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TO: ISO/IEC JTC 1/SC 25/WG3

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SUBJECT: Cycling of RJ-45 Outlets and modular plugs with applied DC power per IEEE 802.3af (DTE Power Via MDI task group) recommendations

Disclaimer:

This contribution is offered by individual experts John Siemon and Dean Stoddart to 'SC 25/WG 3. It has not been reviewed by the US technical advisory group to SC25/WG3 and therefore does not reflect agreement or support by that group on these findings or recommendations.

Introduction:

A number of standards organizations have adopted a method of determining RJ-45 plug/outlet reliability based on the number times the two can be mated and unmated and still provide acceptable low level contact resistance (LLCR). For example, IEC Specification 60603-7 indicates that an outlet shall withstand 750 cycles of mating and unmating with no more than a 20-milliohm increase in LLCR.

The IEEE is currently in the process of developing a specification for applying DC power over existing and new Ethernet cabling infrastructure. The outlet cycling specification should include a method to apply DC power to an outlet during testing, since this type of use will have an impact on the plug/outlet cycling reliability.

Observations:

A test setup was assembled using Siemon MX6 angled UTP RJ-45 outlets and MC6 modular patch cords. A DC power supply was connected to the IDC contacts of each outlet that simultaneously applies power to the "unused" pairs (pins 45/78) and the "used" pairs (12/36). An identical load circuit was connected to each of the pairs described that simulated a worst case powered device (PD) input impedance under normal powering as described by the proposed IEEE 802.3af specification. These loads were connected to one side of the patch cord. The circuit was derived from task force work concerning the impedance of a powered device as described by the proposed 802.3af specification. The other side of the patch cord was used to cycle the outlet. The circuit schematic is show in Figure #1 below. The initial test used the worst-case values shown below.

Voltage: 57 Volts DC
Capacitance: 5 uF
Inductance: 100 uH
Resistance: 105 Ohms

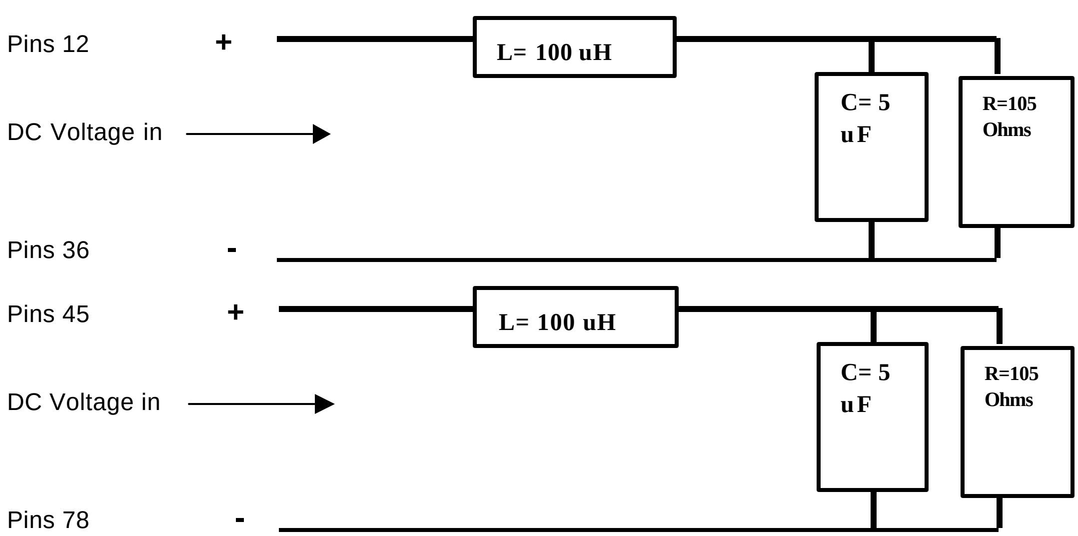

Figure #1 – Proposed PD input impedance circuit – Worst Case

Two of the circuits in Figure #1 above were prototyped and connected to each pair combination. Figure #2 is a photograph of the actual circuits used in the tests.

