

Power Supply Cables and Connectors



Often during the excitement of designing a challenging new system, some of the more mundane engineering aspects get overlooked. This is especially true of connections between the power supply and the load. The extent to which connector resistance causes voltage drops and even connector damage is not widely understood. Without a good connection, even the best switching power supply cannot provide the various output voltages essential for proper system operation. This application note will outline principles which can minimize connector and cable resistance problems. It will also discuss how to most effectively use the types of connectors most commonly found on switching power supplies.

CONTACT RESISTANCE

Resistance in connectors causes major problems by creating voltage drops and generating heat. The majority of resistance in an entire power supply cable occurs at the contacts of the connectors. This is referred to as contact resistance. A 7 amp quick disconnect connector, which will be discussed in more detail later, has a typical contact resistance of 20 milliohms. This is quite high compared to the 6.4 milliohms in one foot of 18 AWG wire. A very poor connection with this type of connector can have a contact resistance of as high as 100 milliohms.

Voltage drops due to contact resistance also degrade the regulation of a power supply. A good supply with 0.1% load regulation on the 5 volt output would have a 5mV drop during a change from a no load to a 5 amp load condition. However, there would be a 500mV drop if there were an additional 100 milliohms of contact resistance at the connector. The 5 volt output would droop to 4.5 volts, degrading the regulation to 10%.

Heat generated from current passing through contact resistance in a connector will increase if the resistance increases. Heat, along with oxidation, will deteriorate the mating surfaces of contacts by accelerating the build up of tarnish. Tarnish contributes to additional contact resistance. Heat will also diminish the force with which spring loaded contact terminals interface with mating pins. Thus, heat and resistance can escalate until a connector is degraded to a point where the proper output can no longer be delivered from a power supply to the system load. In extreme cases, the plastic connector parts and even the PCB of the power supply can discolor and char.

THE RESISTANCE IN A CONNECTOR IS DETERMINED BY THE FOLLOWING FACTORS:

1. The total amount of surface area between the two mating connectors.
2. The quality of the finish of the conductor surface between the two mating

connectors.

3. The amount of forcepressing the two conductor surfaces of the mating connectors together.

These principles can be illustrated by an automobile battery analogy. An automobile may not start due to poor battery connections. The battery may be perfectly good, and the auto's lights and accessories operate fine, but the starter motor will not turn over. The starting problem is often corrected by cleaning and tightening the battery terminals and clamps. Prior to cleaning, there was not enough good connector surface area on the terminals for the high amount of current needed to run the starter motor. There was, however, enough good connector surface area to power the lights and accessories which require considerably less current than a starter motor. In the same way that contact resistance can prohibit an automotive system from operating properly, it can likewise affect the functions of an electronic system.

Mating connector surfaces are plated and finely polished by connector manufacturers, and one may falsely assume that current flows through the entire contact surface area. However, the actual portion of surface area which makes true electrical contact is quite minute, even with plated and polished surfaces. Viewed on a microscopic level, as illustrated in Figure 1, the mating surfaces are made up of peaks and valleys. In order for current to pass from one mating surface to another, it must find a path through those points which actually make contact. Because the entire mating surface area does not conduct, more surface area is required for higher levels of current flow. This accounts for many switching supplies having more than one connector pin on the high current main output.

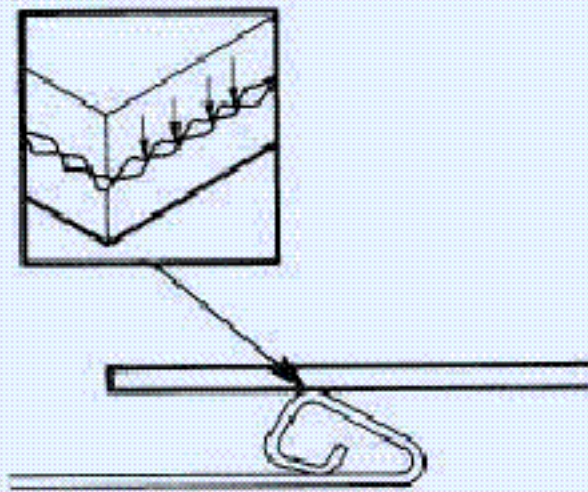


Figure 1. Microscopic side view illustration of connector mating surfaces showing points where current can flow.

