

HARNES CONSTRUCTION

***If this is what is in your toolbox for crimping tools...
then start using these as door stops.***

These crimpers are for quick repairs and not intended for true harness creation.
They crimp these cheap plastic terminals such that you have no idea if they will stay on or not!

This part of the manual explores harness making in detail.

We will explore the different terminology of the connector market,
try to find a crimper for a particular terminal and eventually
crimp a terminal.

We will also discuss wire technology, wire routing,
terminal removal, soldering, heat shrink tubing,
cable clamps, cable ties, electrical tape,
harness covering, and debugging a harness.



MotoTron

Hardware Lingo

Terminals – The metal device crimped to a wire typically preceded by male or female to indicate polarity.

Packard and Molex typically use this notation.

Pins – A specific description of a male terminal, used by Deutsch.

Sockets – A specific description of a female terminal, used by Deutsch.

Shrouds – Packard’s description of the actual connector around the terminal to avoid confusion with male and female, since a particular series of shrouds may differ in the polarity of terminal that is used.

Typically shrouds are the female part of the connector, but uses male terminals.

Towers – Packard’s description of the actual connector around the pin to avoid confusion with male and female, since a particular series of towers may differ in the polarity of the terminal that it is used.

Typically towers are the male part of the connector, but uses female terminals.

TPA (Terminal Position Assurance) – Holds terminals in place to increase quality of connection with mating connector.

CPA (Connector Position Assurance) – Holds mating connectors together.
Decreases the likeliness of a connector malfunction.

SLC – Side Lock Cover.

Used by Packard when the connector uses a side lock to lock the pins to the connector

PLR – Primary Lock Reinforcement.

Some connectors from Packard come as a two piece unit, such as the GT series. The purple cover over the terminals of a GT series connector is a PLR.

When engaged it keeps the tabs inside the connector locked in place.

Seals – Typically the rubber membranes that accompany the connector and/or membranes slid onto the wire.

All seals must be in good condition and properly placed in order to make the connector environmentally sealed to the manufacturer’s specification.

Seals typically have an oily coating. This coating is used to reduce the effect of capillary action of the seal and connector housing. It also helps extend the life of the seal by keeping the rubber soft through numerous temperature cycles.

Shell – Another name for the connector housing.

Deutsch connectors are typically referred to as shells.

Plug – Plugs for Packard describes rubber inserts used to fill any empty cavities in connectors.

Plug – A specific name for a connector housing that accepts a receptacle style connector as its mate.

Notation is used by Molex.

Receptacle – A specific name for a connector housing that accepts a plug style connector as its mate.

Notation used by Molex.

Back Shell – A form of strain relief that matches a particular connector shell.

Typically used by Deutsch.

Wedge – Used by Deutsch to describe the plastic part of the connector housing that locks the terminal inside the housing.

Wire Technology

There are different types of wire each being good in a particular application.

Solid and stranded wire — Solid wire is typically used when vibration is not a concern. All automotive wire uses stranded wire for better flexibility.

When selecting wire, there are three main parts of the wire to be concerned with:

- ___ Conductor Size
- ___ Wire Type
- ___ Wire Color

Conductor Size

Selecting conductor size has much to do with the environment the conductor will be exposed. It is based on the temperature, as well as expected current of the device.

The temperature of the wire includes the size of the wiring bundle. The center wire within a bundle will see much larger temperature swings.

The chart shows typical wire ampacity based on wire gauge size.

The values in this chart are for a free air installation and are a little conservative, but care must be taken when bundling wires.

The ampacity decreases based on the bundle size. Web resources can be used to aid in selecting the right conductor size based on ampacity.

Typically, you will find 18 gauge wire is the best wire for most sensor and actuators.

The only exception is high current devices.

	Free Air Ampacity
22	7
20	11
18	16
16	22
14	32
12	41
10	55
8	73
6	101
4	135
2	181
1	211
0	245
2/0	283
3/0	328
4/0	380

http://www.allaboutcircuits.com/vol_5/chpt_3/index.html

http://www.powerstream.com/Wire_Size.htm

Water flows through a larger pipe much easier than a smaller pipe. As water flow increases, the pressure in the pipe increases until the point the pipe breaks.

This analogy applies to electron flow through a conductor. As the electrons try to move more quickly through a conductor, heat is generated in the wire until the wire begins to melt the insulation.

The heat may melt other wire insulations and cause a short between power and ground wires. Regardless the severity of the melt down, it will certainly ruin your day when this happens.

This person had a bad day when a fire broke out in the engine compartment, suspected to be an electrical fire.



This used to be a battery.



Wire Type

Wire type plays a big role in how flexible a bundle of wires will be once a harness is made. The type also needs to be considered based on the environment of the harness location.

Most wire that is bought from a local store is GPT (Automotive Primary Wire). This wire is good for general circuit hookups, but is not the best wire for a complete harness in a high temperature environment.

TXL wire is the best wire to use for small, very flexible, light weight, high temperature harness.

Insulation Type	Conductor Range	Specification	Temperature Range	Typical use
SGT	06 - 4/0	SAE J-1127	-40C to +80C	battery cable
SXL	20 -06	SAE J-1128	-51C to +125C	high heat
GXL	20 -06	SAE J-1128	-51C to +125C	high heat
TXL	20 -12	SAE J-1560	-51C to +125C	Small diameter, minimum weight, high heat
GPT	20 - 06	SAE J-1128	-40C to +80C	Genarl wiring

Wire Color

Designing a good wiring harness includes coming up with a good wiring standard.

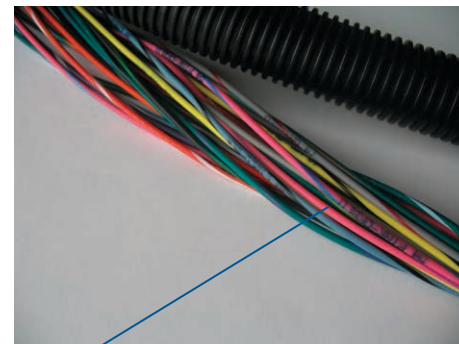
In the automotive world, red was once the standard for positive battery and black was the standard for negative battery. Unfortunately, since foreign automakers have been importing cars to the USA, this standard does not always apply.

You can make whatever standards you want to make for your harness, but it is recommended to follow many of the common standards to help debug problems later.

Within a wiring harness...

- ___ constant voltage,
- ___ switched voltage,
- ___ chassis ground,
- ___ transducer voltage,
- ___ and transducer ground should have the same color throughout the harness.

These wires need to be a standard color within the harness and not to be used for other signals. This allows easier debugging when something isn't working (That is when not if something isn't working. Finding these wires in a bundle and checking the voltages and grounds is much easier.



Which harness would you rather debug?

Signal wires can then be grouped by implementation.

For instance, fuel injectors could all be yellow with a stripe, or sparks could be green with a stripe. Here is a recommended wiring standard for basic 12V, 5V, grounds, 10 pin SmartCraft, and a few sensors.

Cutting Wire

Only basic tools are required for cutting most wire...

Only wire greater than 10 AWG requires bigger tools.



General diagonal cable cutters



Cutter for cutting 10+ AWG wire



Lineman plier – typically used in household wiring



General round nose diagonal cable cutters



General small gauge wire cutters



Insulation cutter for pre-bundled wire

Wire Color	Gauge	Function
black/orange	18	XDRG
purple/yellow	18	XDRP A
purple/pink	18	XDRP B
red/white	16	Switched Power
tan/green	18	Engine Coolant Temperature
white/green	18	Manifold Pressure (MAP)
lt.blue/white	18	Throttle Position
white/blue	18	Intake Air Temperature
red	18	Crank V Ref +
white	18	Crank V Ref -
pink/black	18	Injector
orange/white	18	Idle Air Control
black	18	Driver Ground
yellow/purple	18	MPR Trigger
white/yellow	18	Throttle Position Sensors (TPS)
brown/white	18	Fuel Pump Relay
black/green	18	EST return, ground
red/yellow	16	Fused Power to Coils
SmartCraft	10	Pin connector
A red		Battery
B black		Ground
C orange		CAN3 +
D green		CAN3 -
E black/yellow		E stop
F purple		Switch Power
G yellow		CAN2 +
H brown		CAN2 -
J white		CAN1 +
K blue		CAN1 -

Did someone order a stripper?

There are many different types of wire strippers on the market.

The largest improvement in this field is the automatic stripper. But, not all automatic strippers are the same.

Below is information on how to pick out a good automatic stripper.

Included in your kit is a pair of manual strippers. These work well, but can be time consuming when building a large harness.

Manufacturers will include a recommended stripping range for each terminal. Follow this specification.

If the connection requires a seal, put the seal on the wire prior to stripping and crimping the terminal.

If the terminal is larger than the wire such as a ring terminal, make sure to install any necessary heat shrink tubing prior to crimping the terminal.

Automatic stripper: Basic Use

1. Adjust wire strip dimension if stripper is equipped.
2. Insert wire so the end to strip is on the cutter side and the remaining part of the wire is under the holding jaws.
If the stripper is wire size dependant, place wire inside the correct size cutting jaw.
3. Squeeze stripper handle until insulation has been removed.



General small gauge wire strippers, hard on XL type wire insulation due to the metal construction.



Excellent general purpose manual stripper. Not recommend if making a large harness by hand.



Excellent general purpose stripper with rubber insulation holder that is easier on XL type insulation and green wire strip length adjustment for consistent results.



