Making an HV Output Cable for Glassman Supplies

by Rex Allers ver 1 - jan 2018

Introduction

I've made two HV cables to connect the output for two different supplies. This document is to describe the process of making them.

A Glassman Tech Note says this about the proper cables:

> Standard models are shipped with a detachable high voltage output cable. This cable consists of a center conductor, a polyethylene insulating sleeve, a braided shield wire, and an outer insulating jacket. For connection to any test apparatus, the outer end of the cable should be stripped of both the insulating jacket and braided shield wire for a length equivalent to 1.25 inches per 10 kV of output voltage. The supplied output cable has been stripped adequately for the specific operating voltage of the unit. The entire output cable should then be suspended in air by a cord as its goes from the power supply to the test apparatus to avoid any contact with grounded circuits.

The cable I used was coaxial cable commonly used for RF applications, type RG8-U. The slightly newer spec. RG213 might be a bit better for this. The cable should have solid polyethylene dielectric (not the foam version). The foam is good for low RF loss in the normal application, but is more likely to fail under high voltage stress.

Either RG8 or 213 used for HV is not in the realm of it's intended application. Spellman plays it safe and does not use either for their HV cables. In AN-07, they say this:

> In many high voltage power supply applications, a shielded polyethylene coaxial cable is used. Polyethylene cables provide excellent high voltage dielectric isolation characteristics in a small but robust form factor. The shield conductor provided in a coaxial cable functions as a "Faraday Shield" for the center conductor of the cable that is referenced to the high voltage potential. If any breakdown in the main insulator occurs, the high voltage current will be bypassed to the grounded shield conductor that surrounds the main insulator. This inherent safety feature is one benefit of using a coaxial high voltage output cable.
>
> RG8-U has long been used as a high voltage output cable in the high voltage industry. There is a variation of RG8-U that utilizes a solid polyethylene core. Specifications for this cable do not specify actual "high voltage" ratings, since this cable was not designed and fabricated with high voltage usage in mind. So the reality is, there are no high voltage ratings for RG8-U. Over the years others in the HV industry have used this cable at 20kV, 30kV and even higher voltages. Spellman does use RG8-U cable, but limits it usage to applications where the maximum voltage that will be applied to the cable is 8kV or less.
>
> For voltages above 8kV where a coaxial polyethylene cable is desired, Spellman uses cables specifically designed and manufactured for high voltage usage.

On a looser note, Cliff S, one of the main guys at Spellman, said this in a forum discussion.

> Here's my two cents: When I first started at Spellman, (29 years ago), we used "RG8U" for voltages up to 60kV. Most of the time it worked. But "most of the time" is not good enough for demanding customers. When you are making hundreds of units for a customer, and things like Semiconductor Fab's go down because of a HV cable, and you can't provide them with a datasheet that shows the cable is rated for such voltages, you kinda' need to make a change. So, we started to limit the use of RG8U to under 10kV. Things are pretty forgiving under 10kV, and I have not seen a single RG8U cable failure in such usages.
>
> I have no experience with the foam type cable, so no official opinion on that. But be weary of long term reliability. Air voids will light-up, and PD may cause degradation and failure over an extended time period. Attached datasheet is what we spec/buy for our "RG8U".

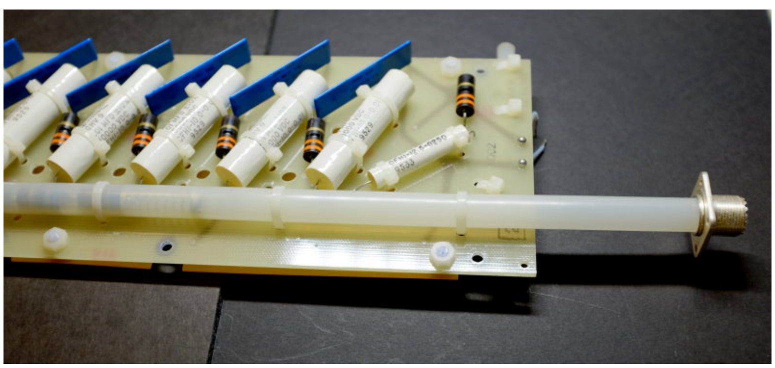
Others have reported using quality RG8 or 213 successfully up to about 50 kV. My take is that the coax shield is grounded, so if the cable dielectric did fail and arc through, the supplies have current limit so the failure should not be dangerous or damaging, except to the cable.