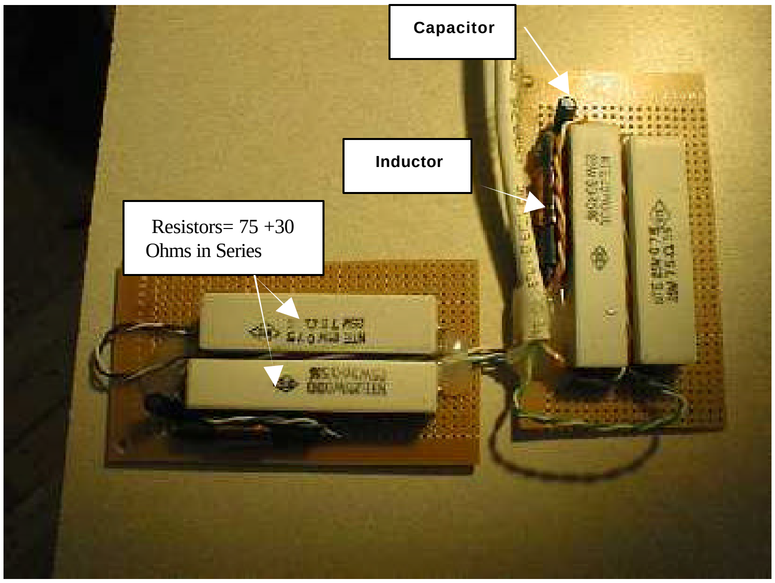

Figure #2 – Test Circuits

Test series #1 – DC Voltage in = 57 Volts (31 Watts delivered to each Load circuit)

In the first series of tests, 57 volts DC was applied through the outlets to the loads, which related to the maximum voltage allowed under the proposed IEEE specification. The delivered power, however, is approximately twice as much as that allowed by the specification. 10 samples each of the outlet and plug were tested for initial LLCR readings and after 750 cycles. The rate of mating and unmating was approximately 1.5 seconds. It was discovered that there was significant arcing during the mating and unmating, which caused damage to the contacts. Two samples out of 10 failed final LLCR readings. Figure #3 shows the damage caused to a nominal plug taken from the test. Pin 1 is on the right of the photograph. There is significant wear and burning of the plug contacts. The contacts that received the most damage are the ones that touch the jack's contacts first, and receive most of the arcing. Figure #4 shows the damage caused to one of the outlets that failed LLCR after 750 cycles. On this particular sample, pin 7 failed (second from left). For reference, Figures #5 and #6 show a plug and a jack respectively cycled 750 times with no power applied. Note that there is significantly less surface damage.

Another observation is that there was no evidence of damage to the plug or outlet as a result of steady state exposure to this combination of source and load. The only damage appears to have been caused by arcing that occurred during repeated mating and unmating operations.

It was also observed that there is less damage to the outlet contacts than the plug contacts. There are two possible reasons. The first is that the plug contact surface is constant and moves along the longer contact surface of the jack. The end result may be that the damage is being spread out over the length of the jack wire, whereas with the plug contact it is concentrated in a smaller area. The other reason could possibly be the hardness and material composition differences between the jack wires and the stamped plug contacts.