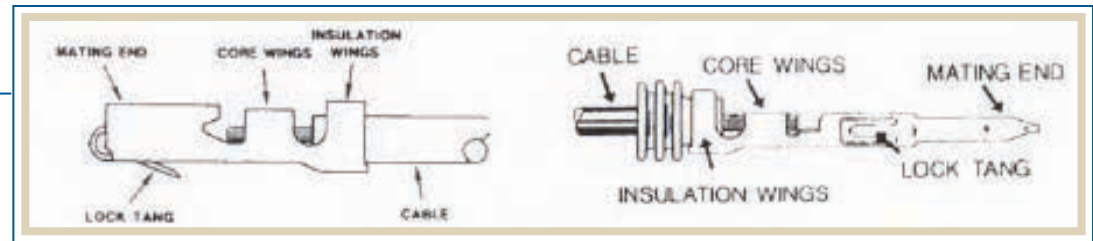
Stripper with predefined gauge sizes from 22 – 8 AWG

Crimp your style

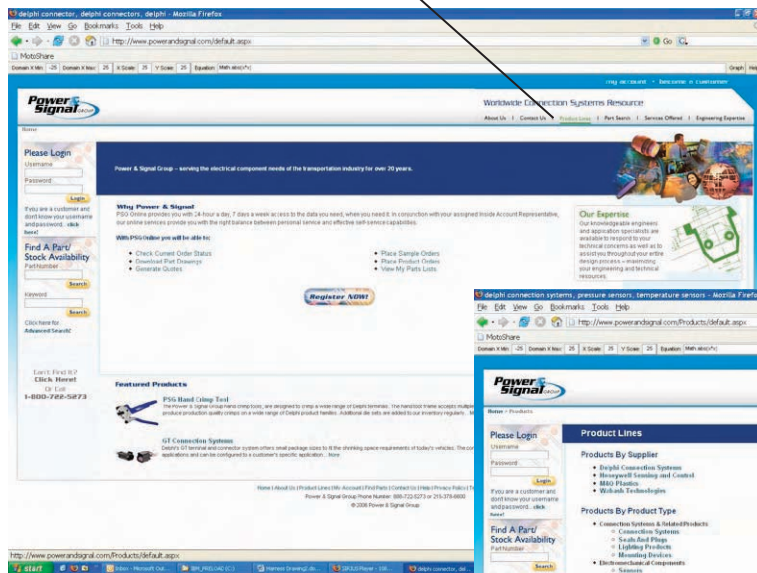
Let's first look at the basic layout of an open barrel terminal. This terminology will be used to describe all parts of terminals throughout this document regardless of manufacturer.

Each specific manufacturer has a recommended crimp tool for the style of terminals, pins, or sockets. If at all possible it is recommended that these specific crimpers are used.

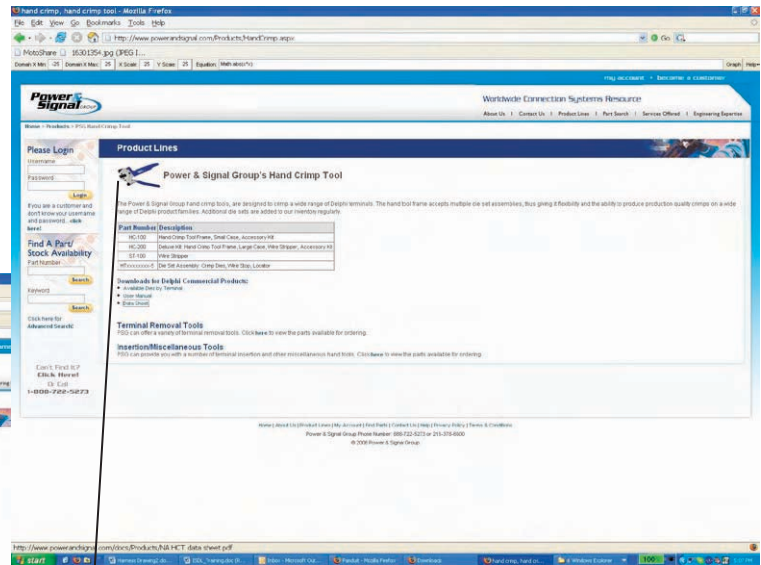
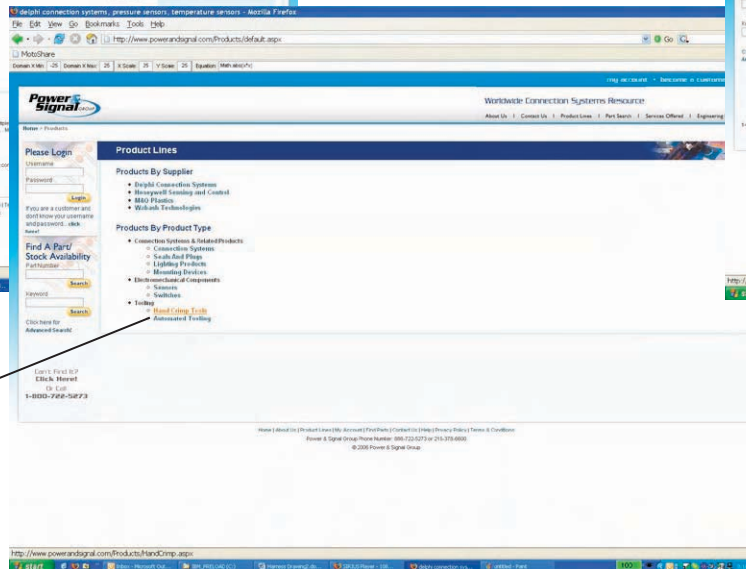
Let's go find a crimper for a GT150 series Packard...
 Back to the trusted Packard website www.power&signal.com



Click on Product Lines



Click on Hand Crimp Tools



Here is what looks like to be a crimper, but no mention of GT series Packard

After digging around and reading the user's manual listed on the web page above, you have to buy a special die for this generic crimper to specifically crimp GT150s. This crimper is actually made by Power & Signals, not by Packard. Their design consists of a single body crimper and then dies are changed to crimp different series of terminals.

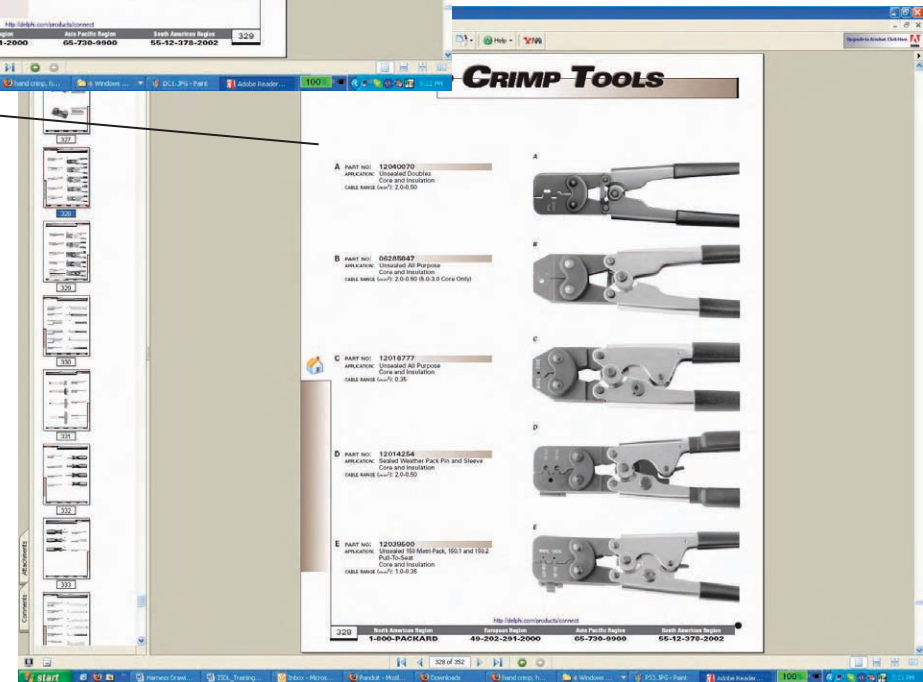
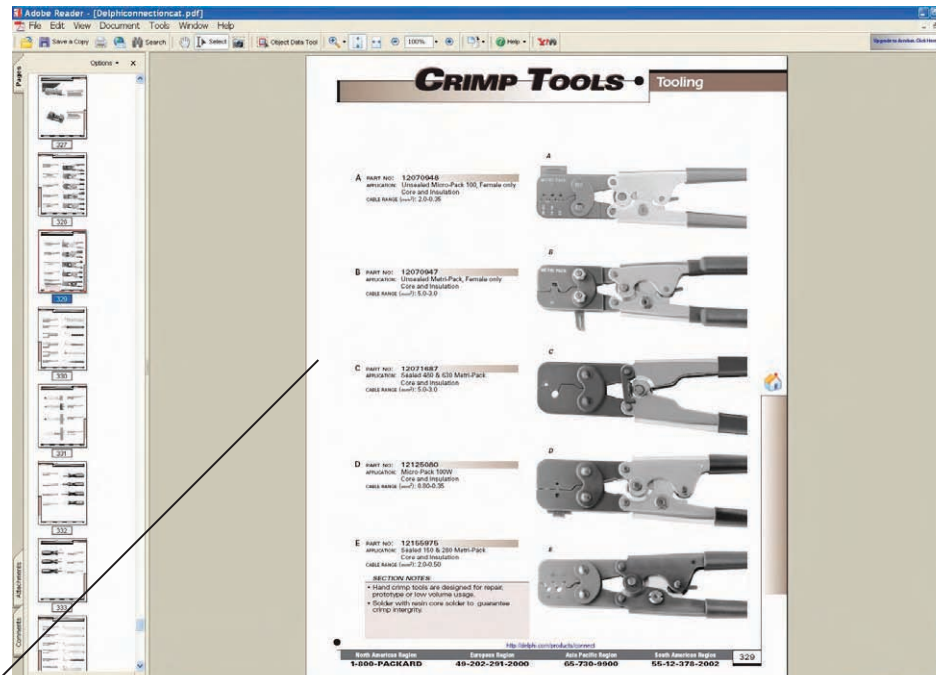
The crimper is an excellent crimper, but it can get very annoying to know which die you need, let alone changing the die every time you change terminal series. As it turns out, even if you search the Delphi catalog on the CD you will find that there is no call out for GT150 crimper.

How in the world can I crimp this terminal?

Calm down, there are many crimpers that will do the job, and as it happens you have some in your harnessing kit.

