDA DB25 pin 1 to the X+ input on the X scanner amplifier, and we connect pin 14 to the X- input. Likewise we connect pin 2 to the Y+ input of the Y scanner amplifier, and we connect pin 15 to the Y- input. Note that, although the scanner amplifiers themselves may have a "Signal Ground" input (labeled SG in the diagram), this is NOT connected!! The reason this is not connected is because if it were, this would destroy the single-point grounding scheme that was established and discussed above in the Power Connections section of this article. Basically, since the scanner amplifiers have differential inputs, it is only those differential inputs that are used for ILDA DB-25 signals. The only ground connection is made from the "Power Ground" to the "Central Grounding Point" already mentioned above.

If a scan-fail interlock were used, it would be connected to the X POSITION and Y POSITION signal from the scanner amplifier. But, there is something tricky to watch out for. You should consult the manufacturer of the scan-fail interlock to determine whether or not the scan-fail interlock itself has a differential position input. If the scan-fail monitor does not have a differential position input, you should NOT connect the "Signal ground" or "Position ground" from the scanner amplifier to the scan-fail monitor. Doing so would, again, destroy the single-point grounding scheme. The scan-fail monitor already has a ground connection to the "Central Grounding Point" established on the Power Connections diagram. You should only connect the scan-fail monitor to the scanner amplifier's ground connection if the scan-fail monitor itself has differential inputs. Pangolin's PASS does have a differential position input, but most others do not.

The scan-fail monitor would also be connected to a shutter or to the laser diode drivers, but the method of connection depends on the exact scan-fail safeguard being used. Consult the manufacturer of the scan-fail safeguard for details.

The color signals are connected in exactly the same way as the X and Y signals were connected, using differential signaling. ILDA DB-25 pin 5 is connected to the "positive modulation input" on the red laser diode driver, while pin 18 is connected to the "negative modulation input". ILDA DB-25 pin 6 is connected to the "positive modulation input" on the green laser diode driver, while pin 19 is connected to the "negative modulation input". ILDA DB-25 pin 7 is connected to the "positive modulation input" on the blue laser diode driver, while pin 20 is connected to the "negative modulation input".

The discussion about color signals above, as well as the diagram makes the assumption that the laser diode driver has differential inputs to begin with. As two examples, laser diode drivers made by Laserwave and by Viasho do have differential inputs, but, as two other examples, laser diode drivers made by CNI and Melles Griot do not. Also, it is possible that the laser projector would have an ION laser and PCAOM used for color modulation. In this case, the same connection scheme and discussion applies. PCAOM drivers made by NEOS do have differential inputs, but PCAOM drivers made by A.A do not. (In general scanner amplifiers to have a differential input, however some very low cost scanner amplifiers may not.)

Since the ISP standard absolutely requires all motion and color signals to be implemented as differential pairs within the projector, this means that if you have scanner amplifiers or laser diode drivers that do not have differential inputs, you will need to implement the differential receiver as a separate circuit. One easy way to do this is with a difference amplifier, as shown in Figure 5. A single op-amp along with four resistors can be used to receive the differential signal from the X, Y, R, G, or B signal, and generate a "single ended" signal which is then connected to the scanner amplifier or laser diode driver. Note that this circuit is drawn and implemented in such a way that it has two inputs and also two outputs. One of the outputs is the "single-ended" signal that drives the component, but the other output is a "ground reference". This needs to be connected to the "Signal ground" input terminal of the scanner amplifier or laser diode driver. The connection is made this way in lieu of connecting this to any other ground, so that "Ground Bounce" can be detected and rejected by this circuit. Also note that this diagram does not show the pin numbers of the op-amp, and also omits the op-amp power supply connections for clarity. The op-amp must receive power from a power supply that is capable of feeding it a minimum of +5V and –5V.

TTL VERSUS ANALOG COLOR MODULATION (avoiding fires!)

The ISP standard requires the color signals to respond in an analog fashion, such that 0V does not produce any light from the projector, 2.5V produces around half the nominal laser power, and 5V produces the full laser power. The ISP standard also assumes that if the laser projector is disconnected from the signal source, there should be NO light coming out of the laser projector (because there would be no difference between the differential color signals).