The plating of connector pins and terminals retards corrosion and formation of film, both of which cause contact resistance. The majority of connectors used on commercial switching power supplies are plated with tin alloy. Tin plating is cost effective, and affords excellent solderability.

Gold is an excellent conductor. It resists oxidation well, even in very polluted atmospheres. Compared to tin, gold plated connectors have a longer shelf life, and the plating wears less from numerous insertions and withdrawals. Since it is more costly, gold is often selectively plated on connector surfaces only where electrical contact is made. A selectively plated gold connector costs roughly 60% more than tin, and a fully gold plated connector costs three times more than tin.

The current carrying capabilities and the amount of contact resistance of gold connectors are not significantly improved over some of the better tin plated terminals.

Tin plating is a much better value than gold for commercial products where the number of insertions is limited, and the connector is protected from harsh environments. Gold and tin are at opposite ends of the galvanic table, and a gold connector will become contaminated if mated with a tin plated one. Always mate connectors of like plating.

The affect of connector force on resistance was illustrated in the auto battery example when the cable clamps were tightened. Increasing the amount of force pressing the mating surfaces of the cable clamps against those of the battery terminal posts allowed more microscopic peaks and valleys to meet, thus increasing current flow. End users can increase force on mechanical connectors with clamping action by tightening them, while slide on terminals are designed with a fixed spring tension to provide engagement force with mating pins. Since a user cannot increase spring tension, he must be very careful not to exceed each pin's current carrying capability. keep in mind that heat and repeated insertions will diminish spring tension over time.

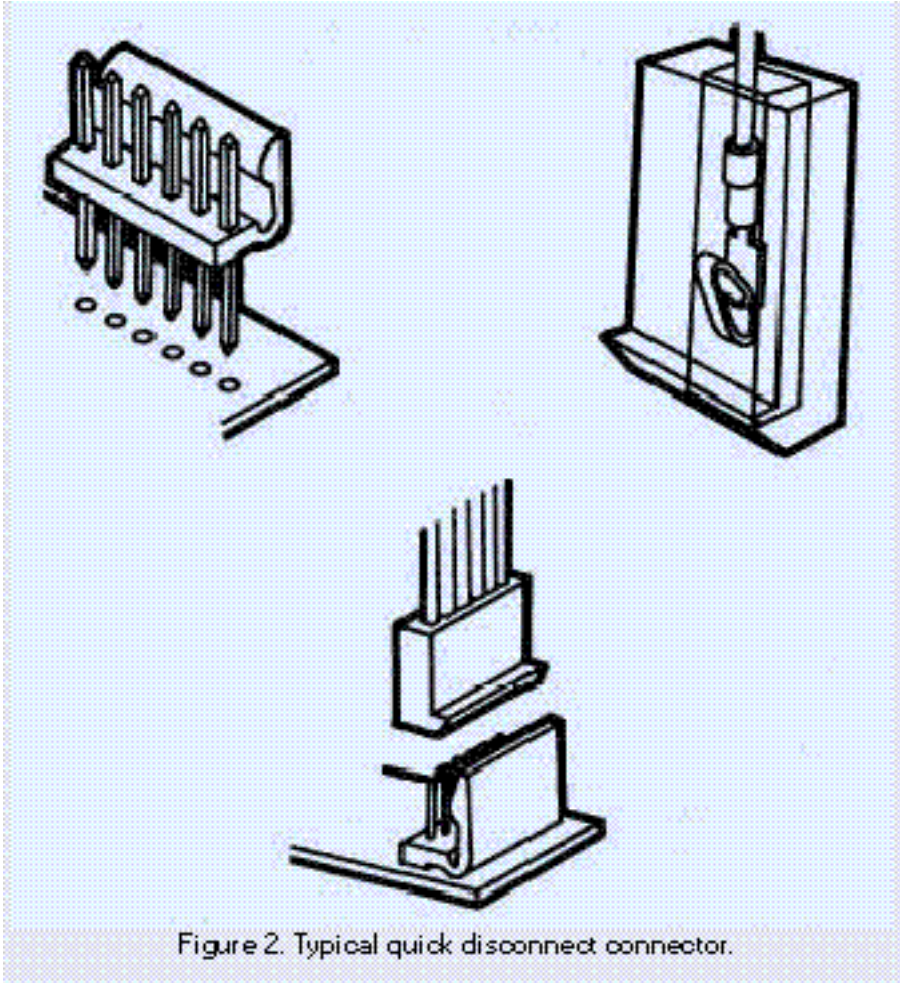
Reducing cable voltage drops can be achieved by following the recommendations of connector manufacturers. Current ratings of connectors are based on contact surface area, plating and finish, and on spring tension. Exceeding the manufacturer's rating, will increase temperature and reduce connector life.