HV Output

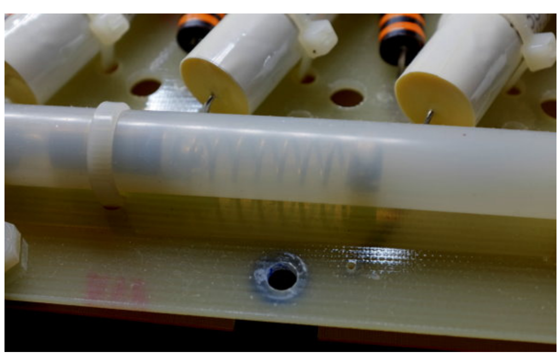
Here is a picture of the HV connector on one of the Glassman Supplies.

The connector is a modified SO239 socket and is grounded to the supply case. There is a plastic tube leading into the case with the HV connection located several inches within.

Here is one Glassman HV module with the plastic tube attached.



The connector at the right is not firmly attached to the plastic tube, just placed here for the picture to show the relationship. The connection for the HV is inside the tube and is a metal disc attached to a spring. Here is a detail of that contact.



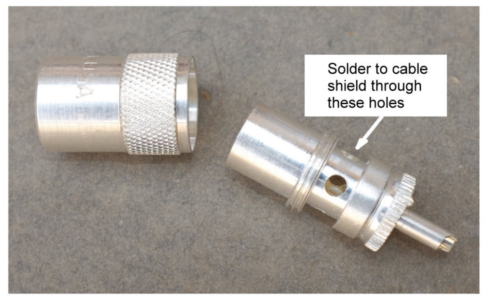
The inside of the cable presses against this spring-loaded contact for the HV connection.

Connectors

The connectors used for this HV output are modified versions of "UHF" connectors that are often used on HF or VHF radios. The plug is PL-259 and the socket is SO-239. Here is a picture of the unmodified connectors.

Plug End

Plug Back - Internal threads screw over cable insulation



PL-259 pieces unscrewed

The right side picture shows details of the PL-259 plug. The outer shell screws onto the SO-239 socket to secure the connection when plugged together, but can also be unscrewed from the inner portion of the plug to separate the two pieces. This is the solder version of the connector. In its normal RF application, the inner portion screws onto the black outer insulation of the cable. The shield is soldered to the cable shield through the holes shown, and the inner coax conductor is soldered inside the plug tip.

To modify these for the HV connection use, the SO-239 socket has the insulation and center socket connection removed. The PL-259 plug also has its center pin and insulation removed. Here are pictures.

In the plug picture, I grabbed the center pin and pried it side to side until the whole pin and insulator came out of the body. This should work fine, but a slightly better method would be to use a smaller drill to remove the center pin and then a larger drill, the same diameter as the coax inner dielectric to drill into the plug insulator. This supports the cable better as shown here.

Either method should work OK, but the drill method is probably slightly preferred.

The Cables

Here are pictures of two HV cables I made for different Glassman supplies.

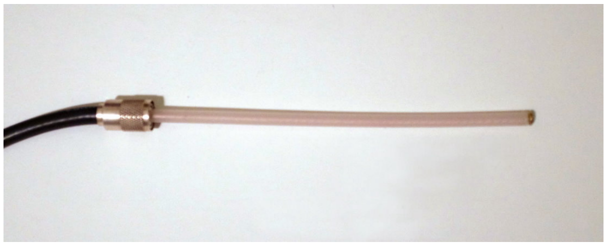
30 KV Supply Cable

40-50 KV Supply Cable

They both are basically the same design. The section that inserts into the supply's connector must have it's length determined by measuring the depth into the connector. The length of the other end must be enough to safely handle the voltage. The Tech Note in the intro section describes a minimum distance (1.25" per 10KV). I have used more like 1.75" per 10 KV for more safety from arc-over. The bottom cable also has vinyl tubing applied over the stripped section.

To determine the length of the cable section that inserts into the supply, I inserted a wooden dowel into the connector until it touched the spring-loaded disk contact inside. Then I measured that length and added about 1/2" (1.3 cm) to allow for compressing the spring contact.

The cable needs some kind of contact at the tip to make contact with disk inside. I made two different styles from brass for this. Each has a small hole in the center to accept the coax inner wire which is soldered on. Here are pics of my two tips.



The simpler tip in the second picture is quite adequate. It is on my higher voltage (40-50 KV) cable.

Spellman supplies use similar design HV cables, but the connector inside the supply is fixed (not spring loaded) and is in the form of a socket. As a result the inserted end of the cable has a plug that connects into the socket. Here is a picture.