I have recently seen several projectors that used laser diode drivers that used TTL modulation inputs rather than analog modulation inputs. TTL modulation basically means that the laser can be fully on, or fully off. This does not conform to the ISP standard. However, what's worst is that the TTL modulation inputs "float high", which means that when the projector is disconnected from the signal source, it produces a full-power, non-moving beam. On a recent trip, I saw this happen on two separate occasions, by projectors made by two separate companies. And in both cases, the non-moving full-power beam landed on dark fabric, which actually caught fire!!

One thing to keep in mind. Under very bad circumstances, laser projectors can blind people and start fires. Projectors must be designed to be safe, and one of the safety aspects is to prevent light from coming out of them when the projector interlock is opened, and when they are not connected. TTL modulation should really be avoided, but if they are used, at the very least, a differential receiver should be used which would force the TTL lasers to “float low” instead of “float high”.

SHUTTER AND DB-25 SHIELD SIGNALS

The ILDA DB-25 pin 13 provides a signal to control a shutter, but its presence is somewhat optional, and may depend on local or federal laws where the laser projector is to be used. For example, for projectors that use solid-state lasers, it might be argued that between the fast and complete extinction offered by the laser diode driver itself, coupled with the fact that the projector interlock actually removes the power from the laser diode drivers, a shutter is therefore not needed. But for ION lasers, even those modulated by a PCAOM, a shutter would still be desired. In general, it can be said that the shutter offers an additional layer of safety for the laser projector, and thus it is a desirable thing to have.

Unlike the motion control signals, and color control signals, the shutter signal is not considered to be an “analog” signal. It is TTL in nature, and thus, the shutter is either fully opened, or fully closed. The shutter is fully opened when pin 13 is roughly 5V when compared to pin 25. Also, the shutter signal is not a true differential signal, since noise immunity is not really needed, due to the fact that it is TTL in nature. However, for the purpose of projector connections, it should be considered to be a differential signal whose counterpart is pin 25.

ILDA DB25 pin 25 is considered to be the “Shield” signal of the ILDA connector. Note that this should not be considered to be a “Ground” signal, since, most often, this signal is not connected to any “Ground” per se.

Since the shutter signal is TTL in nature, and referenced to DB-25 pin 25, one good way to receive this signal is using an optical isolator. The optical isolator will receive the TTL-level signal between pin 13 and pin 25 and allow isolation of these signals from the rest of the projector components.

OTHER PROJECTOR PARTS THAT MAY BE NECESSARY

In addition to the fundamental components described above which are certainly a part of most laser projectors, additional components might also be needed or desired. For example, the United States and certain other countries require additional safety features for laser projectors, including “key-switch”, “cover interlock”, “external interlock”, “time delay” and a “manual reset”. Each of these is described below.

A “key-switch” is required for laser projectors because, under the wrong circumstances, laser projectors could be hazardous, and should be used only by trained laser operators. To prevent untrained personnel from operating the laser, a "key-switch" is used, and the key should only be given to the trained laser operator.

If the projector covers could be easily opened or removed by a user or operator, the laser projector is required to have a "cover interlock", which will prevent the lasers from operating when the cover is opened. This cover interlock is ideally implemented as two spring-loaded switches connected in series with the general projector interlock loop described above. Two switches are used instead of one, to provide redundancy in this safety feature.

Some governments may require an additional connector to be placed on the projector called an "external interlock connector". Electrically, this connector only needs to have two pins, and this is connected in series with the general projector interlock loop. One example of how this connector might be used is when the laser projector is only supposed to project a certain effect (such as a cone shape), at only a certain time (such as, when a performer is in just the right place that the cone will surround them). The external interlock can be connected to a "pressure pad" that is only active when the performer is standing in place.

A "time delay" is used so that, when the projector is turned on, it won't start emitting laser light right away. This is in place so that the laser operator can turn on the laser projector, and then advise others who might be in the room that the laser is coming on. The time delay allows the laser operator and others to take their place to avoid accidental exposure to the laser. Of course, this assumes that exposure would be harmful in the first place, which isn't always the case. Nevertheless, the US and other countries require a time delay to be a part of the projector. The time delay is normally set for 20 to 30 seconds.

