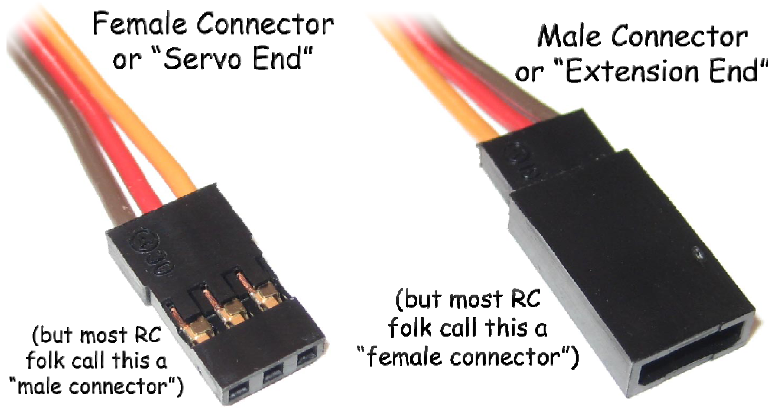
A Brief Discourse on Connector Antics

When we started producing electronics we soon found ourselves buried in tens of thousands of connectors that we knew would be slow to move. We started selling connectors and wire as kind of an afterthought, hoping it would reduce our stock and bring in a few extra bucks. Since we started our connector sales have gone up by leaps and bounds. Based on the load of email questions I decided to write a comprehensive document on the connectors we sell. For the most part this is targeted at radio control hobbyists but I'm very aware that many of our customers buy connectors for entirely different applications, so I'll try and keep it somewhat generalized. Also, I'll attempt to make this an honest tutorial rather than an advertisement for our products. Hopefully you'll find this document useful; I'll add to it as I find time.

-Chris Hansen 12/14/2012

Servo Connectors and 0.1" Connectors

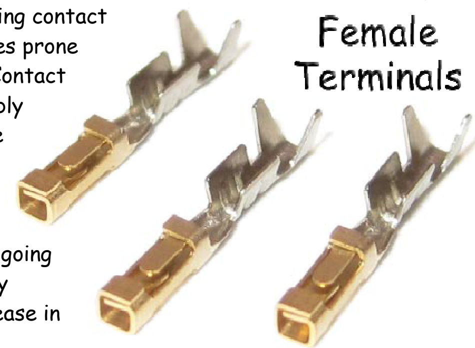
In the electronics industry, connectors are most commonly referred to by the spacing between contacts. The most popular size, without a doubt, is the 0.1" connector. Open up any computer and you'll find tons of 0.1" connectors from IDE cables to USB and Firewire headers. That's exactly the type of connector used by the RC industry for servos and anything else that plugs into your receiver. For the most part, anything said about a 0.1" connector applies to servo connectors and vice versa. It is common to append zeroes on the end, like: 0.100", or use metric (2.54mm) but it all has the same meaning.



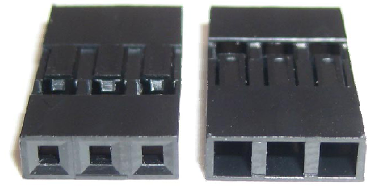
First, let's begin with a little terminology. The *housing* is the plastic part of the connector. It houses the *terminals* which are the metal contacts (often gold or tin plated) which make the actual electrical connection with whatever you're plugging into. Terminals are *male* or *female*, and as is often the case, both work with the same housing as seen in the image below (there is no male or female housing). Connector gender is where the RC industry seems to be backwards from the rest of the electronics industry. In this document, and on our web site, I take the more traditional (and in my opinion, more sensible) approach and sex a connector based on the type of terminal it has. If it has female terminals, as found on anything that plugs into your receiver, I call it a female. This is the naming protocol used by pretty much every other electronics field. Keep in mind, however, that most other resellers and RC hobbyists will refer to connectors exactly the opposite as I do. Sometimes I take a very neutral route and instead of using gender names just say, "servo end" and "extension end".

Terminals:

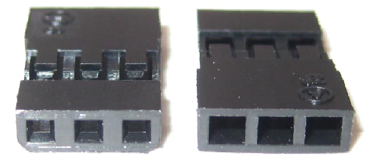
We highly recommend using only gold terminals for your connectors. Tin plated contacts usually have a life of about 10 cycles (a cycle being plugging in and unplugging) before the contact goes outside of its rated specs (possible specs being contact resistance and holding strength). Basically, the plating starts to rub off and the contact becomes prone to oxidation, and the contact(s) start to lose their springiness, increasing contact resistance. "Contact resistance" refers to electrical resistance, which can impede power going to the servo and possibly disrupt the servo signal. In most electronics applications the connector would be plugged in once and never touched again, so 10 cycles would be fine, but they're simply not meant for the repeated use seen from hobbyists. Gold connectors have a life of 50-100 cycles, offer lower contact resistance, and are extremely resistant to corrosion. These numbers probably still seem low but keep in mind that the contact isn't going to fail after 100 cycles, it will just gradually increase in contact resistance and decrease in holding strength (the springiness of the contacts is reduced). You might notice the same thing happening to the outlets near your kitchen counter. If your connector doesn't plug in firmly anymore, that's a good indication to replace it.



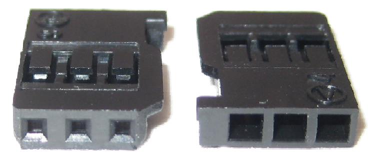
Housings:
The electronics industry commonly uses plain symmetrical connectors which have a rectangular profile. We sell such connectors and an example is shown directly to the right. "1x3" means it is 1 row by 3 positions (we stock up to 1x12 and 2x6). Radio manufacturers like Futaba, JR, and Hitec have opted to make their connectors somewhat unique by making them polarized; in other words, they only plug in a certain orientation. This is achieved by beveling the bottom edges (as with JR/Hitec) and/or adding a keyed edge (as with Futaba). The connectors with the bevels are much more popular and are commonly referred to as "universal" servo connectors because they will plug into any brand receiver. Futaba even started adding bevels to it's connectors in addition to the key (so that you can just cut the key off and have a universal connector). Radio manufacturers also developed a protective sleeve for male/extension connectors. These distinctive features are the reason for the premium charged for servo connectors.