First, look at the Delphi catalog on your harnessing CD and see what specific crimpers are out there and how they differ than a generic crimper. Pages 328-330 list crimpers and removal tools.

Removal tools? No one said anything about removing anything. As it turns out, you will make a mistake, or just need to remove a terminal from the housing and this also requires tools. Luckily those tools are not very expensive.



The Delphi catalog contains general crimpers for unsealed terminals, unsealed doubles, and specific terminal crimpers. Some terminals require a two stage crimp, so the doubles are these crimpers.

Most of the specific crimpers are ratchet crimpers that have been designed to provide just the right amount of pressure to the wings of the terminal to provide a consistent and accurate crimp. These crimpers are the ideal crimpers to have around, but it can get very expensive to have a crimper for each type and style of terminal.

In your harnessing kit you will find two crimpers. One of those crimpers is a Delphi crimper. Let's see what the Delphi catalog has to say about this crimper. Look for part number 12085271.

Imagine that, not even Delphi lists there own crimper tool. Hopefully by now, you are learning that there is a bit of black magic in harness creation.

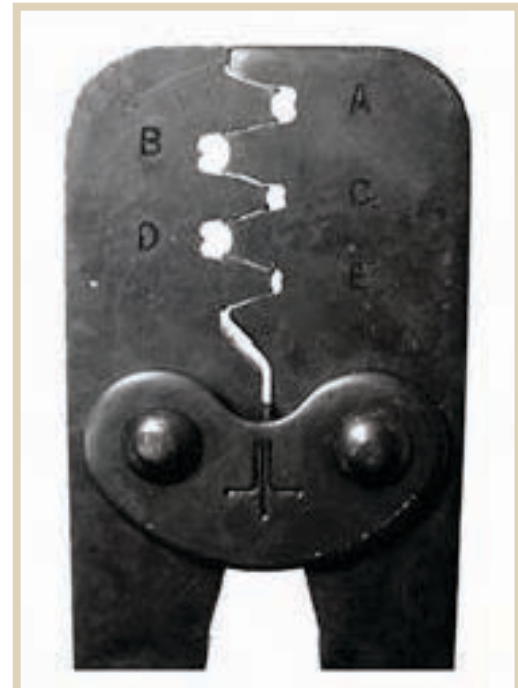
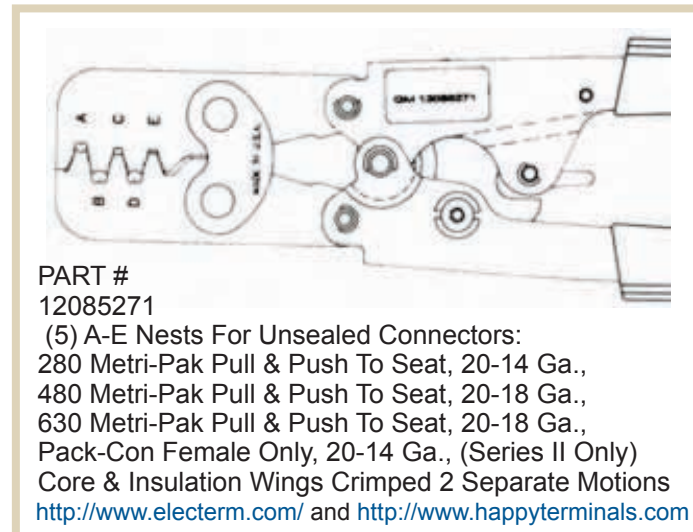
So let's see what Google can find... If we search for "12085271 Packard", we get a hit to www.terminaltools.com that actually provides some information on this crimper.

This still contains very little information about what this crimper actually crimps. Here are some more hits from Google that finally cut to the chase and provide some good information

Finally, we find out that these crimpers are for unsealed Metri-Pak connectors. Unfortunately, our Metri-Pak and GT series terminals include a seal. Now what?

Let's first look at what makes these crimpers ideal for unsealed connectors.

See enlarged crimper illustration at right.



How does this differ?

Let's look at the crimper specifically for Metri-Pak sealed terminals. Delphi crimper 12155975.

You will notice that all five slots are shaped like a W, which is to curl both wings on an unsealed connector in onto the wire.

Slots A,C,E fold the core wing onto the wire based on wire size.

Slots B and D fold the insulation wing for strain relief.



Notice slots B and D are shaped like a W to fold the core wing onto the wire just like the other crimper.

However, slots A and C are shaped more like a U, to properly fold the insulation wing around the seal, without crushing it.



GT Series with Blue Seal



Weather Pack male terminal with Green seal

Shown above is a properly crimped Weatherpack and GT series terminal with a seal.

Metri-Pack terminals follow the same idea.

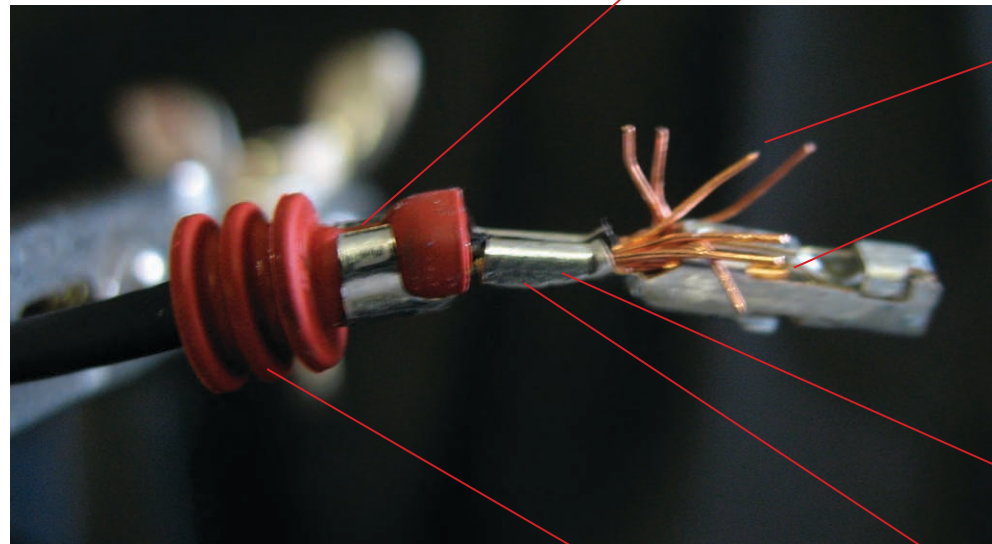
Notice on both terminals, the wire is barely beyond the core wing and the wing is properly folded onto the wire. No stray wires hang on the terminal. The insulation wing is just barely grabbing the seal to hold it in place.

Now, let's review a bad crimp.....

This crimp is a bit exaggerated, but it lists some of the quality features to look for in a bad crimp. Always make sure you tug on the crimp just a bit.

There are 6 things wrong with this crimp. Some are obvious. Others are not as obvious in this picture, but would be if you had the terminal in front of you. There are also a couple of mistakes that aren't obvious unless you are familiar with these terminals

6 Mistakes...



Insulation wing is crimped down on the seal too hard.

Wire is frayed and sticking out of the crimp.

Wire has been shoved beyond the crimp point and is interfering with the mating area.

Crimp is crimping on insulation and not on the wire.

Terminal was bent when the core wing was crimped

Wrong seal.

This is a GT series terminal with a Metri-Pack seal.

One last thing before we get to crimp a GT series terminal. Stay with me, there is an answer. Let's compare the crimpers in your harness kit.

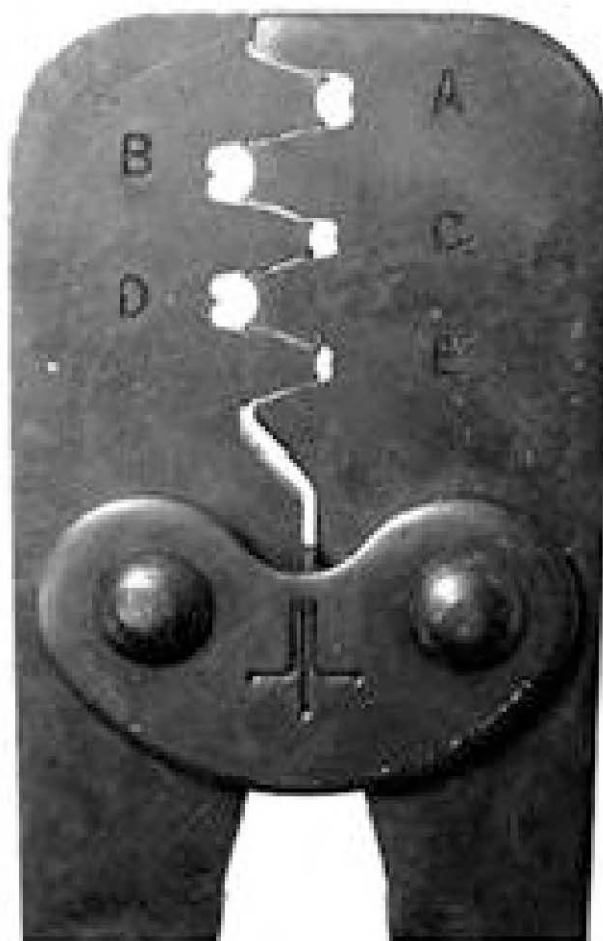
You have a Packard crimper 12085271 built on a ratchet frame and a Mac Tools TCT1028 built on CE (Cost Effective) frame.

Delphi Crimper 12085271

- Pros: Ratchet crimper will provide consistent crimps
 Provides a wide range of crimp ability
 Large handle provides easy crimping for user
- Cons: Technically a crimper for unsealed connectors and not defined as a sealed connector crimper
 Ratchet action crimper makes this crimper more expensive

Mac Tools TCT1028

- Pros: Built on a more economical frame to reduce cost
 Readily available from a Mac dealer
 Comfortable crimp handle
 Provides a wider range of crimp ability very similar to Packard crimper
 More narrower head that minimizes bending a terminal
- Cons: No ratchet action. User has to more apparent of crimp quality
 Technically a crimper for unsealed connectors and not defined as a seal connector crimper.