A "manual reset" is required so that if power is interrupted from the laser projector, and then power is restored at some point in the future, the laser projector will not automatically start outputting light until some manual intervention takes place (such as pressing a button, or cycling the position of the key-switch). The "manual reset" provides an additional level of safety. Consider this scenario. A laser projector is operating in a nightclub, but at some point, the power to the entire night club goes out. Then everybody leaves because there is no power. Some time later the power comes back on. If the laser also comes back on and emits a non-moving beam, and if this non-moving beam is parked onto dark fabric, it could start a fire. Because of this, the "manual reset" is required by certain countries.

The key-switch, cover interlock and external interlock are all easily understood and implemented, but the time delay and manual reset provide some difficulty since off-the-shelf components such as laser diode drivers do not have a time delay or manual reset feature. Often times these two features are implemented in the form of an electronic circuit made by the projector manufacturer. As a point of interest, Pangolin's PASS system incorporates differential receivers for both the color signals and position signals, and also implements the time delay and manual reset features, thus, this multi-purpose projector control board can help to solve some of the most difficult problems in constructing a projector.

CONCLUSION

Lasers are able to create stunning high-visibility graphic displays, as well as breathtaking audience scanning displays. Lasers serve a niche that can not be approached by any other light form. Getting the connections right inside a laser projector will ensure maximum quality of the projected image, as well as a safe display for all.

BIO

William R. Benner Jr. is President and CTO of Pangolin Laser Systems and has been active in the laser display community since 1985. In addition to his current role at Pangolin, he also served for five years as a member of the ILDA board of directors as well as serving for seven years as ILDA's Technical Committee Chairman. Benner holds numerous US and International Patents, and has received personal letters of commendation from former U.S. President Ronald Reagan and former Florida Governor Bob Graham. (In other words, he knows what the heck he's talking about... <grin>)