Use all of the available connector pins on the main output of the supply to carry its higher current. When using more than one pin for an output, don't overlook the additional benefit of running two wires in parallel to the load. The paralleled wires will halve the cable drop due to wire resistance. Keep in mind the necessity of providing the same amount of contact surface area at the load connector.

If the voltage at the load is low, you can determine if the droop is due to cable drops by measuring the output voltage at the power supply, preferably on the supply PCB itself. If the voltage reading is correct at the supply, you can conclude that there are connector or cable resistance problems.

Specific Power Supply Connectors: There are three basic types of connectors used on commercial switching power supplies. On smaller supplies with output currents

less than 10 amps, quick disconnect snap-on connectors (Figure 2) are generally used. They are cost effective, and easy to hook up. The male connector has a nylon/plastic header fitted with square pins. Square pins offer more contact surface area than round ones do. The mating connector consists of cantilevered spring loaded terminals. A wire is crimped onto the terminals, and they are snapped into a housing. Headers and housings which feature locking ramps to help keep them mated are recommended. A 7 amp connector of this type from Molex has a maximum contact resistance of 20 milliohms. Computer Products, Inc. recommends using these connectors at 3.5 amps maximum. The 50% derating allows for the build up of tarnish from heat and oxidation, and for the loss of engagement force which will take place over time. The recommended wire size for this type of terminal is 18 AWG.

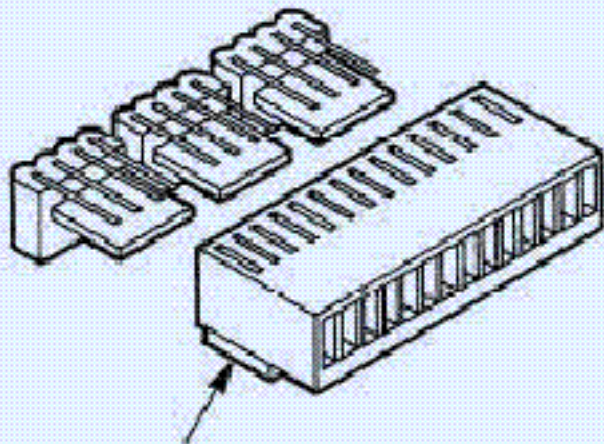


The Molex Trifurcon crimp terminals offer more contact surface area and engagement force than the standard terminal does. The Trifurcon (Figure 3) accomplishes this with additional contact wings on its sides. These extra wings do not improve contact resistance and current carrying capabilities much over the standard terminal. They do, however, eliminate intermittencies during shock and vibration, and they cover more of the contact area to prevent exposure to conditions which can cause tarnish. The wiping action of the extra contact points tends to clean oxides and film from the sides of male pins during insertion. The cost of Trifurcon terminals is comparable to standard ones, and they offer benefits that approximate gold plated terminals. Molex now offers a housing which accommodates both Trifurcon and standard terminals. Figure 2. Typical quick disconnect connector.