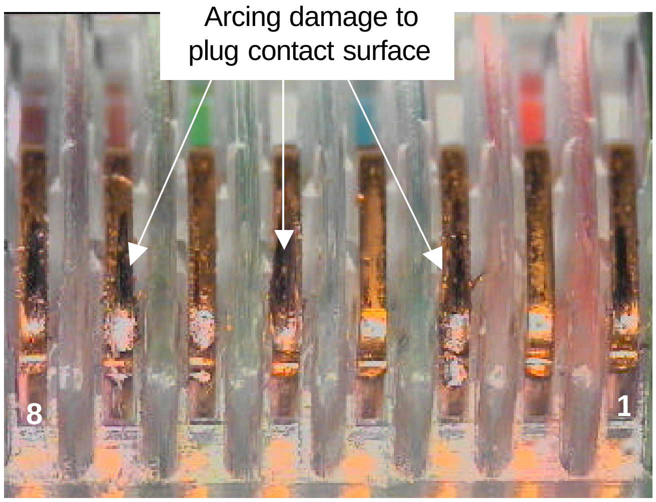

Figure #3 – Test plug after 750 cycles with 31 Watts applied

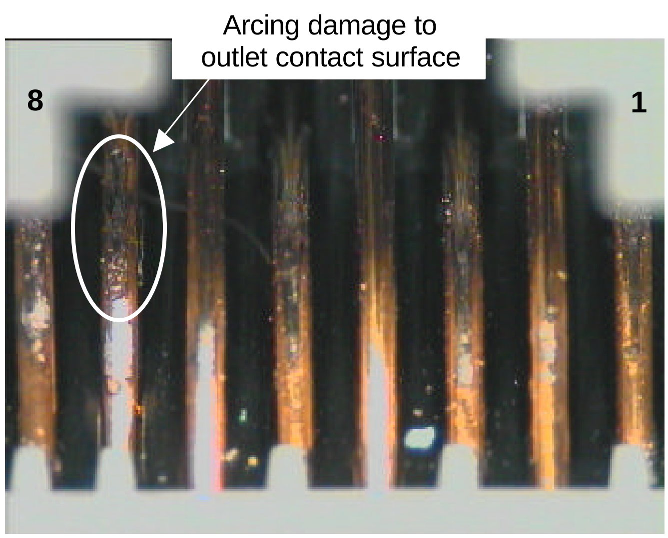

Figure #4 – Test Outlet after 750 cycles with 31 Watts applied

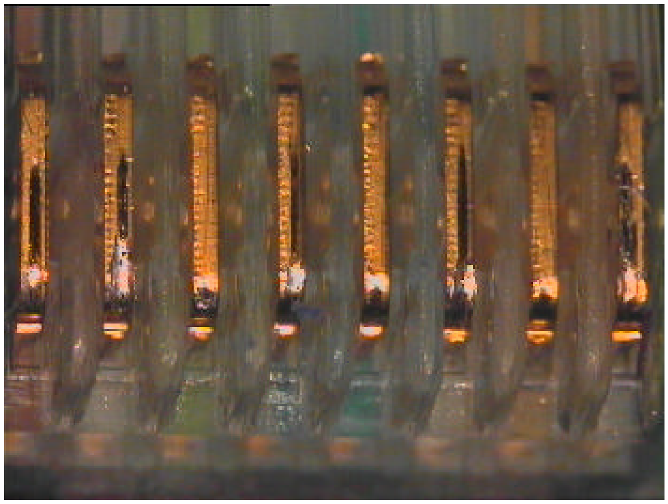

Figure #5 – Test Plug after 750 cycles with no power applied

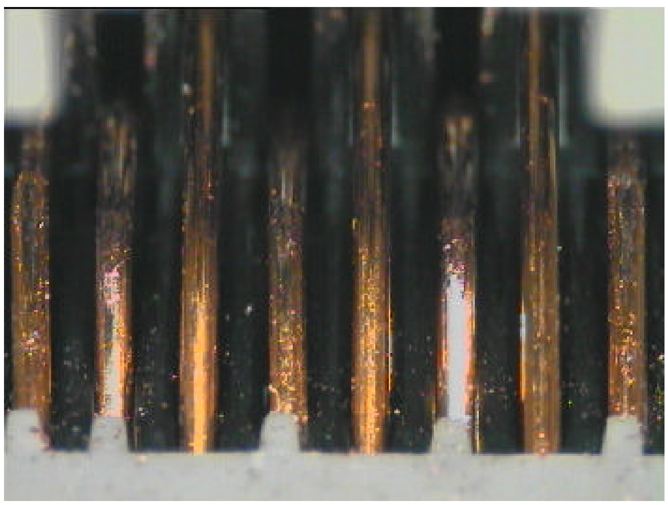

Figure #6 – Test Outlet after 750 cycles with no power applied

Test series #2 – DC Voltage in = 47 Volts (21 Watts delivered to each Load circuit)