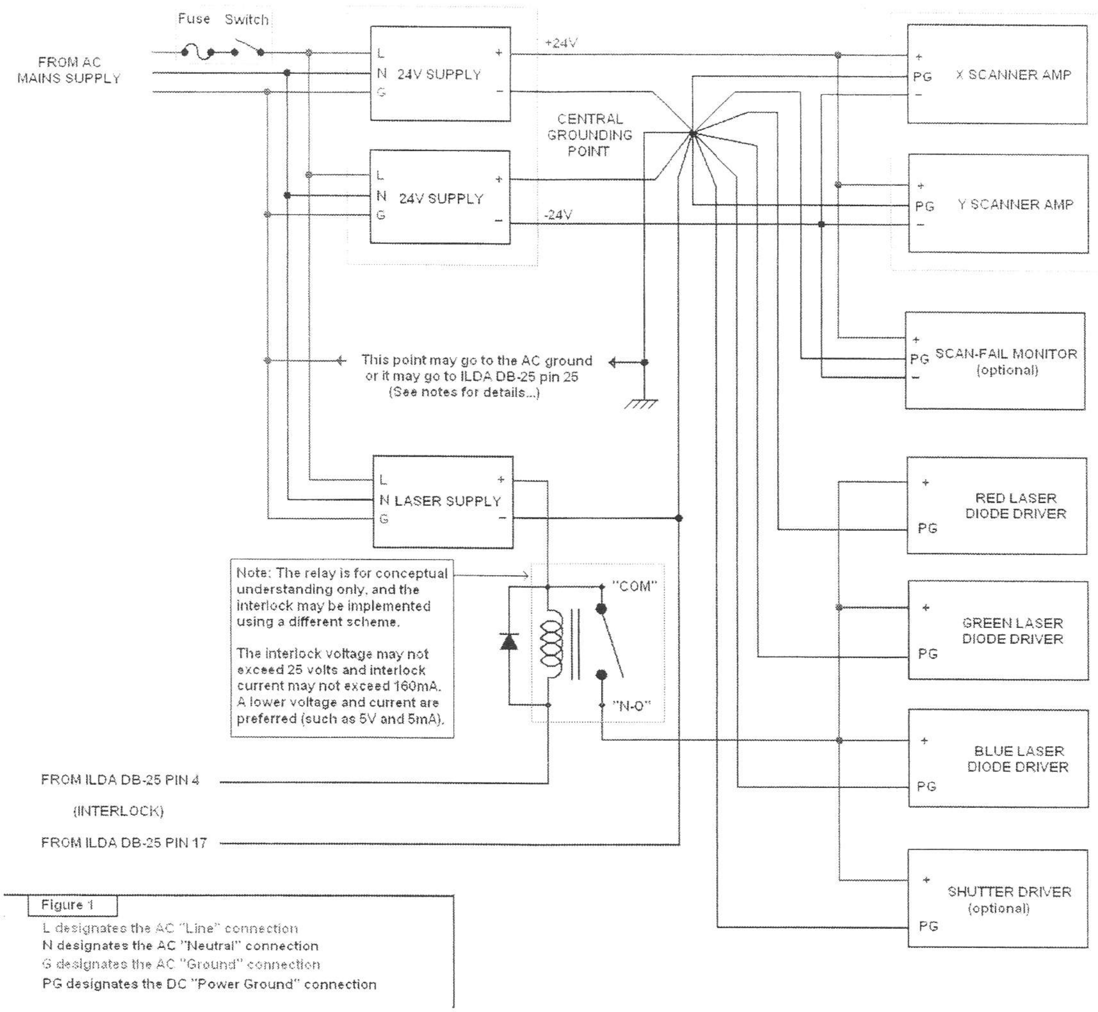


FIGURE 1: POWER CONNECTIONS

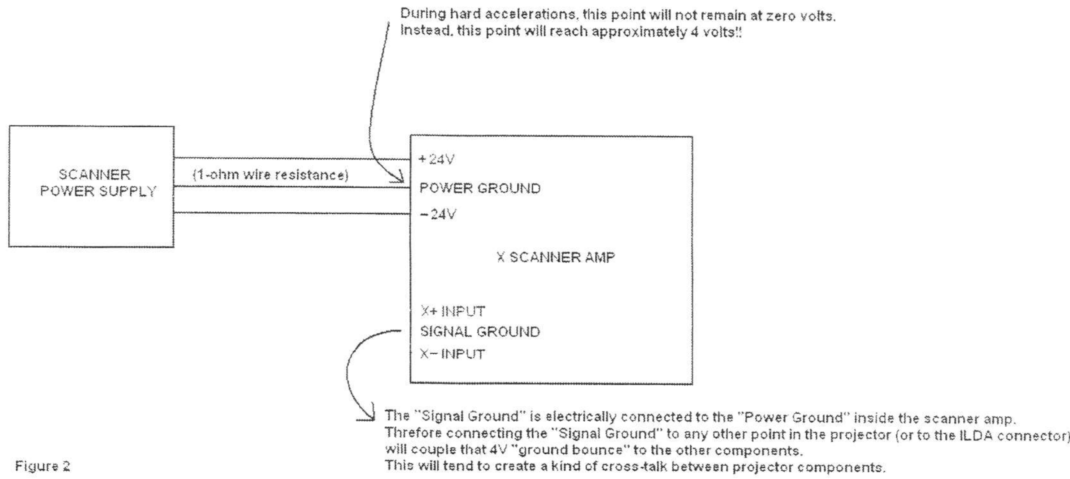
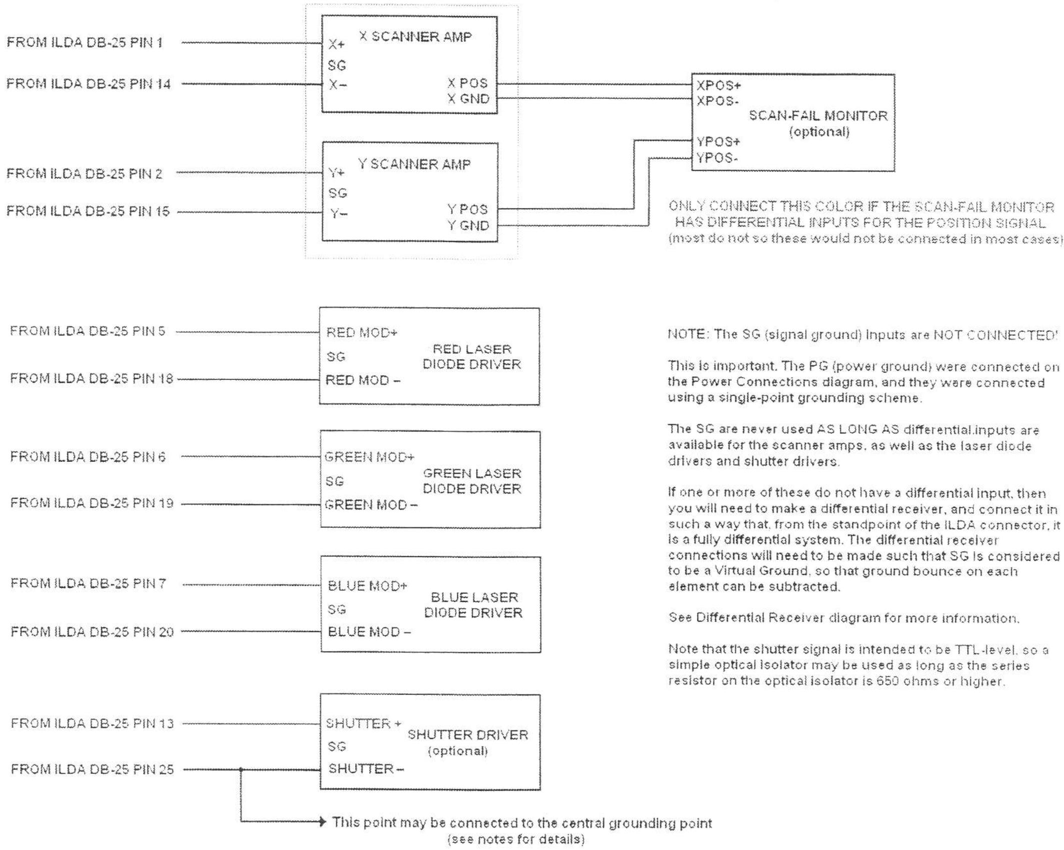