Figure 3. Detail of Molex Trifurcon connector.

Another type of quick connect configuration found on many 40 and 50 watt power supplies consists of a set of three small connectors paralleled together. Each connector pin is rated at 2.5 amps, and the largest size wire its crimp terminals can accommodate is 22 AWG. In order to compensate for the higher resistance of the smaller wire, it is necessary for all 12 pins on the power supply to be hooked up: each with its own wire. It would take three paralleled lengths of 22 AWG wire to achieve a similar resistance of an equal length of 18 AWG wire. Rather than using separate small housings for each of the connectors on the power supply, a single 14 pin connector housing (Figure 4) will fit over all 12 pins of the three connectors at once. This adds mechanical stability as well as single-insertion convenience.



The fourteen-position housing's polarizing rib prevents left or right pin misalignment.

Figure 4. The 14-position connector will connect to all 12 pins at once.

Power supplies with higher main outputs of 20 to 50 amps require the extra surface area and wedging force which barrier terminal strips provide. In order to handle that much current flow, more than one terminal is often provided for additional contact surface area. These connectors (Figure 5) consist of nonconductive phenolic or plastic base, a threaded plate, and screws to clamp spade lugs or fanning strips. The 6-32 pan head screws should be torqued onto the mating lugs at 8 to 9 inch-pounds. Exercise caution while torquing to prevent breaking the plastic barriers which separates the individual terminals. The size of wire used should be 18 to 16 AWG. It is not advisable to clamp bare wire to terminal strips: always use some sort of terminal lug.

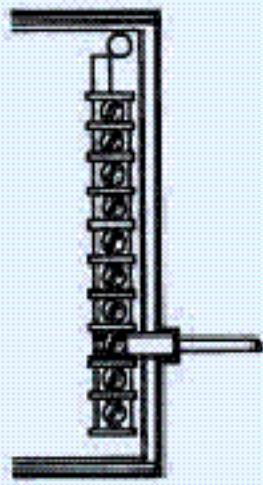


Figure 5. Screw barrier strip connector often used for higher current carrying capability.

On outputs rated at 50 amps or more, 1/4 to 5/16 inch terminal studs are used. The studs have more contact surface area, and provide more wedging force to clamp the mating lug. The terminal nuts require 14 to 22 inch pound of torque. The recommended cable for 50 to 60 amp outputs is a twisted pair of 12 AWG or a bundle of three 14 AWG wires. Welding cable should be used on 100 amp and higher outputs.

CONCLUSION

The primary focus of this application note has been on cable drops caused by contact resistance in connectors. When considerable cable drops in a harness from a power supply to a load, the resistance of the wire also needs to be taken into account. Therefore, the length of a cable harness should be kept as short as possible. It is advisable to limit the voltage drop due to wire resistance in a power supply harness to 1% of the output voltage. Thus maximum wire voltage drop in a 5 volt output and return leg should not exceed 50mV. The table below shows the resistance of various gauges of copper wire.

RESISTANCE* OF ANNEALED COPPER WIRE			
AWG	mΩ/FOOT	AWG	mΩ/FOOT
10	1.00	22	16.14
12	1.59	24	25.67
14	2.53	26	40.81
16	4.02	28	64.90
18	6.39	30	103.20
20	10.15	32	164.10

At 20°C Note: Wire diameter halves for every three wire sizes. On connector terminals, follow the manufacturer's recommendations regarding shelf life and handling. Take precautions to keep pins and terminals clean. When crimping wires onto terminals, use tools and dies recommended by the terminal manufacturer to insure strong connections, and to minimize cable drops.

Although the principles discussed in this application note are elementary, sufficient attention to the details outlined here will minimize cable drops which can degrade or interrupt the operation of a system. An increased awareness of connector idiosyncrasies and exercising forethought and caution, can contribute to long term and trouble free power to your system.

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