1x3 0.1" Connector Housing

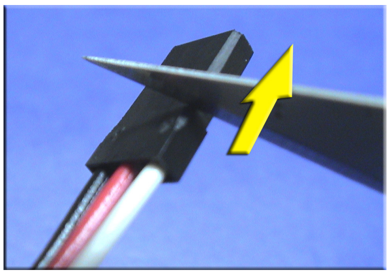


"Universal/JR" Housing



"Futaba J" Housing

One solution to lower costs is to just use standard 0.1" connectors to make servo connectors. They're identical aside from the polarization, which can easily be added. In the image to the left a rectangular housing (we've dubbed our "economy servo connector housing") is made into a "universal" servo connector by scraping a sharp blade over the bottom edges. It's fast and easy to do and the results are extremely high quality. Depending on your other hardware, this may never even be necessary. Many micro receivers don't even have cases and therefore don't have keyed connector ports. Pretty much all Futaba receivers will accept a rectangular connector without modification.



Servo Wire

Just like with servo connectors, the RC industry has taken something fairly common and tweaked it for our hobby. Most wire used for servo leads and extensions is made with high strand-count wire, and a more supple insulation than you would see elsewhere. The finer copper strands are more flexible and can withstand repeated flexing and vibration

We currently sell two types of servo wire; the first has been dubbed our "economy servo wire" which has a lower strand count and is less flexible than most servo wire – this is standard UL1007 wire. The second has been dubbed our "deluxe servo wire" and has a very high strand count (about 2-4 times as many strands as the UL1007 wire) and is very pliable. Both are high quality, and the choice depends on your application. For any long runs the economy wire would probably be best – it's cheaper and will be much easier to route through wings (or whatever your routing through) since it's stiffer. It also has a tougher insulation which would stand up to abuse better than most softer wires. If you need super flexibility or have a high-vibration environment (like in a helicopter) then the high strand-count stuff is the way to go. A higher strand-count wire will stand up to repeated flexing longer.

Servo wire with a silicone insulation is becoming popular now. It is typically sold in 20-22AWG and is probably liked because the silicone insulation makes it extra flexible (like cooked spaghetti). Another advantage is that silicone will stand up to higher heat before melting. If you've ever shorted out a battery you may have experience the self-destruction that occurs when the high current flow heats up the battery leads and causes the insulation to melt; even if you fix the original short, the leads may have drifted into each other and made a new one and the only thing to do is yank the leads off as quick as you can (with some pliers), or throw the whole thing outside in the snow. Silicone wire is fairly pricey, so it may be best reserved for battery leads only.

Twisted vs. Ribbon Wire:
Most servo wire is sold in a ribbon form where the three conductors are fused together side by side. Some servo wire is sold in a twisted form where the three wires are simply twisted in a spiral. If you buy wire with a silicone insulation, it will usually be twisted since silicone typically can't be fused together like PVC. I find that ribbon wire is neater and easier to work with. One downside of twisted wire is that the twist consumes some of the wire length. To make 10ft of twisted wire, you may need 12-15ft of each color of wire. The result is that you have more wire weighing down your plane and adding to the electrical resistance of the loop. I've heard claims that twisted wire filters out noise better than ribbon wire. This may be true for computer networking wire, where differential transceivers are sending 250MHz signals over a twisted pair 100m long, but I find the claim rather specious for RC systems sending 50Hz PWM signals a few feet. If anyone has done any real studies on this I would like to hear from you.

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Wire Size:
Servo wire can range from thick 20AWG (American Wire Gauge) wire to tiny 30AWG wire. Manufacturers typically outfit standard servos with 24-26AWG wire, micro servos with 26-28AWG wire, and nano/pico servos with 28-30AWG wire. Many of the higher power digital servos are being outfitted with 20-22AWG wire now. The most common question we're asked is what size wire can be used with 0.1" connectors. I've gone down to 20AWG, but it really depends on the insulation thickness (too thick and it won't fit into the housing). On the smaller end (30AWG or smaller) you may need to perform some trickery to get the crimp done properly.

When deciding what type of wire to use you should consider not just the servo, but the length of the wire as well. The longer the run, the thicker the wire ought to be to reduce the electrical resistance to the servo. Also remember that the wire size doesn't tell the whole story – connectors add resistance as well (see the "Resistance and Voltage Drop" section below). After considering the above, the next thing to think about is if you need to be concerned about the weight of the wire. Last, keep in mind that 22-24AWG wire is just plain easier to work with than anything much thicker or thinner. When I talk to people about their wiring projects, 9 out of 10 times ease-of-use drives the wire choice (over any electrical/weight considerations).

One of the most irritating things you'll find when buying servo wire is that the listed wire sizes never seem to be consistent with what somebody else is selling. I learned this right away and got frustrated because no resellers seemed to be labeling their wire sizes correctly – this makes it difficult for the customer to know what they're buying. I decided to purchase some servo wire from several popular suppliers and take measurements so people could make comparisons. In the table below I list the source, part number, seller's description, measured resistance (in ohms per 1,000ft), and the effective American Wire Gauge (AWG). To determine the AWG, I took the measured resistance and indexed it to this chart: http://en.wikipedia.org/wiki/American_wire_gauge, then rounded the results to the nearest tenth. Of course, you'll never hear anyone say "twenty five point two gauge wire", but these numbers will serve well for the purposes of comparison. I also made a sincere, but less scientific attempt at rating the flexibility of each wire. I also had a helper perform the flexibility test and we averaged our scores.