A = C
 B = A
 C = D
 D = B
 E = E

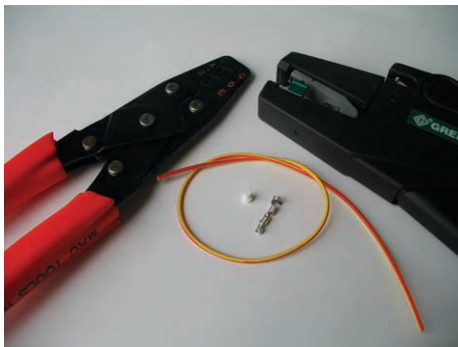


At the end of the day these crimpers will crimp the same connections and are only limited to the construction.

Crimping a GT Series connector.

I recommend using the Mac tools crimper because of the smaller head. This tool will not bend the terminal as you crimp, providing a better terminal in the end. You do have to worry about how good the crimp is.

1. Get your MAC tool crimper, a wire stripper, wire, terminal, and seal.



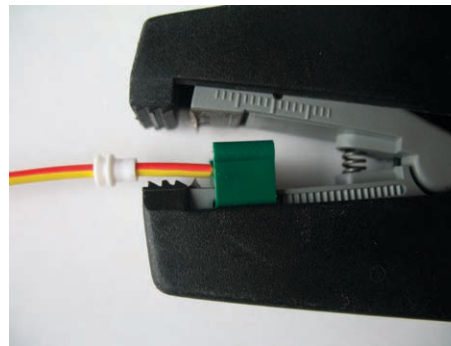
2. Push seal onto wire.

Using the white GT seal because I am using TXL wire, which has a smaller diameter than most.



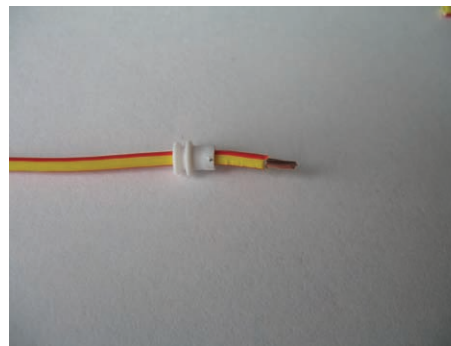
3. With the seal back far enough, use the wire stripper to strip the end to the specified length.

Remember to set the length slide if your stripper is equipped.

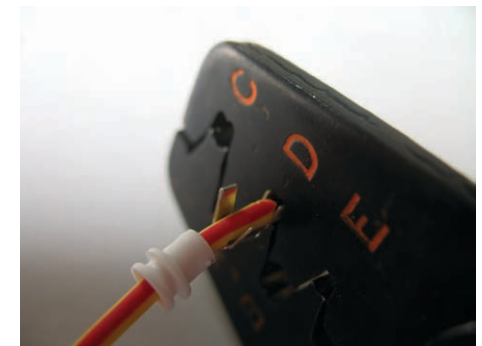


4. Here is the wire ready to crimp.

Notice the marring on the wire from the stripper — this isn't too bad, but similar metal crimpers are much harder on XL type insulation (TXL, GXL, and SXL).

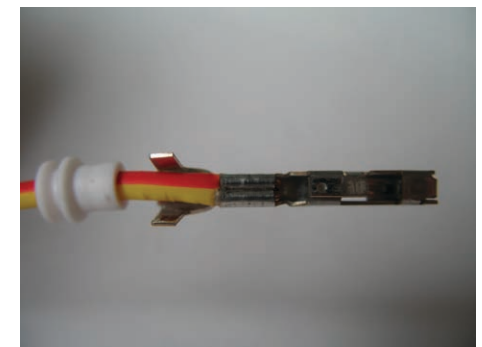


5. Using slot D on the MAC tool crimper, crimp down on the core wing with the wire installed.



6. WE DID IT! We crimped a GT Series terminal.

It looks good based on the factors listed above. Give it a tug to see how well it crimped.

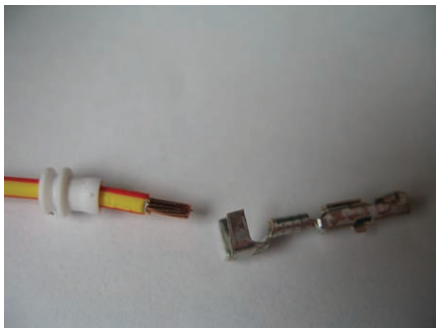


**7. CRAP! The terminal fell off.
Why? A couple of reasons**

The terminal may have not been aligned in the crimper properly, causing only one wing to really come in and crimp down on the wire.

More likely, trying not to over crimp, there wasn't enough pressure when the crimp was made.

This is the limitation of this crimper because it is not built as a ratchet. It is also much more important to check the quality of the crimp when using this type of crimper.

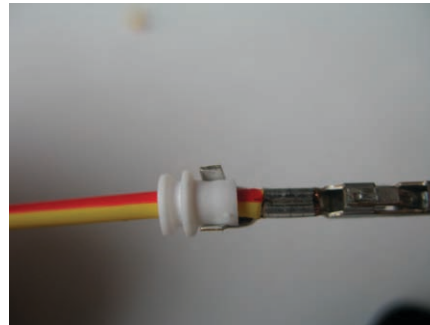


8. Get a new terminal and try again.

Giving the new crimp a good pull shows a good crimp. Delphi recommends that each terminal crimped by hand also is soldered. This can be time consuming, but is a good idea.

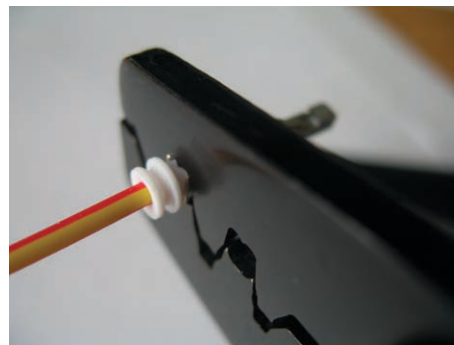
Do not use too much solder. The solder can wick up the wire under the insulation and potentially break the wire under vibration.

We will cover the myth behind soldering in the next section.

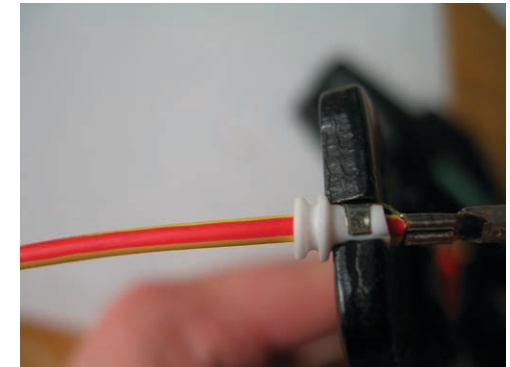


9. Now crimping the seal.

Use the A slot and just slightly crimp to bring the insulation wings together, don't let the wings fold in on the seal.



10. Use the end of the crimper to adjust the seal crimp if necessary.



WOO HOO! We finally crimped a GT150 terminal with a seal using a crimper intended to be used for unsealed terminals.

Now only a 1000 more and you have a good harness. Have Fun!



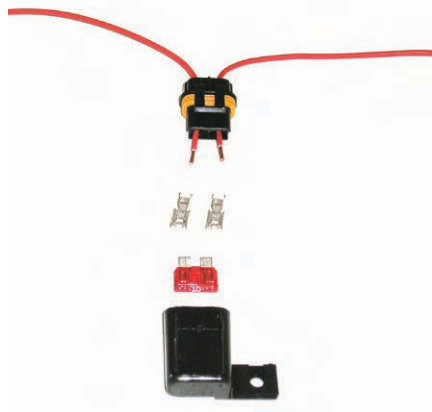
Crimping a Metri-Pack 630 pull-to-seat.

The process to crimp a pull to seat is similar to push to seat terminals. The main difference is the wire must be run through the connector prior to crimping the terminal.

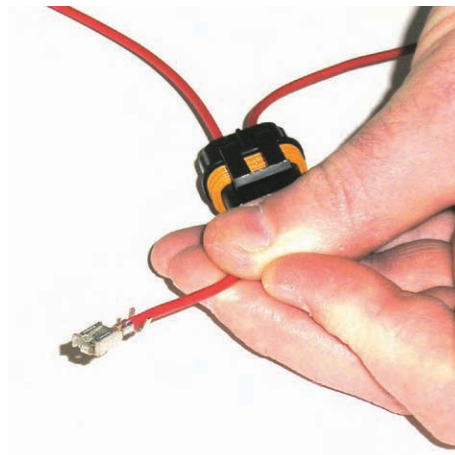
Because of this design, most pull to seats have built in seals, so crimping a seal to the terminal is unnecessary.



1. Insert each side of the connector through the seal. Once through, use a wire stripper and strip back the insulation.



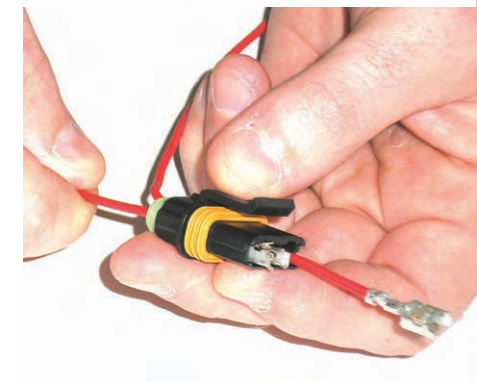
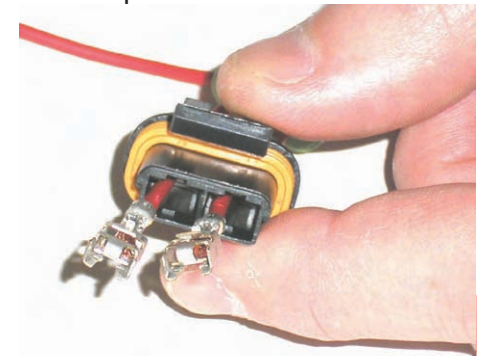
2. Use a crimper to crimp the core wing of the terminal to the wire.