Typical Spellman Detachable High Voltage Cable

Assembling the Connector on the Cable

The connector to be installed on the coax is a modified PL-259 as described earlier. This must be the type for RG8 or RG213 cable. There are other versions of these plugs for smaller RG8X or RG58. Those are not OK. Also, I used the version of PL-259 that solders onto the cable shield. There are other PL-259 plugs that crimp onto the cable. They might be OK but I haven't tried them and they require a heavy crimper tool to install.

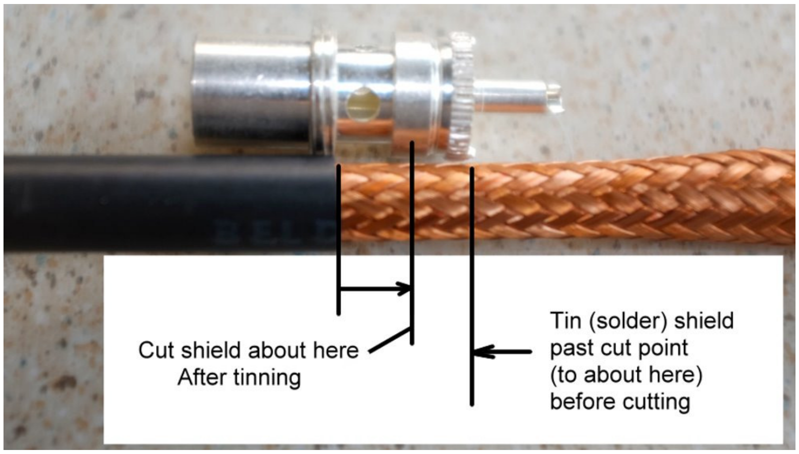
The first step is to strip off the outer insulation of the coax for the length determined by measuring the supply socket depth. I suggest stripping about an inch (2-3 cm) more than the measured length to leave extra length on the inner section that can be cut to exact length after the connector is installed and just before soldering on the tip connector.

To strip the insulation, I use a sharp knife like an X-acto or a razor blade could work. First make a cut around the circumference at the length to cut and then a cut lengthwise to allow splitting the insulation for removal. Use a light touch and try to be careful not to cut into the shield braid. The shield should stay intact. Pictures here:

These pictures show a cut length that is much shorter than should be required. They are just showing the method.

In my technique, I tin the shield before cutting it back to length and installing the connector. Some people don't do this, but I think it makes for cleaner cut, prevents stray shield wires, and makes the later soldering of the connector more likely to be a good joint.

To determine the length of shied to tin then cut, place the connector piece next to the cable as shown.

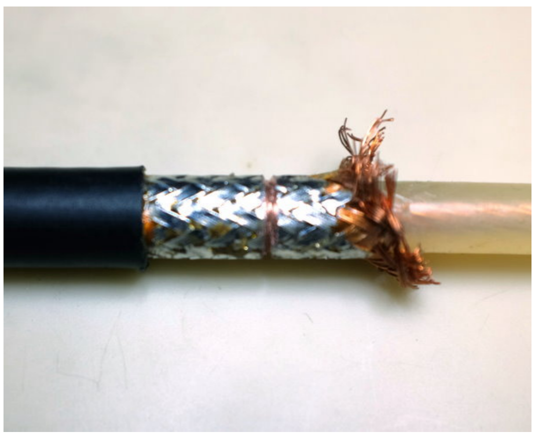


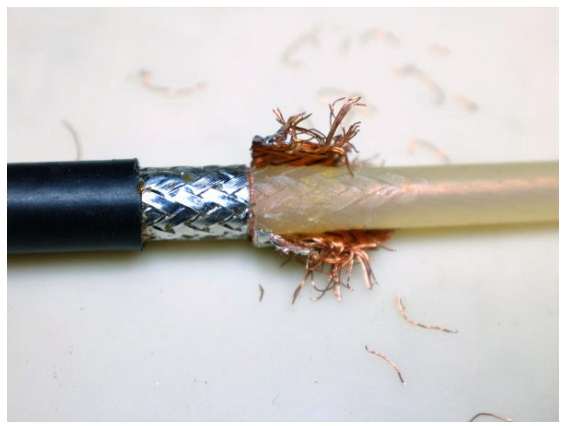
For tinning the shield use a hot iron with a big tip. Soldering the shield will do some melting of the inner polyethylene dielectric, but we hope to keep that to a minimum. A large hot tip will solder faster so should have less melting than a slower cooler tip. Before tinning the shield I paint it with solder flux to help wetting. (A solder flux pen is handy for this.) It might not be a bad idea to cut a short scrap section of cable to practice this technique before the real cable.

