Recommended Wiring Practices for PWM Servo Devices

PWM amplifiers by their nature can create electrical noise which may potentially disrupt logic and analog signals in a motion control system. Signals such as encoders, I/O and communications may be affected. Servo system wiring typically involves wiring a controller, servo amplifier, power supply, and a motor. Wiring these components is fairly easy when a few simple rules are observed. By following the wiring guidelines in this paper, the effects of noise can be minimized or completely eliminated.

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Components
The three components connected to the drive/amplifier will be the focus of this paper.

- Motor: motor feedback and motor power
- Power supply
- Controller
Introduction
All noise paths can be broken down into three parts:
- Noise source
- Noise transmission medium
- Noise receiver
Interrupting one or more of these components can eliminate the problems caused by noise.

Wiring

Wire gauge
As the wire diameter decreases, the impedance increases. Higher impedance wire will broadcast more noise than lower impedance wire, therefore when selecting the wire gauge for the motor power wires, power supply wires and ground wires it is better to err on the side of being too thick rather than too thin. This recommendation becomes more critical as the cable length increases.

Cable routing
Route cables to minimize length and to minimize exposure to noise sources. The motor power wires are a major source of noise and the motor feedback wires are susceptible to receiving noise. This is why it is never a good practice to route the motor power wires with the motor feedback wires even if they are shielded. Although both of these cables originate at the amplifier and terminate at the motor, try to find separate paths that maintain distance between the two. A rule of thumb for the minimum distance between these wires is 10cm for every 10m of cable length.

Twisted pair signal wires
Twisted pairs of wires are quite effective in reducing noise. The successive twists cancel noise transients along the length of the cable. All signal cables should be shielded with twisted pair wires. The combination of twisted pair wires and a differential signal significantly adds to noise immunity. The encoder and command signals benefit greatly from this combination.

Twisted motor power wires
The motor power wires supply power from the amplifier to the motor. Twisting the motor power wires reduces the amount of noise coupling to sensitive components. For a brushless motor twist all three motor wires and the motor case ground wire together as a group. For a brushed motor or voice coil twist the two motor wires and case ground wire together as a group. These should be bundled and shielded in their own cable and kept separate from feedback signal wires.
Twisted power supply wires
AC powered amplifiers use single or three phase AC that is directly supplied from an incoming building AC source. DC supplied amplifiers use power that has been converted from AC into DC using a power supply. All AC and DC supply wires should be twisted and if a shield is available it should be grounded at a central grounding point near the amplifier.

Additional capacitance for DC power wires
If a DC power supply is used, the distance between the power supply and amplifier should be minimized since the length of cable between the two is a source of noise. If this distance is greater than 3 feet, then a 1000uF capacitor should be added within 1 foot of the drive. This capacitance helps to stabilize the voltage supplied to the drive as well as filter noise on the power supply line.

For long power supply cables, add 1000uF of capacitance within 1 foot of the amplifier.
**Daisy Chains**

It can be tempting to daisy chain the wiring in a servo system. On the surface, daisy chain wiring looks clean and simplified, however this type of wiring is a major cause of noise and should be avoided. If multiple drives are present in a servo system then each drive must have power lines that trace directly back to the power source. Cable shields and ground wires should all lead to a central grounding point using the shortest possible path.

These wiring schemes are commonly practiced but often times contribute to noise problems. Each additional node in the chain adds to the amount of noise and unnecessarily loads the connectors in each link.

For demonstration purposes this is a correctly wired system. However in practice, each wire pair should be routed together and twisted. For AC input amplifiers, AC power should be distributed from a central AC source, not a capacitor!!!
Shielding
All signal wires should be twisted pair shielded including the feedback wires leading from the motor to the amplifier and the signal wires leading from the amplifier to the controller. The motor power wires should be shielded as well. All shields should be grounded at one end only. Shields grounded at both ends will create ground loops and will amplify noise rather than reduce noise. Since the amplifier PWM will likely be the source of noise the shields should be grounded near the amplifier at a central point. Shield ground wires must be of a heavy gauge and securely connected to the central grounding point.

Grounding
Central point grounding reduces the chance for current loops and helps to minimize high frequency voltage differentials between components (noise). All ground wires must be of a heavy gauge and be as short as possible. The following should be securely grounded at the central grounding point: Amplifier case, motor case, controller case, power supply case and cable shields. Grounding is also important for safety. It is the responsibility of the system designer to follow applicable regulations and guidelines.

In many cases the signal ground and/or power ground can be referenced to earth ground. First decide if this is both appropriate and safe. If this is the case, they can be grounded at the central grounding point.

All grounding is wired to a central grounding point including the case and shield grounds.
**Noise Suppression**
Additional noise suppression devices can be used if the above wiring guidelines had to be compromised due to space or other constraints.

**AC Line Filter**
It is possible for noise generated by the machine to ‘leak’ onto the main AC power and then get distributed to nearby equipment. If this equipment is sensitive it may be adversely affected by the noise. AC line filters can filter this noise and keep it from getting onto the AC power.

The AC power filter should be mounted flat against the enclosure of the product using the mounting lugs provided on the filter. Paint should be removed from the enclosure where the filter is fitted to ensure good metal to metal contact. The filter should be mounted as close to the point where the AC power enters the enclosure as possible. Also the AC power cable on the load end of the filter should be routed as far from the AC power cable on the supply end of the filter and all other cables and circuitry to minimize RF coupling.

**Ferrite Suppression Cores**
If PWM switching noise couples onto the encoder signals or onto the signal ground, then a ferrite suppression core can be used to attenuate the noise. Take the motor leads and wrap them around the suppression core as many times as reasonably possible, usually 2-5 times. Make sure to strip back the cable shield and only wrap the motor wires. There will be two wires for brushed motors and 3 wires for brushless. Wrap the motor wires together as a group around the suppression core and leave the motor case ground wire out of the loop. The suppression core should be located as near to the amplifier as possible.

**Inductive Filter Cards**
Inductor cards are added in series with the motor and are used to increase the load inductance in order to meet the minimum load inductance requirement of the amplifier. They also serve to counteract the effects of line capacitance found in long cable runs and in high voltage systems. These filter cards also have the added benefit of reducing the amount of PWM noise that couples onto the signal lines. This means they can be used in place of the suppression cores mentioned above.
Wiring Example with Advanced Motion Controls Servo Drive

This picture shows an Advanced Motion Controls servo drive that has been correctly wired using the recommended wiring practices. If implemented correctly, noise should be greatly diminished or completely eliminated.

**Gauge**
Heavy gauge wire was used for power wires and grounding.

**Routing**
The communication cable (CN1) and controller cable (CN2) lead away from the other cables. Although the motor power and motor feedback cables start and end in the same place they are kept separate as much as possible.

**Twisted Pair Signal**
Although not viewable, all signal wires are twisted and paired.

**Twisted Power**
The motor power lines and the amplifier power lines are twisted and shielded.

**Daisy Chains**
No daisy chains are present.

**Shielding**
All cables are shielded and grounded at the amplifier end.

**Grounding**
All grounds lead to a central grounding point. This example shows the motor case ground wire, motor cable shield wire and the amplifier case ground going to the central grounding point.

**Ferrite Suppression Core**
Although unnecessary for many systems, a ferrite suppression core is shown correctly wired to the motor cable. The shield and case ground wires were stripped back and the three motor wires were wrapped around the toroid as a group (common mode). We recommend 2-5 wraps to be effective. Ferrites made from material 43 and material 31 from Fair-Rite Products Corp provide excellent noise suppression.