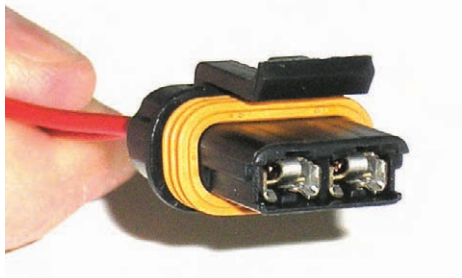
3. Now crimp the insulation wing.



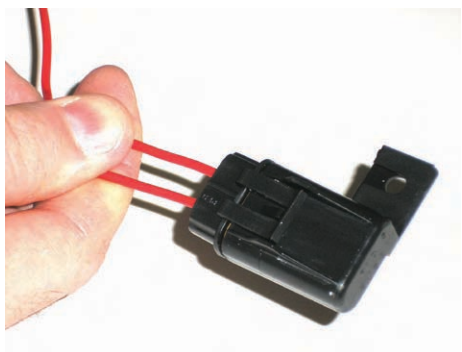
4. When both terminals crimped, pull the wires back into the connector to lock them in place.



5. Since this connector happens to be a fuse holder, insert the appropriate fuse.



6. Apply the fuse cover.

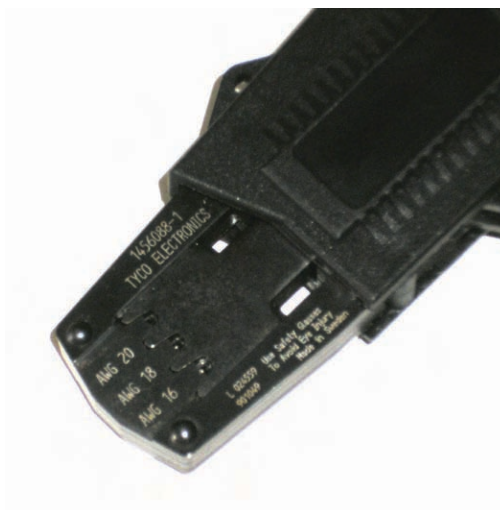


Other Crimp Tools

There are other crimpers out there you may want to consider...

Below is the true TYCO/AMP crimper for crimping MotoTron's ECU pins.

The crimper is pistol style crimper and cost in the \$150.00 - \$200.00 range. Luckily, the provided crimpers will also crimp those.



Below is a close up of a Deutsch crimper. Deutsch has both open barrel terminals as well as solid terminals. This crimper crimps the solid terminals.

You can see the teeth that come out to crimp the terminal, in a four different places. They also have open barrel terminals that use a crimper very similar to the TYCO crimper above.



Inserting and Removing Terminals from their connectors

You should now be well on your way to crimping terminals. Now what happens when you make a mistake or for some other reason need to remove a terminal from a connector housing? Fortunately, you are not required to start over with that 100 pin connector.

You might guess there is a universal technique for removing terminals for all brand and all series. NOT!!!!!! There are many different ways to remove a terminal from a connector based on brand and series.

Here are most of the common connectors and how to remove there terminals.

A couple of tools are required, but are inexpensive.

Push to Seat Terminals

AMP ECU pins, Deutsch, Metri-Pack, GT Series are mostly push to seat.

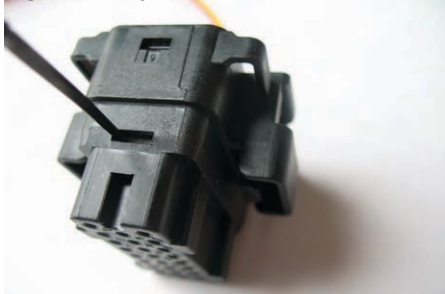
The only exception is Metri-Pack, who make pull to seat terminals as well.

TYCO/AMP ECU Pins

Once you have inserted all the pins for the ECU, push the lock closed to securely hold the terminals in place.

There are also small tangs built into the connector that initially hold the terminal in place. This is the click sound you hear after inserting the wire. Removing can be a little tricky.

1. Slide the lock open by pushing on the recessed side of the slide lock and firmly pushing sideways. The lock will move slightly.



2. There a couple of terminal removal tools that can work. One is made by Thomas & Betts (600101). However, the Deutsch tool (0411-240-2005) seems to be the best and cheapest solutions.

Your temptation is to pull the terminal out by yanking on the wire, or getting an object and shoving it up from the connection side to push the terminal out. However, this may damage internal tangs inside the connector housing, making the connector unreliable.

If this part of the connector is malfunctioning, then the slide lock is the only mechanism to hold the terminal in place. If the slide lock does not catch the terminal properly, the connection can come loose and you will scratch your head to find that one.

Anyhow, slide the release tool down the terminal socket from the wire side and remove the wire.

Make sure the release tool gets far enough down the socket to cover the entire terminal. There are two parts of the terminal that can catch on the internal tangs — covering both of these will ensure the wire will come out without any problems.



FYI: The internal tangs — notice how fragile they are. I do not recommend taking the connector apart because sometimes it doesn't go back together and stay, causing bigger problems in the field than you like.

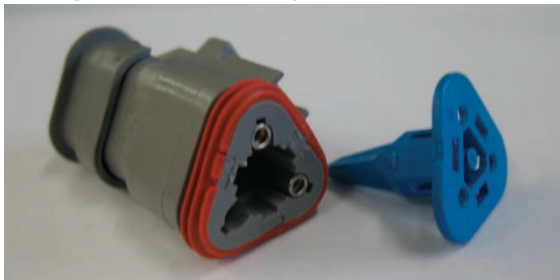


Deutsch

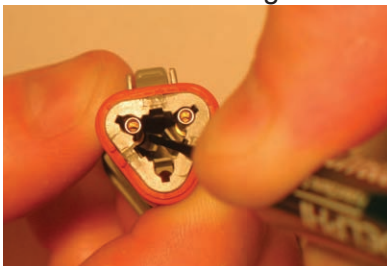


1. Remove Wedge from center of connector with a screw driver or a pair of pliers.
 This wedge is on a female terminal and is easy to get to with a screw driver. Many wedges for the mating male side actually is positioned inside the housing and may require a pair of needle nose pliers.

Always disconnect power to connector prior to poking at it with metal objects such as pliers.



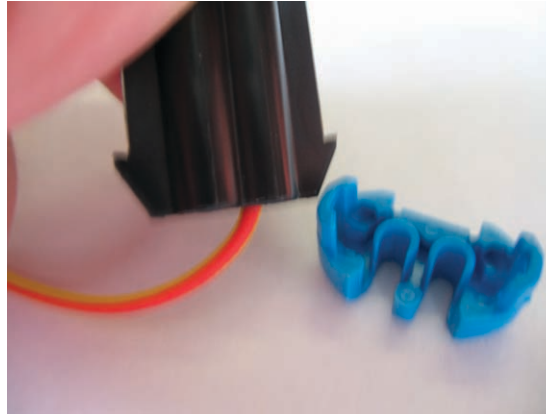
2. Using a screw driver or pick, release the tang holding the terminal in place and at the same time pull on the wire slightly so when the tang has been completely moved, the wire will release from housing.



3. Pull out wire from the seal side.

Metri-Pack

1. Remove the TPA from the rear of connector.



2. For Female terminals, there is a small slot on the latch side of the connector to push in the removal tool inside your kit (12094429)

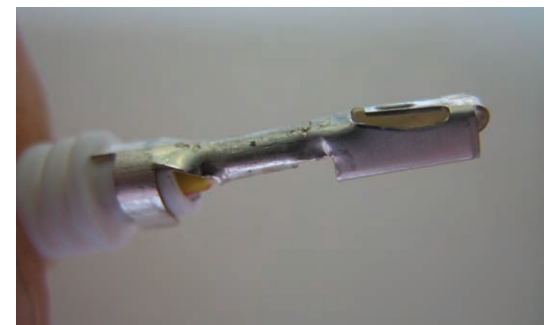


3. For Male Terminals, place the removal tool inside your kit down the center of the terminal, just above the male section and push the handle of the removal tool slightly away from the terminal.



4. The removal tool is pushing the tangs on the terminals out of the way, so the terminal may be removed.

If you plan to reuse this terminal, remember to push the tang back out so it will lock in place once pushed back in the housing. Consider replacing the terminal if you see any wear on tangs or signs it may prematurely break.



GT Series

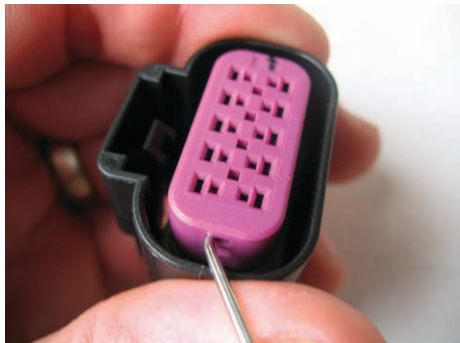
1. Remove any TPA that may be connected to the back of these connectors

2. The PLR (purple cap) has a two stage clip, pry up so the cap releases the first stage using a screw driver or other pick.

Here I am using Packard 15313892 pick.

Now for female terminal shrouds, you can pry on the side of the cap.

For male terminal towers, use a pick (1513892) or similar tool to pry on the cap using the larger holes running through the middle of the connector.



3. Insert the Packard terminal tool in your kit (12094429) through the small holes just beside the terminal holes.

Unlike Metri-Pack, GT Series tangs are built on the connector and not the terminal. This releases that internal tang.



4. Pull wire from housing from the back side.

Had you completely pulled the purple cap off, you would have seen the tangs holding the terminals in.

When the cap is fully engaged, it pushes out on the tangs to hold the terminal in place, this why you must pull the cap out by one level.