In the second series of tests, 47 volts was applied through the outlets, which related to the nominal voltage allowed to a device under normal powering based on the proposed IEEE specification. The delivered power of 21 watts is approximately 50% more than that allowed by the specification due to selection of worst-case values for the RLC load circuit. A quantity of 10 samples each of the outlet and plug were tested for initial LLCR readings and after 750 cycles. The rate of mating and unmating was approximately 1.5 seconds. It was discovered that there was less arcing during the mating and unmating, which resulted in less damage to the contacts. No samples failed final LLCR readings. Figure #7 shows the damage caused to a nominal plug taken from the test. Note that there is significantly less damage. Pin 1 is on the right of the photograph. Figure #8 shows one of the outlets after 750 cycles with some evidence of plating wear.

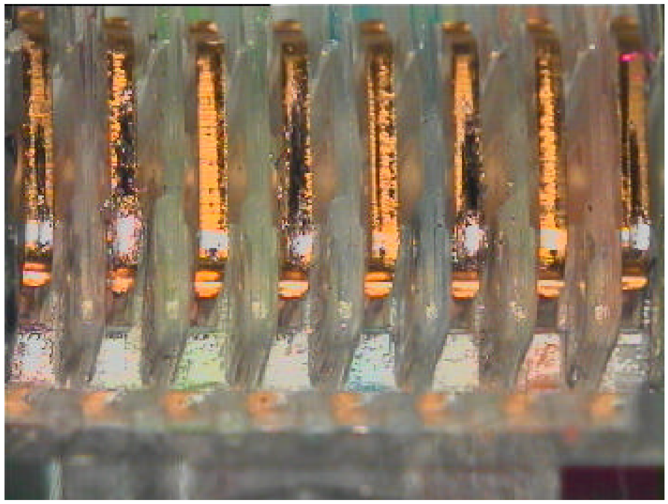

Figure #7 – Test Plug after 750 cycles with 21 Watts applied

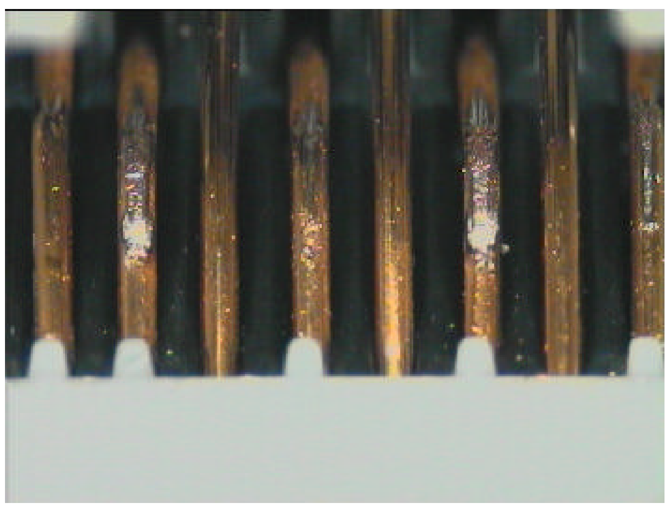

Figure #8 – Test Outlet after 750 cycles with 21 Watts applied

Test series #3 – DC Voltage in = 37 Volts (13 Watts delivered to each Load circuit)

In the third series of tests, 37 volts was applied through the outlets, which related to the minimum voltage allowed to a device under normal powering based on the proposed IEEE specification. 10 samples each of the outlet and plug were tested for initial LLCR readings and after 750 cycles. The rate of mating and unmating was approximately 1.5 seconds. It was discovered that there was less arcing during the mating and unmating, which resulted in less damage to the contacts. No samples failed final LLCR readings.