Source	Part Number	Stated Gauge	Strand Count	Ohms per 1000ft	Measured AWG	Weight (oz/ft) / (g/m)		Flexibility
Hansen Hobbies	HH-SW_SI20	20	99	10.50	20.1	0.222	20.6	●●●●●
Hansen Hobbies	HH-SW_EC20	20	21	10.35	20.1	0.251	23.3	●●
Hansen Hobbies	HH-SW_EC22	22	17	15.55	21.8	0.182	16.9	●●
Hansen Hobbies	HH-SW_EC24	24	11	24.53	23.8	0.131	12.1	●●
Hansen Hobbies	HH-SW_EC26	26	7	39.30	25.8	0.096	8.9	●●
Hansen Hobbies	HH-SW_EC28	28	7	60.97	27.7	0.074	6.9	●●◖
Hansen Hobbies	HH-SW_ECLITE_28	28	7	60.37	27.7	0.046	4.3	●●◖
Hansen Hobbies	HH-SW_ECLITE_30	30	7	98.47	29.8	0.030	2.8	●●●
Hansen Hobbies	HH-SW_ECLITE_32	32	7	149.95	31.6	0.023	2.1	●●●◖
Hansen Hobbies	HH-SW_DX22	22	60	18.97	22.7	0.156	14.5	●●●●
Hansen Hobbies	HH-SW_DX26	26	30	36.86	25.5	0.092	8.5	●●●●
Hansen Hobbies	HH-SW_DX28	28	20	52.88	27.1	0.052	4.8	●●●●
Radical RC	W3S-22FJ	22	60	16.64	22.1	0.152	14.1	●●●
Radical RC	W3S-26FJ	26	30	33.57	25.1	0.095	8.8	●●●
Radical RC	W3S-30FJ	30	20	50.21	26.9	0.058	5.4	●●●◖
Servo City	SW24J	24	30	35.87	25.4	0.096	8.9	●●●◖
Servo City	SW22JT (twisted)	~~20~~ 22	60	19.26	22.7	0.162	15.1	●●●●
Servo City	SW22JT (untwisted)	~~20~~ 22	60	17.92	22.4	0.151	14.0	●●●●
Hitec / Tower	PN 57417 / LXN661	24	40	25.16	23.9	0.114	10.6	●●●◖
Hitec / Tower	PN 54804 / LXPWC1	20	60	16.45	22.1	0.148	13.7	●●●

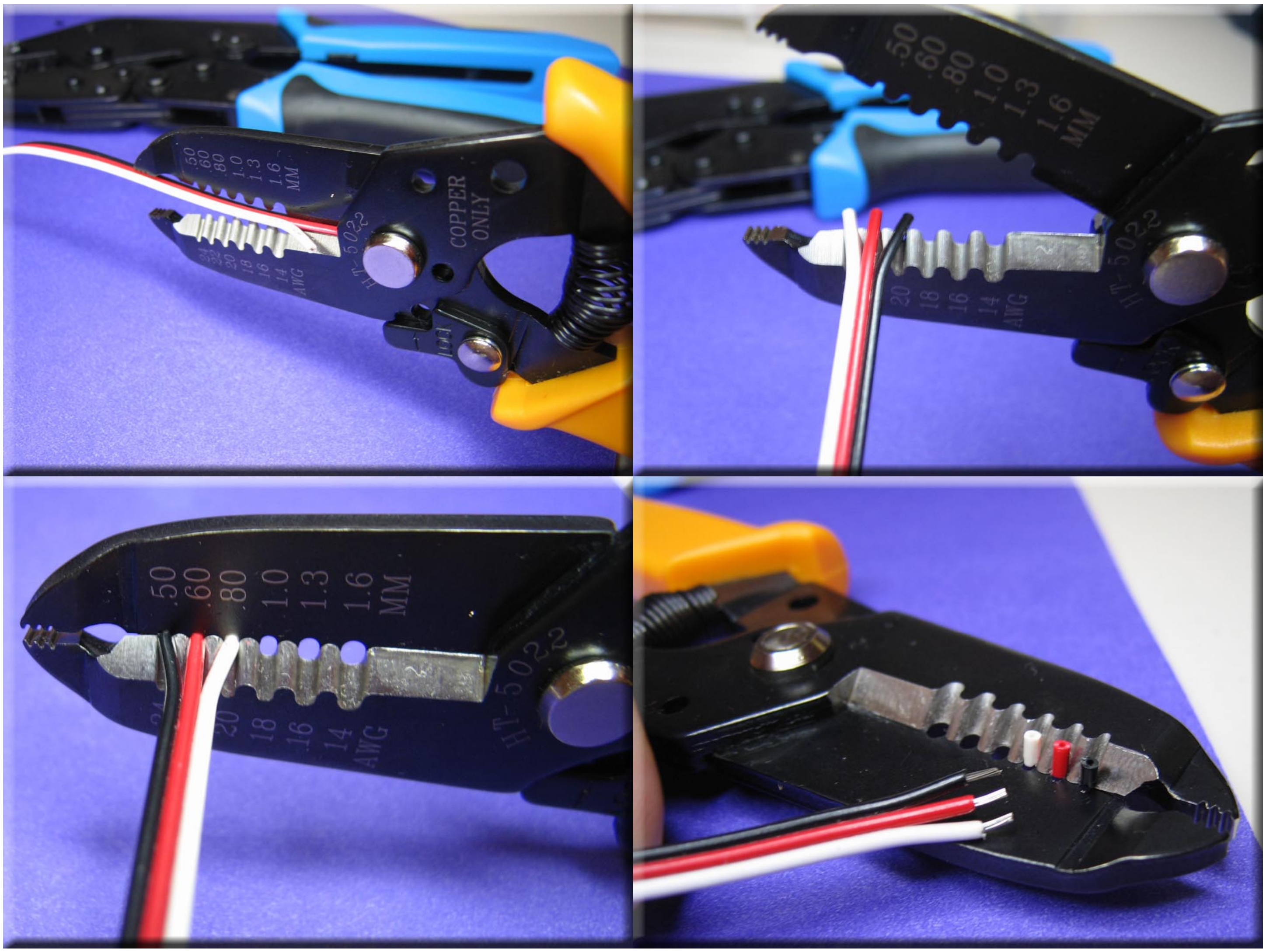
As you can see, the listed wire gauge is not always dependable. The lesson to be learned is that you should probably pay no attention to the listed gauge and just look at the wire resistance. If your supplier isn't able to measure it for you, ask them to send me a sample at least 10ft long and I'll measure it and add it to the chart here! Our Economy Wire aside, there's good consistency among wires of similar strand counts. So if you have 60 strand wire, it's likely close to 22.3AWG, 30 strands is likely close to 25.4AWG, and 20 strands is likely close to 27AWG.

I tested one type of twisted wire and you can see that when untwisted the length increased and therefore the ohms/ft went down and decreased its effective gauge. I feel the change would have been more significant, but even after untwisting the wire it still didn't want to relax out to its natural length.

Stripping Wire:
I prefer the type of wire stripper with several size teeth in a row. This is the type we sell on our website. The reason I like it (besides having used this kind all my life) is that you can quickly strip servo wire with it. It isn't meant to be used like this, but I find this method works great:

1) First separate the wires using the cutting part of the jaw as shown.
2) Position the wires in the first three teeth and close the jaws.
3) Flip the wire over and close the jaws again.
4) Pull away to remove the insulation

This method is extremely fast and gives even clean results. It may not work properly on all wire types, however. I use the first three teeth when working with our Economy 24AWG wire and Deluxe 22AWG wire. You'll have to experiment with different wire sizes to see what works best.