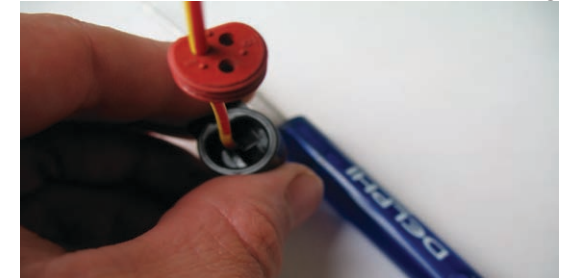
Pull to seat Metri-Pack 150

Leave plenty of slack in the harness when using this terminal to fix problems.

Metri-Pack 150 terminals are probably the most difficult terminals to remove. I suggest cutting off the connector and starting over. This is where the slack comes in. However, if you must attempt to remove the terminal below are the steps.

1. Attend a local establishment and have a few drinks of your choice before attempting such a feat, it will keep your since of humor.

2. Remove the rear seal from the housing



3. Push the Packard terminal removal pick inside your kit on the side with the reversed tang.

On the first time, you may have to consult a new terminal to get a good reference to the direction and side of the tang.



4. Pushing the terminal out of the housing in the opposite direction.

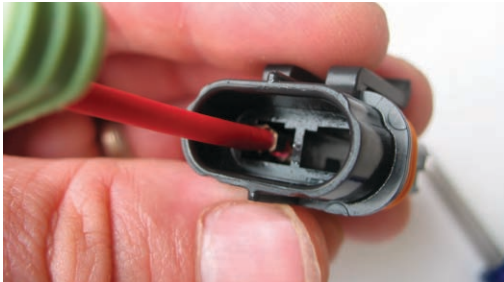
You may find this is very frustrating and sometimes the tang just doesn't want to give. Work with it enough times and you will most likely be successful.

Metri-Pack 630

630 series terminals are much less difficult than the 150 series, due to their larger size.

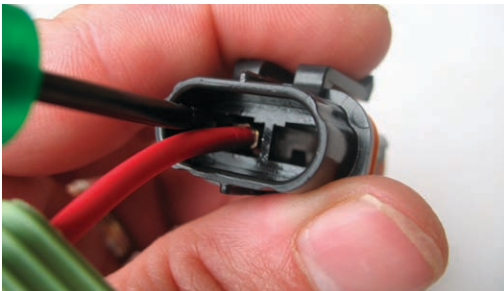
The 630 terminals are typically used on the fuse holder and relay housings.

1. Remove the rear seal from the housing.

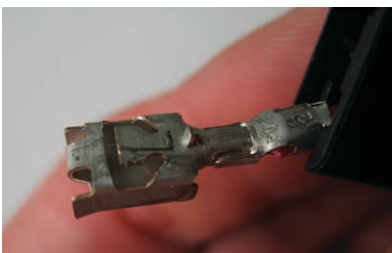


2. Push the Packard terminal removal pick inside the kit on the side with the reversed tang.

On the first time, you may have to consult a new terminal to get a good reference to the direction and side of the tang.



3. Push the terminal out of the housing in the opposite direction.



To solder or not to solder

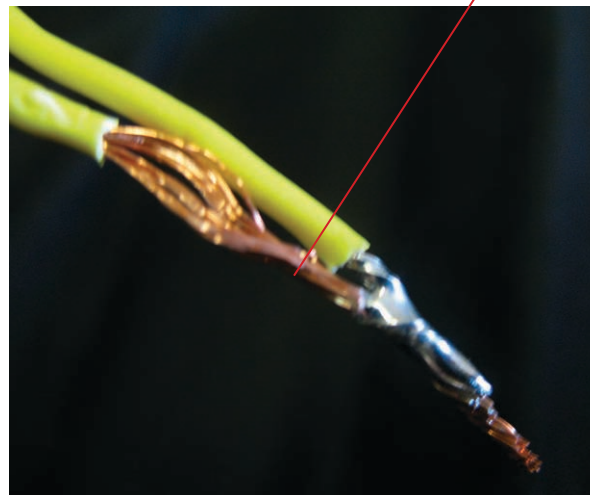
Is soldering better than splice crimps?

A solder joint makes the wire unable to flex with the motion of the wire and potentially will break under long durations of vibration.

A properly installed splice crimp supported by good heat shrink tubing is in fact better than a solder joint.

When soldering wire you also have to consider that the solder will travel up the wire (wick) under the insulation. It is not obvious how far the solder wicks just by looking at the wire. A splice crimp has a better frame of reference for installing heat shrink tubing and can be done more quickly with minimal tools than soldering.

Stripped back after soldering shows the solder traveled under the insulation about a 1/2". Where the strand stops fraying is where it is stiff from the solder.



When soldering is the right answer, here are some good soldering tips...

Use a clean soldering gun with a nice point.

Allow the soldering gun to completely heat.

Apply a thin coat of solder to the tip known as tinning.

Tinning creates a good heat transfer surface and will help initiate transfer of solder onto the wire.

Place the soldering iron on to the wire bundle to be soldered and wait for the copper to absorb the heat.

Once the wire has been thoroughly heated, place the solder onto the copper wire and allow the wire to absorb the solder.

If the wire does not except the solder, allow copper time to continue heating.

Do not try forcing the solder in by touching the iron tip. This does not help make the joint and potentially creates extra solder once the wire begins to except the solder.

Twist bare ends together including some of the insulation to provide strain relief.

Twisted wires to be soldered running in the same direction.



Solder end and try not to allow solder to travel up the wire under the insulation.

Image - Joint after it has been soldered.



Twist bare ends together and run wires in opposite directions.

Twisted wires to be soldered running in different directions.



Solder connection and try not to allow solder to travel up the wire under the insulation.

Joint after it has been soldered.

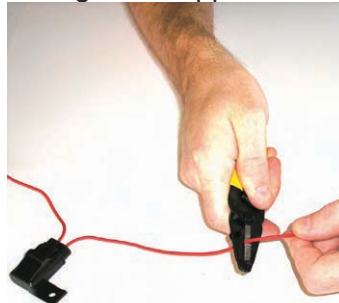


Splice Crimps

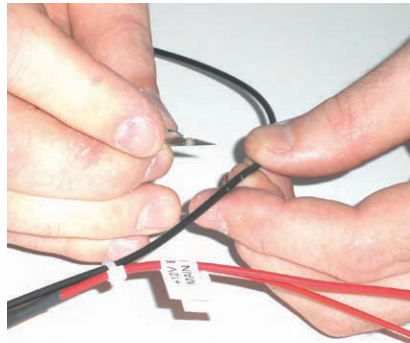
Splice crimps come in handy when branching out power and ground wires. Here is a step by step description for installing a splice crimp in-line to a wire. For power taps, make several splices through a main larger wire.

Not all splices have to occur at the same point.

1. Using a manual stripper, make two marks on the wire insulation about $\frac{1}{2}$ " - $\frac{3}{4}$ " apart, but not cutting through the copper conductor.



2. Using a straight blade or a pair of diagonal cutters, cut away the insulation between these marks.

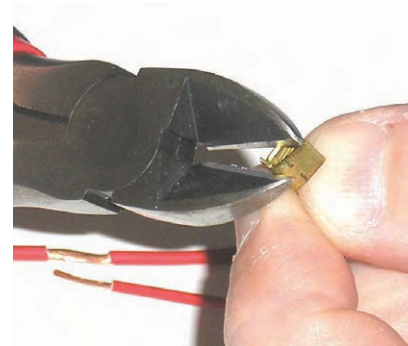


3. Alternatively, you could cut the wire, strip each end and bring them back when installing the splice crimp

4. Place heat shrink tubing on the wire.

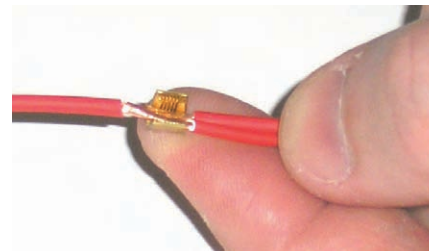
Crucial — especially if all the wires have large connectors or terminals already installed on the other ends.

5. Using a pair of diagonal cutters, cut away the sharp edges of the splice crimp. These edges can cut through the heat shrink tubing and cause the wire to short.

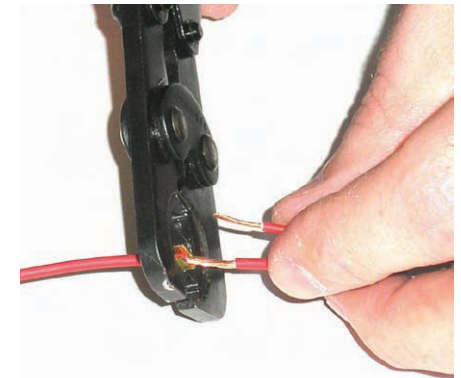


6. Strip the end of the wire to be added about $\frac{1}{2}$ " - $\frac{3}{4}$ ".

If you cut the wire, just strip all the wires back $\frac{1}{2}$ " and join the wires back together, with the newly added wire installed with the splice crimp.

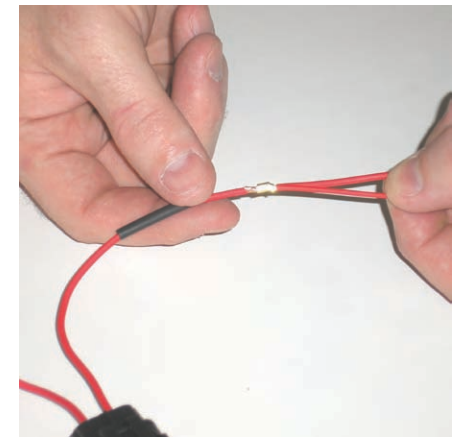


7. While holding the splice crimp onto the wires, place a proper crimper onto the splice crimp.



8. Firmly crimp the splice crimp until the tabs have folded onto the wire.

9. Gently pull on the wire to make sure the splice crimp is properly holding.



Protecting the connections

Whether splice crimps or soldering is used, the connection must be protected from the environment. The best way to make this happen is with heat shrink tubing.

As with many other wiring issues there are very different kinds of heat shrink tubing with different performance options.