After tinning the shield, you need to score it at the point where it will be cut off. Again use the connector to get the distance. I used a knife to mark the line all the way around. In theory, you could use a knife to cut through the shield, but that would be difficult without cutting into the dielectric plastic. You don't want to damage that dielectric and weaken it for HV breakdown. After marking the cut point with a knife, I used a small jeweler's file with a narrow edge to slowly file through the tinned shield, following the marked line.

With the shield scored, you want to cut off the shield beyond the score line. To get a place to cut close to the tinned section, you can push back the shield from the end to make a bulge that you can cut into with cutting pliers.

Here are steps of cutting off the unwanted shield. I used small cutting pliers.





Now, the shield cut to length, you can screw the modified connector onto the cable's outer insulation. *note* Before you do this, be sure to slide the outer barrel of the connector onto the cable facing in the proper direction. Depending on the other end of the cable, you may not be able to get it on the cable after soldering the inner connector piece.

Screwed on and ready to solder

To solder the connector on, I put the corner of the Iron tip into one of the soldering holes around the connector. I melt a small blob of solder -- that will help to transfer the iron's heat into the connector and shield. When the solder starts to flow into the space between the connector and shield, apply more solder to flow into the connector. You should see solder evenly connecting the connector and cable. Try to work as fast as possible.

You probably need to rotate the cable to apply solder in the other soldering holes. I recommend letting the joint cool a bit before going to another hole. This should help to not totally melt the inner dielectric plastic.

Here's a nicely soldered connector on the cable.

Now the tip remains to be done. Measure from the end of this connector to the length that you determined is required from the supply connector dimensions. At this point, score around the dielectric with a sharp knife, being careful not to cut into the copper wire. Remove the excess dielectric. You may need to cut it lengthwise, as with the outer insulation, to help free it from the wire.

Insert the wire through the center of the contact disk you have chosen to use and solder it to the inner wire of the cable.

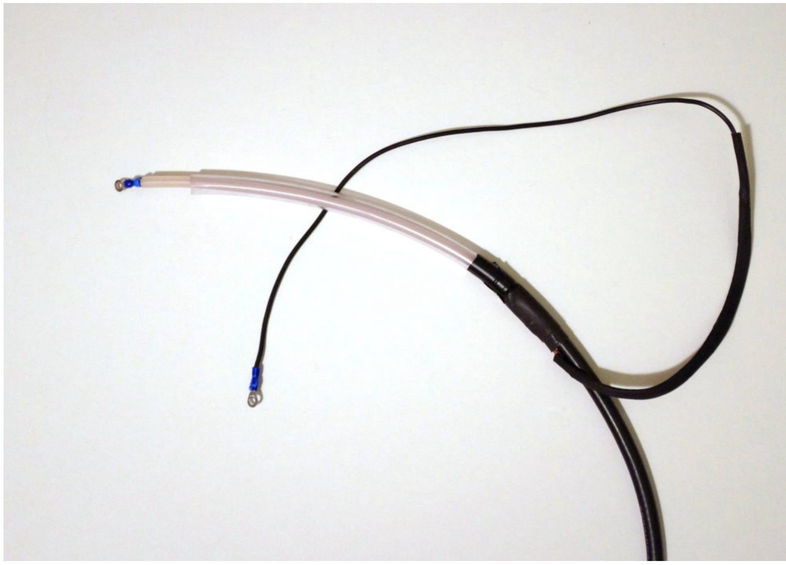
Load-end of the Cable

To prepare the end of the cable opposite to the power supply end, first strip back the outer insulation for a length sufficient to not have air arcs of the full high voltage. For my 40 - 50 KV cable I used about 10 inches (25 cm).

Push back the shield and cut off most of it, leaving about 2 in (5 cm) beyond the outer shield. Unravel the braid and twist it into a wire. Solder this "pigtail" wire to a sturdy wire long enough to ground safely at this hot end.

Strip the end of the inner dielectric to expose a short section of wire for the HV output. You can securely attach terminals of your choice for the connections of HV and ground.

Here's the output end of one of my cables.



On this one I used some shrink-wrap tubing to neaten the ground pigtail and to also give it a little more mechanical strength. I also put a piece of vinyl tubing over most of the dielectric plastic end section to give it a bit more arc resistance.

Grounding

You should use the ground provided by the shield in this cable but you should also have a separate heavy gauge wire for grounding between the supply's ground lug and the apparatus.

When connecting the cable to the supply. Insert the end into the supply and lightly screw the modified PL-259 onto the supply's socket. Before firmly tightening this connection, rotate the cable a bit at the supply and ensure you feel raised pips on the plug are aligned in the grooves in the socket.

If you try this method to make a cable, PLEASE BE CAREFUL with voltages that could easily be fatal.