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Crimping Tools:
We currently sell two tools to crimp terminals, again dubbed “Economy” and “Deluxe” crimping tools. Both tools have their pros and cons. Here’s a straightforward review of each:

Economy Crimping Tool: The economy tool makes a good crimp but requires a lot of squeezing power which translates into sore hands after a while. It tends to bend the terminal a little when crimping so it has to be bent back straight. Also, the terminal may not readily release from the teeth (if you squeeze it has hard as I do). This tool has a wire cutter on it which can come in handy, and can also serve as pliers. This tool makes a lousy looking crimp with JST/BEC terminals, but it works. I’ve made over a thousand good crimps with this tool. Beware, there is another red-handled tool that looks nearly identical to the one we sell, but it has 3 sets of teeth in the jaw instead of two. This other tool was made for butt-insulated connectors, piercing spade lugs, and open barrel connectors and gives poor results on servo connector terminals. Often I have had people walk up to me at expo’s and groan about “the red-handled tool” when they really should be groaning about the person who sold them the “3-toothed red-handled tool”.

Deluxe Crimping Tool: The deluxe tool is much easier on the hands due to its leveraging mechanism. It has a ratcheting jaw which is useful for locking the terminal in place before making the crimp. I’ve never had a terminal get stuck in the teeth. If it has any flaw it is that sometimes it crimps the rear wings of the terminal too wide to slide easily into the connector housing (more on that later). This tool makes a stronger crimp than the economy tool due to its higher compression, and crimps JST/BEC connector terminals perfectly. I’ve made thousands of good crimps with this tool, faster, and my hands don’t get sore.

By the way, pay little attention to the wire gauge sizes listed on the side of the crimping tools. Trial and error is the best way to decide how to crimp something.

Of course, you don’t have to use a crimping tool. You could also solder the wire to the terminals. Unless you have a special rig to do it, soldering is probably a slower and less consistent process. An improperly made solder joint is also much more likely to break due to vibration or flexing.

Making the Crimp:
Both tools have two different crimping teeth for various wire sizes. The connector terminals have two sets of wings – one is made to crimp onto the bare wire strands, and the other is made to crimp onto the insulation; we’ll call them ‘strand wings’ and ‘insulation wings’. Also notice that the crimping tool has a deep gully for the insulation wings and a shallower gully for the strand wings. For a good crimp, the insulation wings should wrap tightly around the insulation, and the bare wire wings should roll inward very tightly onto the strands. Notice the small ridge in the gully – that’s there to aid the wings in curling around. There are two good ways to crimp the terminal:

a) Place the terminal on the wire first (the insulation wings should hold it on – if not, squeeze the insulation wings together a little bit to make it hold on tighter) then hold the wire between the crimper teeth and crimp.

b) Place the terminal in the crimper teeth first, lightly close the teeth to hold it in place, then slide the wire into the terminal and crimp.

Crimp the terminal VERY tightly. The deluxe tool makes this easy – in fact you can’t even open the tool back up until it’s been fully closed (like a turtle’s jaws, I understand). With the economy tool the jaws should close all the way.

Making a Female Servo Connector with the Economy Crimping Tool:
Whichever housings you decide to use, making the connector is the same. The gold terminals we sell fit all of the 0.1" and servo connectors we sell. Here I:

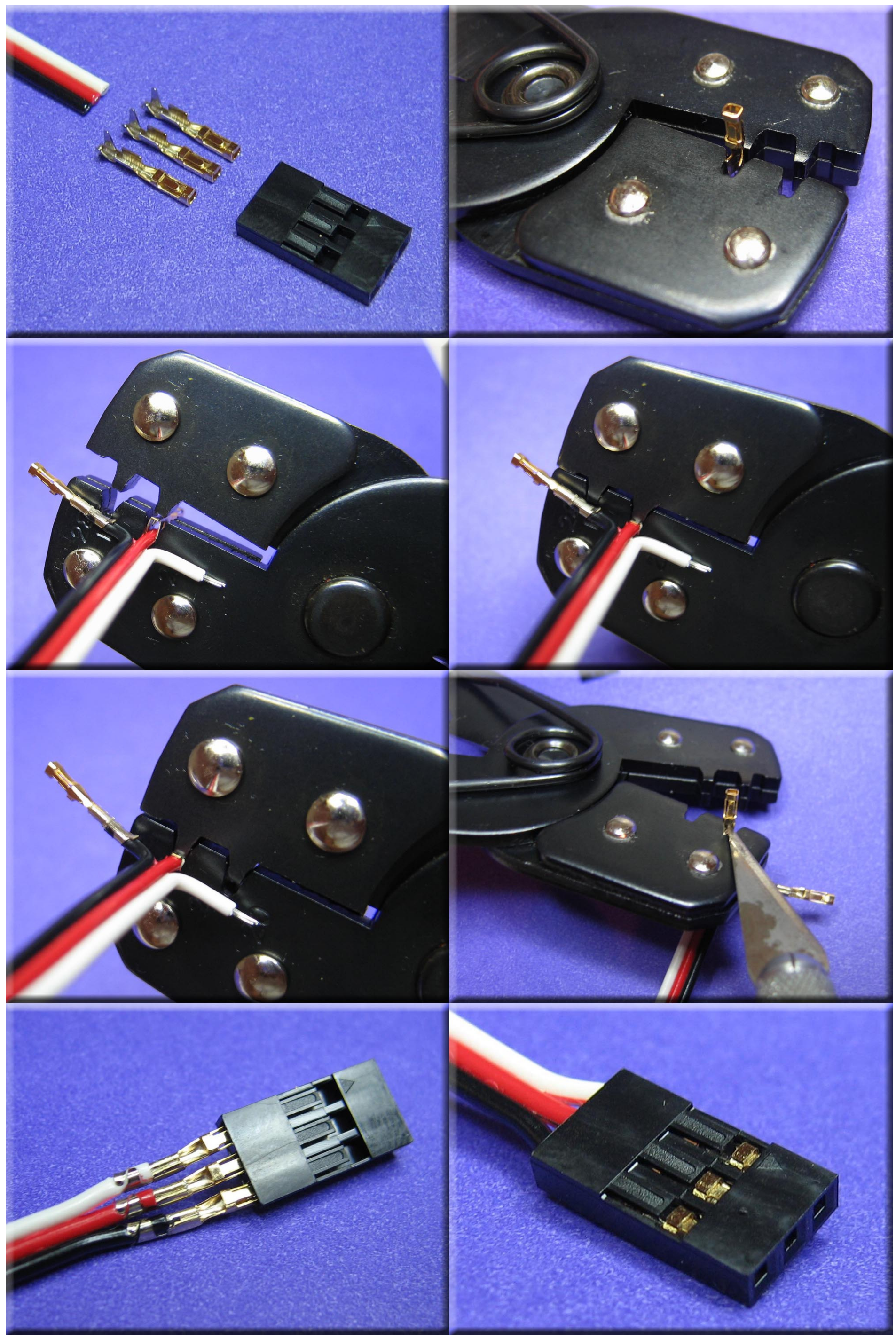
1) Strip the wires as describe above.
2) Set a female terminal in the larger set of teeth and close the jaws to lightly hold it in place. Do not press down.
3) Starting with the BLACK wire, slide the stripped end in until you feel the insulated part of the wire hit the change in tooth depth.
4) Crimp by pressing the handles until the jaws close completely.
5) Remove the crimped terminal and set it in the smaller set of teeth and re-crimp, pressing good and hard.
6) If the terminal gets stuck in the teeth (and it probably will if you pressed hard) I pop it out with a hobby knife as shown.
7) Insert the female pins into a connector housing until the little flaps lock the pins into place.