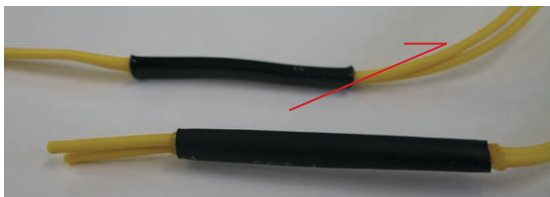
Do not skimp on the heat shrink — it only takes one strand of a wire to push itself through the heat shrink to potentially create an intermittent short.

The other option is using a quality electrical tape. As you might guess, not all electrical tapes are the same. Your best option is to use quality heat shrink tubing.

There are a couple of different types of material for heat shrink. The best material is polyolefin. Some PVC heat shrink does not have a large melting radius and does not stay in place well.

The image below shows PVC heat shrink compared to dual wall Polyolefin.

Notice the inside wall of the polyolefin is melted and comes out the side of the outer layer.

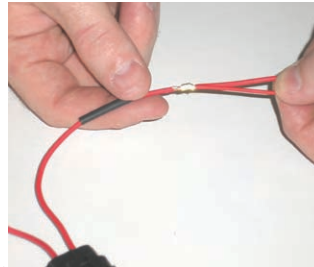


This is an unfair comparison since the polyolefin heat shrink has “glue”, but no good heat shrink should be able to move once installed.

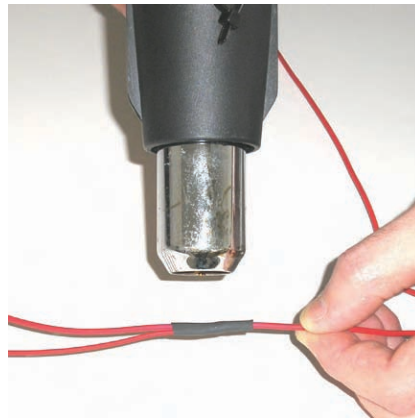


Applying Heat Shrink

1. Cut a length of heat shrink at least ½” longer than the length that needs to be covered.
2. Place heat shrink onto wire prior to crimping terminals or applying connectors that may inhibit the heat shrink from being applied later.



3. Using a heat source, shrink the tubing once it is in place.



4. You can then use quality electrical tape, or cable ties around the splice crimp to provide some strain relief and clean up the harness.



Options: Heat Shrink Tubing

Flexible Polyolefin – Good general purpose heat shrink tubing. Can sometimes be light weight and when used with larger wire can have a tendency to push through.

Dual Wall Polyolefin – Inner wall melts to provide a better and stronger seal.

Semi-Rigid Polyolefin – Stiffer than the flexible polyolefin but still has some movement

Semi-Rigid Dual Wall Polyolefin – Stiffer than the flexible polyolefin but still has some movement. Inner wall melts just like Dual Wall Polyolefin.

Flexible Vinyl (PVC) – Flexible, but has limited shrink ability and does not stay on wire as well as some of the polyolefin.

Widely used because it is cheap.

Electrical Tape

Many tapes found off the shelf are general purpose tape, which may lose the ability to stay together over time and through many cycles of temperature changes. For this reason, choose a good tape such as 3M Scotch 33+.

Scotch 35 and Scotch 88 are also good varieties of electrical tape. Scotch 35 can be ordered in multiple colors for color coding purposes.

When wrapping a wire bundle or other parts of a harness, leave the last couple of wraps loose. This allows the tape to adhere to the lower layers at its normal size.

The tape will expand and contract as it is exposed to varying temperatures. Trying to pull the tape tight will accelerate the tape's deterioration and pull away from the wire bundle.



Cable Ties

Cable ties come in a variety of styles. Some have tags on them for labeling. Others have mounting clips already attached.

The most important thing to keep in mind when using cable ties is that they need to be rated for the environment. If the cable tie is going to be at a constant 70 degrees and not see much temperature fluctuation, then a cheap cable tie will suffice.

However, for an application such as automotive, the cable tie has to survive major temperature variations and possibly UV rays from the sun. In this case, a cable tie made specifically to resist UV rays will also resist high temperatures.

Cheap cable ties in this environment dry out quickly, become brittle, and fall apart under vibration.

Cable Clamps

Cable clamps come in many different sizes. All have features and should be picked based on location of the harness and necessary routing. Below is a comparison chart of the most popular cable clamps.

Not all possibilities may be listed.

Special Precautions when Wiring High Current Systems

Systems that require anything larger than 10 AWG wire is probably a high current system and special precautions should be made to insure safe wiring of these systems.

Wrap any common wrenches used on these systems with insulating electrical tape.

Fully insulated tools are available, but are typically very expensive.

Cover any loose wires, as well as any exposed high current connections, on devices to be wired.

For example: cover the battery terminals with rubber boots while handling.

Once a connection is made, use the appropriate protection over the wire and device.

Battery boot installed after cable has been attached to battery post.

Use the rubber boots provided with a new battery to protect against an accidental short across the battery terminals.



Wrap tools with quality electrical tape to reduce the risk of injury in the event the tool was shorted across terminals.



An exposed high voltage / current cable is covered with a safety boot made from quality electrical tape and convoluted tubing



Routing the Wires

Now that a basic understanding of wire and tools required getting a wiring job done, we can discuss how to route wires and determine lengths.

It is best to gather or create 3D drawings of the system. You can use these to mock up the harness and get an idea of lengths and routing options. Sometimes this information is not available or because of time constraints or this it is a one off application and time is better spent prototyping the harness on the actual device.

In this case you have a couple of options. You can run string to get an idea of lengths, build the harness off the vehicle, and then integrate into the vehicle once completed.

Make sure that if the harness has to go through a wall, leave the connectors removed and attach them after the wire is ran.

The other option is to wire the system one wire at a time. Run it and verify that operation seems to be correct. Then, remove the harness and complete final finishing.

This is typically the way to go if many sensors and actuators need to be discovered. You will find yourself moving wires around while learning the system.

Know the mechanical system you are wiring enough to know where all the moving parts are and what area those moving parts require. This helps identify human and wiring pinch points.

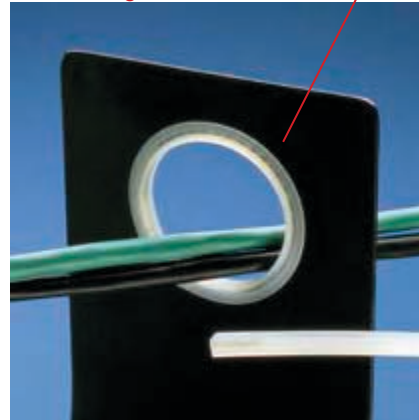
Never run wire through a door jamb unless it is wire that is traveling from the vehicle to electronics in the door and it is run through a protective boot.

The door jamb can be a simple way of routing wires to test, but never make this permanent. It will haunt you.

When new holes have to be made, make sure a grommet is used to minimize wire chafing.

Over time the edge of sheet metal can work like a knife and if it is power that is running through those wires – Do you smell smoke?

Panduit sells a roll of edging that can be applied to sharp surfaces for cable pass through. What is nice about this stuff is it can fit any shape hole and only requires a minimum sized hole to install. A rubber grommet requires a much larger hole to install.



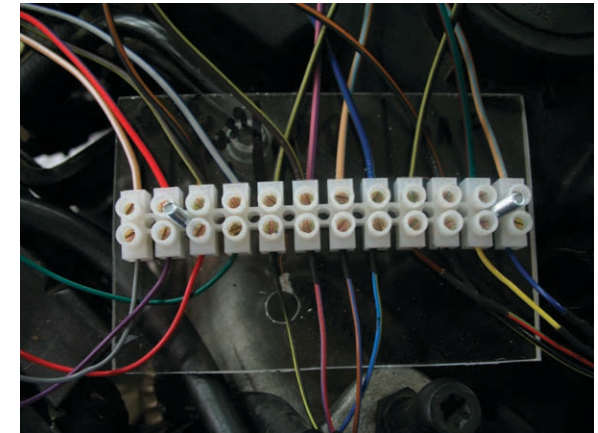
Harness the power

When prototyping, you will find yourself making many connections to constant power, switched power, transducer power and transducer ground often.

For prototyping, make some decisions on placing power points in the harness. Once the harness is solidified, the power points can be removed and splice crimps used in their place to make a good robust harness.

There are a couple of different options for power points...

Terminal strips — These are OK for just initial testing. In the image below, the terminal strip is used to take the place of a connector that the installer was waiting for from a vendor.



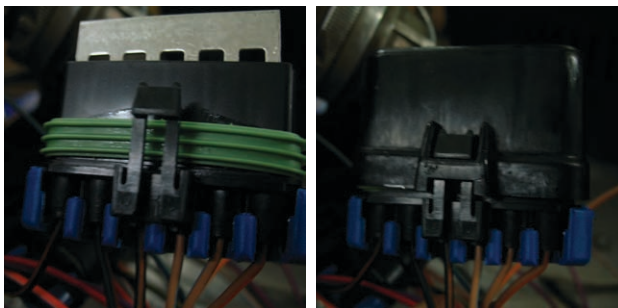
These power points come in two flavors: a stud and a bolt through.

These can handle large current and have isolation mounts for mounting to metal objects. They are available in red and black.



These splice packs utilize a Packard 6 pin mini-fuse connector with a custom bridge clip.

The clips can be bought as a 2, 3, 4, or 6 way and can be purchased at www.waytekwire.com. This connector was bridging XDRGs in a harness. When finalized, this junction will become splice crimps.



Picking the Right Connector

You only need 100 books with 1000+ pages to have every connector known to man listed. For prototyping the decision often times depends upon what you have around. But, you have to consider all the options and potential suppliers for more custom installations.

Things to consider...

Do you need a bulk head or panel mount connector for interface to a firewall?

Do you need a relay and fuse center or will in-line fuses and relays be suffice?

How many wires will be on the connector?

Are the wires all the same size for any connector, or is it a mixed bag?

If it is a mixed bag of wire sizes, do you use two connectors or find one connector that can accommodate all the sizes?