Figure 2

FIGURE 2: WHY USE A SINGLE-POINT GROUNDING SCHEME

FIGURE 3: EXAMPLE OF POOR IMAGE QUALITY DUE TO IMPROPER CONNECTIONS



NOTE: The SG (signal ground) Inputs are NOT CONNECTED!

This is important. The PG (power ground) were connected on the Power Connections diagram, and they were connected using a single-point grounding scheme.

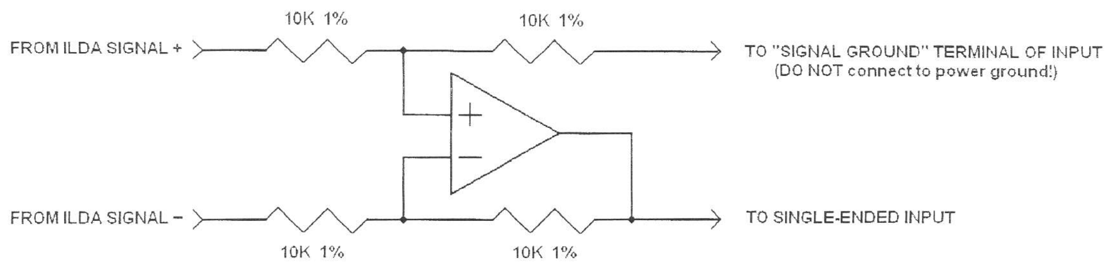
The SG are never used AS LONG AS differential.inputs are available for the scanner amps, as well as the laser diode drivers and shutter drivers.

If one or more of these do not have a differential input, then you will need to make a differential receiver, and connect it in such a way that, from the standpoint of the ILDA connector, it is a fully differential system. The differential receiver connections will need to be made such that SG is considered to be a Virtual Ground, so that ground bounce on each element can be subtracted.

See Differential Receiver diagram for more information.

Note that the shutter signal is intended to be TTL-level, so a simple optical isolator may be used as long as the series resistor on the optical isolator is 650 ohms or higher.

FIGURE 4: SIGNAL CONNECTIONS



NOTES:

OP-AMP may be any type that is stable at unity-gain. TL084 is a popular choice for a single package with four op-amps.

The OP-AMP also has power terminals which are not shown in this diagram.
The power terminals must be fed from split supplies with a voltage level of at least +5V and -5V.
Connecting the power terminals of the op-amp to a positive voltage and ground only (with no negative supply) will not provide sufficient head-room against negative-going common-mode signals which will certainly exist.

FIGURE 5: DIFFERENTIAL RECEIVER