Notes: If the terminal is not crimped with enough pressure then the wire could pull out of the terminal during use. I've destroyed dozens of servo connectors, including those made by just about every radio manufacturer. In strength tests, a well crimped terminal will break through the plastic housing before the wire pulls out of the terminal. Even when pulled on with pliers, the strands of the wire will usually fail and break before they're pulled out of the terminal.

The reason I crimp the contact twice when using the Economy Crimper is that I feel that the crimp is shaped (or annealed) better by first crimping in the large, then the small teeth.

The crimp can be further strengthened by soldering the strands to the terminal, although this is probably overkill and could make the wire prone to breaking if the solder were to wick up the wire (making it brittle). I would not recommend soldering.

If using our deluxe tool you should start with the white wire, since the teeth are flipped on that tool.



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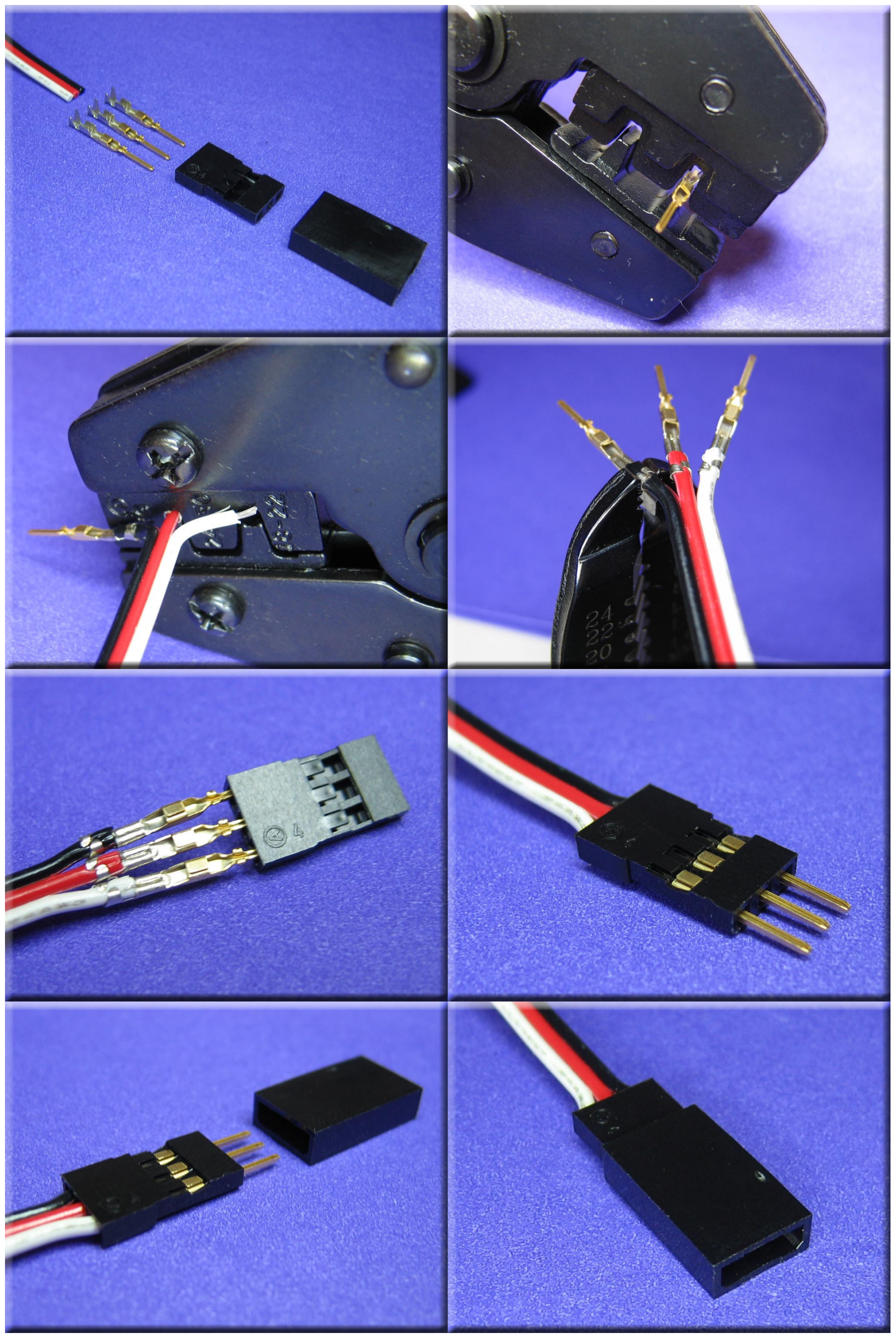
Making a Male Servo Connector with the Deluxe Crimping Tool:
A male servo connector is very similar to a female connector, just don't forget to reverse the order of the wires. The same housing is used, along with male pins instead of female pins. That's right, it's the exact same housing for the male connector. Then, if you choose to, you can finish it off with a protective plastic sleeve as found on pretty much all male connectors in the RC industry. To make a male connector we'll use the same process to crimp male terminals onto the wire. This sequence shows our deluxe crimping tool in action along with our 0.1" gold male terminals, universal housing, and universal sleeve. This is how I like to do things:

1) Strip the wires as describe above.
2) Set a male terminal in the smaller set of teeth and close the jaws just enough to hold it in place.
3) Starting with the BLACK wire, slide the stripped end in until you feel the insulated part of the wire hit the change in tooth depth.
4) Crimp, and repeat for the other wires.
5) If you experience problems inserting the pins into the housing due to the insulation, remedy by very slightly squeezing the rear wings with pliers (I use our wire stripping tool to do this), or whittle down bulging insulation with a sharp knife.
6) Insert the male pins into a connector housing until the little flaps lock the pins into place.
7) At this point, the connector is perfectly usable, but the unprotected pins could short out on something or get broken.
8) The male sleeves have little bumps on the inside that will snap into the little windows in the housing. Press the sleeve on, bumps first.

Notes: You could also use our economy 1x3 connector housing to do this. If you modify the housing as shown above then you can press the protective sleeve over it.

When making a Futaba J type male connector, you'll want to start with the white wire. The order should be reversed from that shown in the photos to the right (because the Futaba J sleeve flips the key orientation). Note that a Futaba J sleeve will snap over an economy 1x3, universal, or Futaba J housing.



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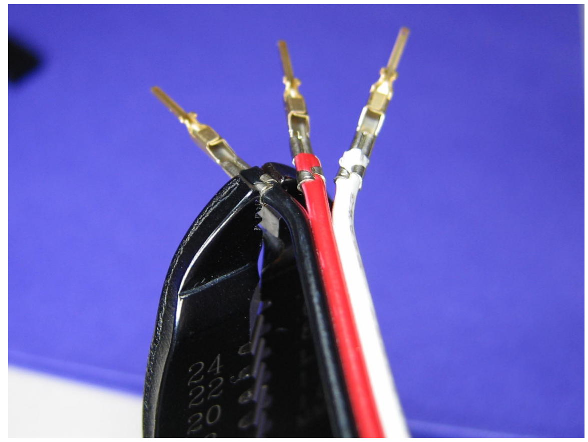
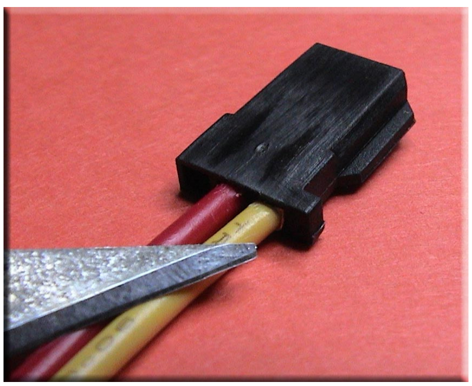
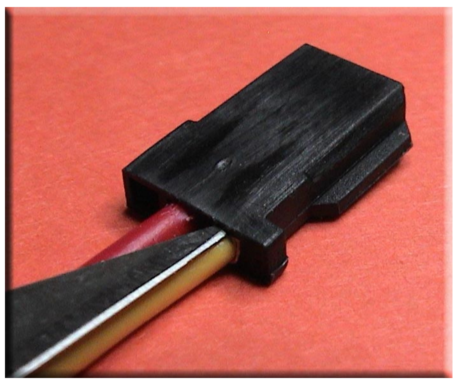
Inserting and Extracting Terminals:
Typically, the terminals will easily slide into the servo housings and snap in place. Sometimes I find that when using thicker wire the rear set of wings on the terminals sometimes come out a tad too wide, and the terminal has trouble sliding into the housing. This issue is more noticeable with our 0.1" housings than with our servo connector housings since the 0.1" housings have pin compartments ever so slightly narrower than the servo connector housings. When using our stiffer economy wire this may not matter so much because the wire is stiff enough that the terminals can just be pushed in against any resistance, but when using a more flexible wire you might find your efforts similar to that of trying to push a rope, if you know what I mean.

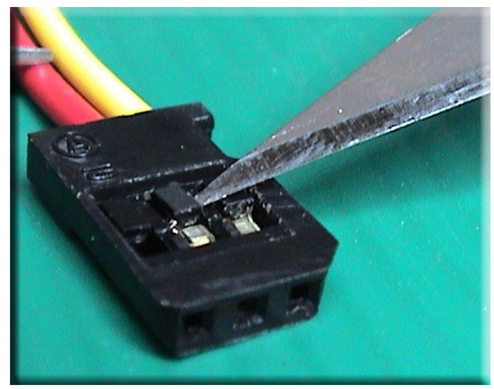


One solution is to just give the insulation wings a little squeeze to reshape them as shown to the right, but I prefer to leave the terminals alone and just push them into the housing using a small tool. The simplest thing I've found around my workplace is a hobby knife with a blunt tip (you can just break the tip off with some pliers). Please be very careful if you do this – make sure the blade is dull enough not to cut you. I keep a dulled blunted No. 11 blade in my connector kit just for this. You could also use a very small screwdriver, or any number of other widgets. Push on the bottom part of the terminal until it slides all the way in and the locking flap snaps in place. The previously uncooperative terminals end up nice and snug and happy.

To remove the terminals from the housing the little locking flaps have to be carefully lifted up while you slide the terminal back out. If you don't intend to reuse the housing you can go nuts and bend the flaps all the way back, but if you want to reuse it, bend them back only enough to give the terminal clearance. To do this I revert back to my trusty hobby knife.







Making a connector with thin wire:
Both of our crimping tools give good results when crimping terminals onto our 28AWG wire. If you go smaller than that then I recommend you make a crimp then perform a pull test to see if the wire can easily be pulled out of the terminal. If it can, then you'll have to solder the wires to the terminals. I would crimp it first, then quickly and neatly solder the copper strands to the terminal. It's important to do it quickly and with a minimal amount of solder so the solder doesn't wick up the copper strands beyond the wings of the terminal, making the wire brittle where it needs to be able to flex. For smaller wire I prefer the Deluxe Crimping Tool and I get good results using mine down to 32AWG wire.