Do you want the connectors to interface to the wire covering, such as a strain relief?

What type of environmental rating is required for this connection?

What type of connectors does the sensor or actuator have?

Packard connectors are probably the easiest to buy and cheapest connectors to use.

Deutsch is a good source for bulk head connectors if you are building boxes or need a good firewall type connector.

Molex also has some good weather proof bulk head type connectors, as well as normal style connectors.

Molex recently introduced a line of weather proof connectors — utilizing features from other popular connectors.

Tyco/Amp have some wire to wire connectors, but they specialize in wire to circuit board connectors.

Finishing the wire bundle

There are a couple of layers of protection for the wires in the harness.

First make sure all open connections are covered with heat shrink tubing.

Wrapping the harness every several feet with electrical tape or small zip ties will keep the harness in a neat bundle for covering.

Convolute Split Tubing

There are many options for covering the harness. The most popular and probably the easiest are using split loom vinyl tubing.

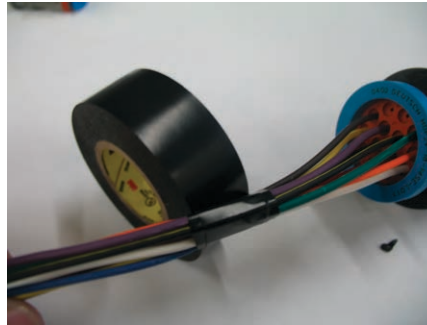
This tubing can be bought in different colors, but black is the most popular.

Look in your vehicles engine bay — this is the wire covering typically used through the automotive and marine industries.



Using split loom tubing on a harness bundle ends when no direct connection to the convolute is provided.

1. Apply small amount of electrical tape to wire bundle on end without a convolute interface.



2. Apply convoluted tubing to this end — leaving electrical tape sticking out of the split.



3. Wrap the wire bundle with convoluted tubing to hold loom onto wire bundle.

4. Make the last couple of wraps of electrical tape loose.

If the tape is pulled tightly it accelerates the tape coming loose because of the tape's elasticity.

Leaving the last couple of wraps loose keeps the tape at its nominal size, so it can shrink and expand with temperature at a normal rate.



Using split loom tubing on a harness bundle that includes a convoluted tubing interface...

There are a couple of options, depending on the connection type.

Some connections specifically for convoluted tubing will be made to go around the tubing and actually hold it in place as well as the wire bundle.

Other interfaces that are designed to go on the inside with the bundle require a bit of electrical tape or a piece of heat shrinkable tubing.



Sleeving

Looks really sexy, but on long runs can be challenging to install.

There are some that have a split seam to make longer runs easier.

Some braiding is also heat shrinkable to give a really good custom look.

The disadvantage is being able to look at wires inside the bundle if you suspect a short or an open has occurred in the bundle. Once it has been cut open, there is not good way to close it up.

(A) Expandable sleeving

Some can be heat shrunk after applying to wire.

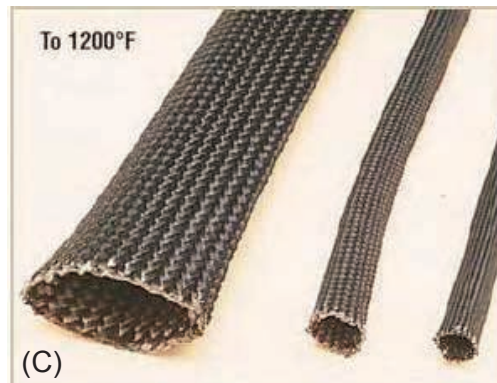
(B) Expandable sleeving with a slit.

(C) Fiberglass expandable sleeving, used in really high temperature applications

(D) Woven nylon sleeving, typically used when flexible and extra rugged is required.

This type is often used on tractor front loaders for wires and hydraulic tubing.

It protects the hoses and wires from getting pinched in the articulation sections of the loader.



Spiral Wrap

Only choose when using the pull-to-seat connectors and if you are trying to make a really difficult harness.

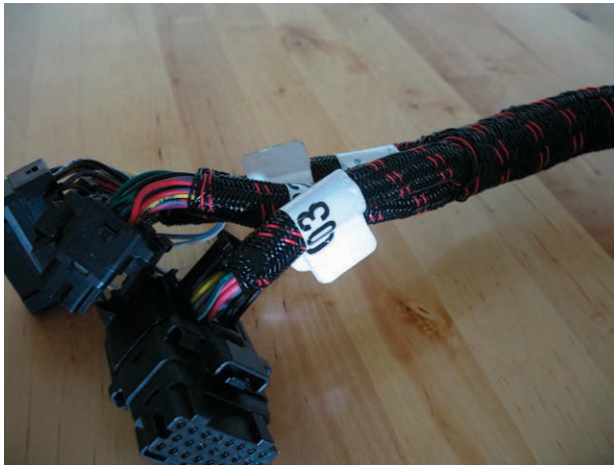
The spiral wrap is a bit more durable because of the plastic they use and wires in the bundle can be identified quickly, but without a special application tool, spiral wrap can be frustrating to install.



Stranded Web Covering

This is typically a production harness covering that requires a special webbing machine.

This type of covering is very durable and looks really sexy, but again for prototyping where changes may need to be made, this covering is not recommended.



Solid Conduit

Solid conduit is typically used when durability is critical in a harsh environment.

Just like connectors, solid conduit has environmental sealing properties.

This type of conduit is typically used in industrial applications for durability.

Installing solid conduit can be challenging.

This conduit meets CSA standards on certain sizes.



Extra flexible electrical tubing



Snap In
Straight-in fitting

Threaded
Straight-in fitting

Threaded
Right angle fitting

Liquid Tight Conduit

The next step up from the solid conduit is Liquid Tight conduit which meets much stricter requirements.

It is certified by both CSA and UL and is typically used in industrial applications where water and other fluids are regularly present.

This is again not typically used in automotive. It is a very stiff conduit and can also be a challenging installation.

It is recommended that electrical pulling lubrication is used for this type of conduit when the length is long.



Liquid tight conduit



Straight-in fitting

Right angle fitting

Debugging

Use a highlighter to trace a wire connection in a busy schematic. Once eliminating this circuit, use another color over the first.

For example, initially highlight it yellow, then use a blue highlighter once this circuit is verified.

___ Yellow indicates current circuit.

___ Green indicates circuits already checked.

This also works well when using a schematic for building a harness one wire at a time.

Using a blue highlighter over a yellow, creates green wires that indicate the circuit has been tested and/or wired.

Yellow indicates the circuit currently being tested and/or wired.

Finding shorts can be sometimes troublesome. This is where fuses, relays, and other connectors in your system help.

Place a light tester or amp meter between the negative wire of the battery and the negative post.

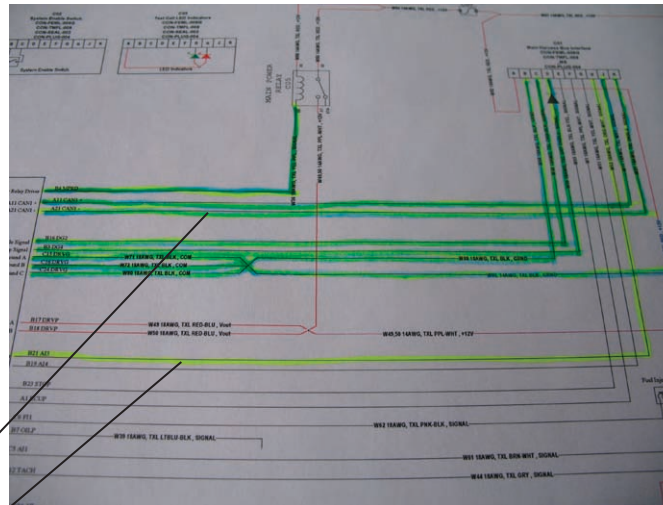
Warning: Don't start the vehicle. The wire in the amp meter or light tester is not capable of handling this current.

Now, you have positive identification of what kind of current is being placed on the battery with the vehicle completely turned off.

First things first, eliminate the obvious circuits by pulling the fuses for the interior lights since you probably have the doors open.

Now make sure everything in the vehicle seems disconnected.

Any accessory plugged in the cigarette lighters?



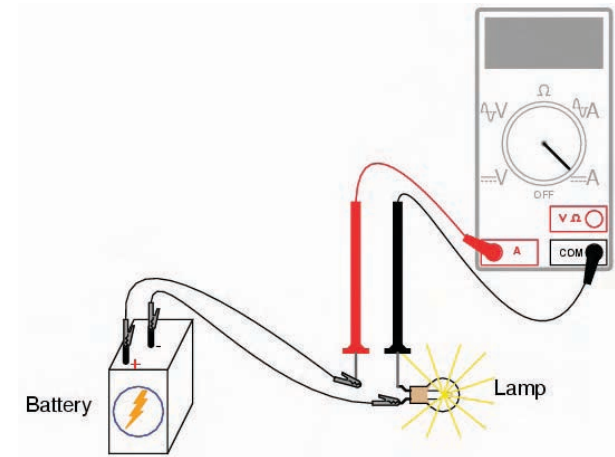
Now you have determined the shorted current you are looking for.

Begin unplugging fuses, relays, and connectors. Note each current drop or if the light bulb on the tester dimmed when it was unplugged.

Once the amp meter reads near zero or the light is off or barely on, then you have found the circuit that is short the battery.

Begin checking the supply voltage and signal wires in that circuit to further determine or locate the short.

The short may very well be within a device such as a sensor, actuator, or control module.



If you find yourself wanting to point a finger at the ECU, use your boot cable, boot key (if necessary) and program a known good build.

Likewise, reprogram the module with the new code using the boot cable and identify if it still exhibits the problem.

If the boot cable works fine, then there is chance the module is not at fault of the problem.

A good program to track along with changes made to the application, as well as the block diagram, is a basic I/O test module that includes all the proper I/O blocks utilizing probes and display variables to toggle and read the hardware.

This is the smallest application possible and will help determine the state of the ECU as well as the hardware.