Conclusions:

1. The procedure for the application of power during cycling as shown applying 21 Watts in this document using a worst case RLC load from values taken from draft specification IEEE 802.3af can be used as a method of testing modular plug/outlet cycling reliability.
2. None of the three levels of DC Power applied to the devices (31 Watts, 21 Watts, or 13 Watts) caused any damage to the IDC contacts, internal current paths of either the plug or outlet or the wires connected to them.
3. None of the three levels of DC Power applied to the devices (31 Watts, 21 Watts, or 13 Watts) caused any damage to the outlet's printed circuit board. The samples used an FR-4 material with 17.8 µm (0.5 ounce) cladding with 0.305 mm wide traces.
4. In order to optimize the test time involved to perform the above procedure, power was applied to two sets of pair combinations simultaneously. No adverse interaction was observed between the two circuits during any of the tests performed. If necessary, this procedure could be modified to apply power to only one set of pair combinations at a time, but would require that the test be performed twice; once for each of the two specified pair combinations.
5. The test set-up used is more stringent than what a powered device would demand in a proposed 802.3af environment in two respects: First is that the maximum power a device is allowed to deliver under the proposed specification is 15 Watts. The test that yielded acceptable LLCR performance used 21 Watts. The second is that due to proposed detection scheme, a device would never be connected with power on. A device would only have power applied to it after the successful detection of a device that requires power. Such a device would only be disconnected with power applied.

Recommendations:

1. Adopt a requirement for mating and unmating under load to qualify connector performance for existing and future applications such as 802.3af and building automation systems. IEC 60603-7 series drafts address this need with a specified maximum change in LLCR of 20 mohms for any test circuit after the specified number of mating and unmating cycles. No change recommended to the pass/fail criteria.

2. The test circuit should contain resistive, capacitive and inductive elements that represent worst-case load conditions as specified in 802.3af. Existing 60603-7 series drafts specify that the test circuit be comprised of a resistive load only based on supply voltage of 56V and current of 0,175A (i.e., a 320 ohm load). The test circuit should be revised to include inductive and capacitive elements as shown in figure one.

3. The July 2001 draft of 802.3af specifies power at the input of the powered device (PD) of 12.95W. Power sourcing equipment (PSE) output is specified at 15W. In order to accommodate this and other applications for power delivery, it is recommended that the connector qualification for mating and unmating under load be above 15W. A qualification test with power dissipation of 21 watts provides a margin of 40% over the 15W value. Existing 60603-7 series drafts specify conditions for 10W dissipation over a resistive load. The resistive load (320 ohms) or supply voltage (56 volts) should be adjusted to dissipate 21W at the load.

4. Although the draft 802.3af specification does not deliver power during connector mating it is recommended that the qualification test be applied for both mating and unmating in anticipation of applications that do not have intelligent sensing circuitry to activate power delivery after connection.

5. Although 802.3af specifies power delivery over two pairs with the option to use pairs 36/12 or 45/78, it is recommended that the qualification test be performed with two load circuits in parallel, such that all pairs are conducting current. This qualification allows for connection schemes and applications that may require delivery of more than one power circuit, or more than 21 watts, to a single TO.

Ongoing Research:

1. It may be valuable to repeat the above procedure using screened products to determine how a shielded product construction behaves under the same conditions.
2. The method could possible by modified so that during cycling power is only present during the unmating part of each cycle. The speculation is that this will cause less damage to the outlet and plug contacts.
3. Mixed flowing gas after 50% of the mating cycles is part of the standard 60603-7 series of tests. This testing should also be conducted to verify that the samples would still pass when power is added to the cycling test.
4. Since the plug seems to be affected most by the cycling, it needs to be determined if a new plug can be used for the LLCR tests after cycling.

Acknowledgements:

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