Making a connector with thick wire:
Our Economy Crimping Tool performs well down to 22AWG wire, but does not yield good results on 20AWG wire. Our Deluxe Crimping Tool performs very well across the 20-30AWG range. All wire is different, so when in doubt the best thing to do is give it a try, then do a pull test to see if the crimp is solid. Again, you should be able to yank on the terminal/wire pretty hard (I just grab the terminal with some pliers, which crushes it and yields it unusable) before the crimp fails. When using our gold terminals on 20AWG wire you may find the conductor wings don't wrap completely around the copper strands. In pull tests I find that the results are not ideal, but the crimp is still very solid and trustworthy. If you have concerns/problems, you can always revert to crimping then soldering.

The biggest issue you'll run into with thicker wire is that the insulation makes the wire too thick. This can cause trouble when crimping the rear wings of the terminal, as it will not wrap around the insulation nicely if it is too thick. It can also cause problems with inserting the wire into the housing. Test to see if the wire will fit into the plastic housing before crimping. If it is too big you will have to get sneaky. One approach I've taken to make 20AWG wire work is to whittle down the insulation a little bit so it will crimp nicer and fit into the housing.

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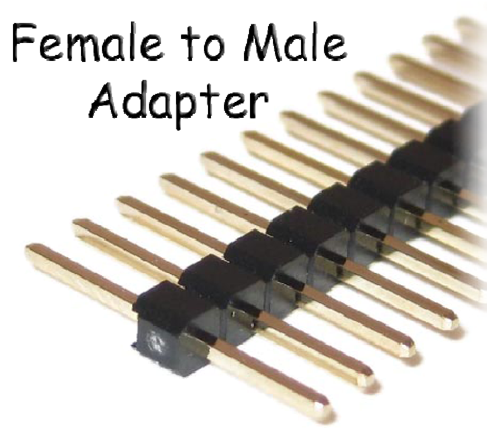
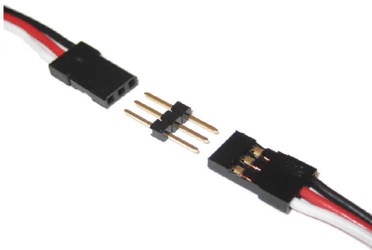
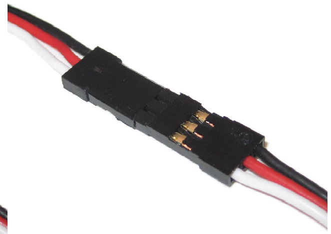
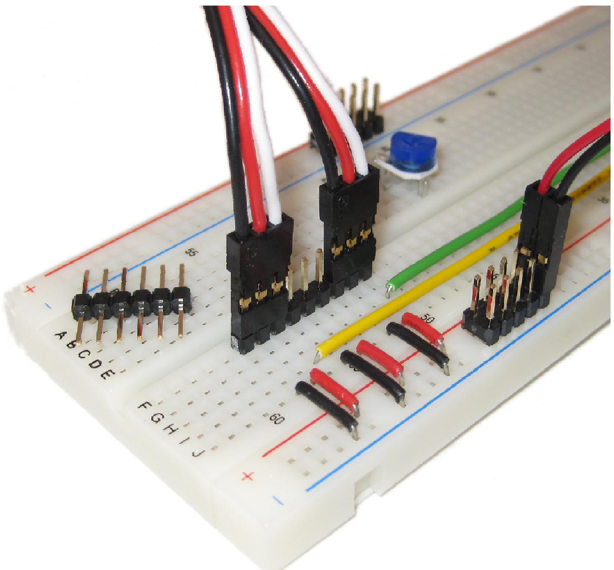
Female to Male Adapters:
We had these adapters made to let you turn a female connector into a male connector. They can be very handy, as they allow you to plug two female connectors together as shown below. You may choose to work only with female connectors and avoid male connectors altogether. If you're an electronics builder you'll be very happy using these to plug female connectors into a breadboard - they really make prototyping a lot easier.



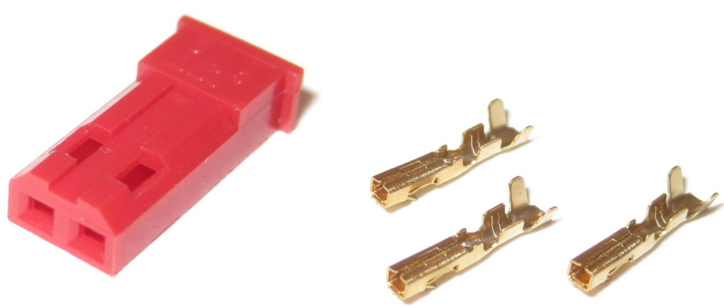






BEC Connectors

The connectors we sell as "BEC Connectors" (BEC stands for "Battery Eliminating Circuitry") or "JST Connectors" are commonly seen in the power systems for small electric planes. They're used to connect the battery to the ESC (Electronic Speed Control) and sometimes to connect the motor to the ESC. It seems they're most often called "BEC Connectors".



The gold terminals included with these connectors are not that same as those we sell for 0.1" connectors. They're larger and made to handle larger wire. They can be crimped with either of our crimping tools using the same methods described above, although I highly recommend using the Deluxe Crimping Tool for these, as it makes a much nicer crimp (the economy tool kind of deforms the connector in a usable, but unpleasant way). In general, use the smaller set of teeth in the deluxe tool and the larger set in the economy tool, but experiment with your wire to see what's best.

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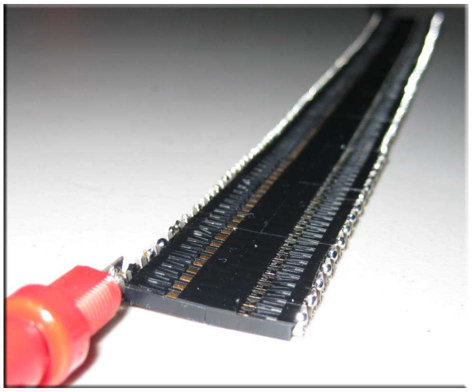
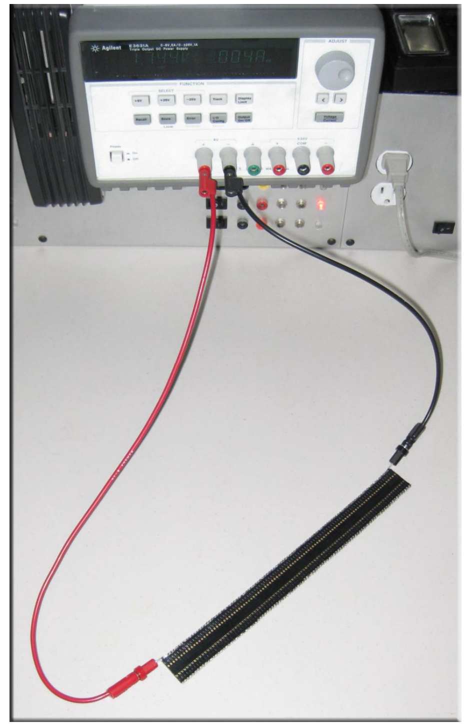
Resistance and Voltage Drop

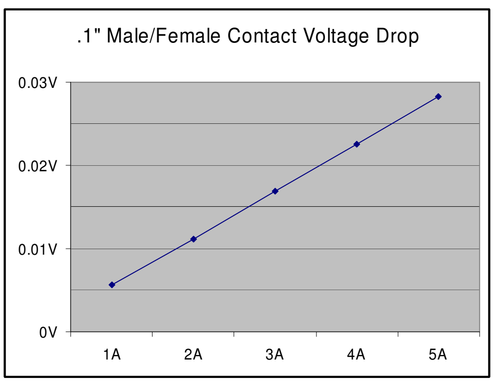


Since I get so many questions/comments on wiring for high demand applications like high-draw systems, high torque digital servos, long servo leads, and quality of contacts, I though I would write a section that talks about power considerations in these situations.

Resistance in the System:
In order to keep your servos and electronics working at their best, you need to keep the resistance down in your connections. This means using suitably sized wire, making runs as short as possible, and reducing the number of connections.



I was curious about the contact resistance for the gold connectors we sell, but manufacturers don't often supply these numbers (usually only a current rating). I set to work on an experiment to measure it: I figured in order to detect it accurately I would need to measure a bunch of them together, so I made up a 100 contact connector using a bunch of 1x10 housings with the back eighth of an inch cut off to expose the rear of the terminals. One side was filled with male and the other with female terminals then I soldered the rear wings of every other terminal together and added banana plugs on the first and last terminal. This gave me 100 male to female contacts in series, a good sample set. I connected the chain to a precise power supply and measured voltage drop across the chain for various currents up to 5A and then I graphed Current vs. Voltage (divided by 100 to get the voltage drop per contact). The graph is shown below and you can use it to find the voltage drop across a single contact. If you take the slope of the I/V graph, you get resistance: 5.625mΩ



A few things should be noted about this study:
1) We're assuming that most of the resistance in the system is from the contacts and that the resistance within the metal itself and the solder joints is relatively low. This seems like a safe bet.
2) The contact resistance may change after a given number of cycles (plug & unplug). My guess here is that it might go down a tiny bit after a few cycles rubs away any oxidation and surface debris, stay flat for, who knows, 100-200 cycles, then start to go up as the contact is cycled so much that it loses it's springiness and the gold coating starts to rub off.
3) This study shows the resistance between a male and female crimp pin, but the resistance between a female connector pin and the solid square header pin found in your receiver may be different. My guess is that the latter is slightly lower because the flat sides of the square pin offers more surface area.

Let's apply this data to an example. Suppose we have a battery, plugged into a switch, plugged into the receiver. We also have a high-torque digital servo in our wing with a 12" lead that's connected to the receiver via two 24" servo extensions. Every time there's a connection in this system, there are two contacts, and current has to flow through both of them to get back to its source. In this setup we have 6 connectors for a total of 12 contacts. If the servo were to surge 3 amps we can see in the graph above that each contact in the loop will drop about 0.017V, and all of them together will drop 0.017 x 12 = 0.204V.

Let's further suppose that all of the wire is 24AWG wire and there is 20" on the battery/switch side, and 60" total for the servo/extensions. Again, current has to flow through the positive wire and back through the negative wire, so we really have 160" of wire. 24AWG wire has 25.7Ω of resistance per 1,000ft, so there is about 0.343Ω of resistance in our system. Given a 3A draw, we would see a voltage drop of 3 x 0.343 = 1.03V.

As you can see, when our servo demanded 3A of current it also saw a voltage drop of 1.234V. This is about an 18-25% power loss depending on your receiver battery voltage. If we redid the math with 22AWG wire, and a custom 43" extension for the servo, that voltage drop becomes 0.740V. Use 20AWG and the drop is 0.515V. As a final trial, let's scratch the whole extension idea and instead just open up our servo and solder in a new 55" 20AWG lead. We'll also toss the switch and just plug our battery straight into the receiver using doubled up 6" 20AWG leads. The same 3A surge only causes a 0.344V drop. In this example keep in mind that we only considered one servo. When multiple servos are running the battery connection becomes especially important because all of the current is being sourced from that one point.

The idea here is not to tell you exactly how to wire your plane, but to make the point that wiring can make a difference, and give some basic info so you can make smart decisions on wiring and connections.

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Other Thoughts

Here, I'll just write some random ideas as I think them up.

The Truly Universal Connector:

Universal servo connectors are named so because the female connectors will plug into any receiver. The only problem is that a female Futaba J connector can't plug into a universal shrouded/sleeved male connector because the key gets in the way and it may not have bevels. Many of our customers like to make all of their female connectors with universal housings, and all of their male connectors with Futaba J sleeves. This way anything can plug into anything. Note that the Futaba J sleeves will snap overtop any of the housings we sell (economy 1x3, universal, or Futaba J housing).

Receiver Adapter:

Here is an adapter I made using the connectors we sell. In an online forum (rcgroups) someone made a comment about moving their receiver from plane to plane and wearing out connectors. If you swap receivers a lot then it makes sense to have one common connector instead of a bunch of separate servo connectors. Using our 1x3 housings, a 2x5 and a 1x5 housing, and some female to male adapters I made an adapter that brought the servo ports out to a single 0.1" 3x5 header. The idea is that each plane would have a single female 3x5 connector that plugs in. Of course, we could just get rid of the female to male adapters and use a male connector in the plane, but who can resist all that extra gold?

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