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1. Introduction

The installation and user benefits provided by being able to power products such as telephones via a LAN are significant and will be important to the successful deployment of these new products. While obvious for products such as telephones, the same benefits are applicable to many products. The range of products that could be supported will only be limited by the maximum power that can be provided. For example, a laptop could be powered via the LAN or a desktop PC could be held up by a centrally located UPS.

With the intent of enfranchising the widest range of products, this contribution focuses on the DC characteristics including safety, foreseeable misuse and power management issues that will allow a wide range of power to be provided via the LAN wiring. The contribution assumes that power could be provided via a single pair of wire or via a phantom powering configuration that would use two or more pairs of wire.

It is also assumed that power could be provided to or from devices such as servers, hubs or routers. For example, a recognized need in IP telephony applications is to power a remotely located hub or switch which could in turn power the telephones connected to it. A conclusion based on this example is that the need to support a wide range of power levels and the ability to power at least one level of intermediate device will be key to the successful mass deployment of products such as LAN based point of sale terminals and telephone systems which will consist of large numbers of terminals. To be economically viable, support for a wide power range and the powering of intermediate devices must not place any economic burdens on the low power systems that will make up the majority of the market.

2. DC Capabilities of Existing LAN Components

To be practical, any methodology used to deliver power via LAN wiring should be compatible with the wiring and connector systems that are in place today. In the sections that follow, the system components are considered in terms of any limitation that they may place on the power that can be delivered to a particular LAN device.

2.1. Wiring

The most common wire used today is 24 AWG Category 3 and 5 cable but some 26 AWG cable is still in use. Based on a maximum length of 100 meters the DC characteristics are;

For 24 AWG and 26 AWG wire the resistance ranges from 8 to 9 ohms or 12 to 14 ohms per 100 meters respectively. The highest resistance is for solid wire, which is also the most commonly used type for the longest sections of a given run. Assuming that 26 AWG wire must be supported, a loop resistance of 18 ohms per 100 meters should be used as a worst case.

- For single conductor, the rated current carrying capacity is 4 and 6 amperes for 26 and 24 AWG wire respectively. While this may seem high, it must be derated significantly to limit the temperature rise when used in bundles. When you consider that bundles of a 100 or more 4 pair cables are common in LAN wiring the derating factor will reduce the practical current to less than 1 A. For example, a bundle of 100 category 5 cables (24 AWG) that supplies 1.5 amps to a device connected to each cable via a phantom powering scheme that uses 4 conductors (0.75 A each), will have in internal temperature rise of 20°C. This temperature rise would place a realistic current limit on most installations.

- Older wiring used in data networks was designed to be used with analog telephone systems and had to carry DC voltages of up to 105 volts with superimposed ring voltages of 90 volts RMS and was rated at 150 volts. Newer wiring is more commonly rated at 350 volts or better.

2.2. Connectors

Specifications for the eight position modular plugs and jacks used in LANs vary widely but even the lower ratings will provide good DC performance.

- Current carrying capacity ratings typically range from 1 to 2.5 amps. Some manufacturers also derate this capacity to as little as 0.2 A as a function of temperature or total current carried by all the contacts in the connector. Assuming an ambient temperature of 50° C, a practical upper limit is 0.75 A per contact.

- Modular connectors were originally designed to withstand the high voltages produced by ringing generators as well as the 1,000 to 1,500 volt lightning surges so in spite of their small size, will handle high voltages. The eight position modular plugs and jacks used for data networks inherited this construction and have regulatory agency ratings of 150 volts.

2.3. Power Limit Imposed by Existing LAN Components

If the wiring system limitations above are considered, the power that can be delivered to a device on a LAN is considerable. This is shown in the table below.

Parameter	**Phantom Power (2 pair)**		**Dedicated Single Pair**	
Conductor Size	24 AWG	26 AWG	24 AWG	26 AWG
Supply Voltage	150 Volts	150 Volts	150Volts	150Volts
Supply Current	1.5 A	1.2 A	1 A	0.8 A
Supply Power (Max)	225 W	180 W	150 W	120 W
Cable Resistance	9 Ω	14.3 Ω	18 Ω	28.5 Ω
Voltage Drop	13.5 V	17.2 V	18 V	22.8 V
Cable Loss	20 W	20 W	18 W	18 W
Load Power (Max)	**205 W**	**160 W**	**132 W**	**102 W**

Table 1 Power Limits and Dissipation for Common LAN Wiring Systems

Please note that the maximum current used in Table 1 is based on temperature rise rather than connector current ratings. While it is unlikely that all the cables in a bundle would be fully loaded, it is possible, so the limitation has been used in this example.

2.4. Safety Considerations

Safety agencies are most concerned about minimizing the risks to users, installer etc, from product hazards. These include electric shock and energy hazards, thermal hazards, and fire hazards. While requirements may vary from country to country, IEC950 and the national variants of it are internationally accepted. For this reason, IEC 950 has been used to establish the limits used for this contribution.

In IEC 950, the requirements for the protection against electric shock are based on the circuit configuration (grounded, ungrounded, level of pollution) and the operating voltage. While all of the voltages used to power network devices can all be considered hazardous, the requirements for systems operating at less than 60 volts DC and that conform to the requirements for SELV circuits are considerably less stringent than those operating above 60 Volts.

For operating voltages of less than 60 volts that are well isolated (double or reinforced primary insulation) from the mains, only operational insulation, (no insulation in some cases) is required between the SELV supply voltage and the user. Suitable insulation is likely to exist in most LAN interfaces today.

For an ungrounded device operating above 60 volts, the insulation system used to provide protection for the user must be double or reinforced. While double or reinforced insulation can be provided by the housing for simple devices and is easily provided with modern wiring products such as double insulated wire, factors such as transformer size will be affected. As such, there will be an additional cost involved for products that operate for supplies that are higher than 60 volts. To ensure that these factors do not place a burden on low voltage products, it will be desirable to have at least two classes of power systems. The most common would be a lower power system that would be based on a maximum of input 60 volts and a special purpose higher power scheme based on supply voltages over 60 volts but under the 150 volt limit set by the connectors.

2.5. Foreseeable Misuse

In addition to the mandated safety requirements, there are a lot of common sense factors that should be considered. These can be safety related or simply an annoyance. Some examples include:

Eight position modular connectors are small enough to be easily placed in a child's mouth. As LAN appliances proliferate and powering via the LAN becomes more common this will happen. Even though there are no mandated requirements to prevent this and studies have shown that the resulting shock is not likely to be lethal due to the close spacing of the pins relative to any other return path, the voltages and currents involved will cause serious burns. A prudent design would therefore try to devise a way to reduce the likelihood of such an incident. One way to fulfill this objective is to ensure that power is not supplied to circuits that are not connected to a device that can be recognized by the power source.

While originally intended for use in telecom systems, eight position modular connectors are not special use connectors. Unlike mains plugs that should only be used in a recognized manner, eight position modular connectors are used in a variety of applications including telephony products, LAN connections, barcode scanners and keyboards. While there is a possibility that a hazard (shock or fire) could be created by the accidental misuse of any combination of these devices on a powered LAN connection, it is more likely that the result would be damage to the device or power source. Neither is desirable so the LAN power system should be designed to minimize damage caused to other products including LAN interfaces with terminations that can be destroyed by even a moderate power source. Once again, this objective can be satisfied if power is not supplied to circuits that are not connected to a device that can be recognized by the power source.

Offices often have several LAN connections in a single wall plate. It is therefore foreseeable that two powered LAN connections will be interconnected with either LAN cable or some other type of cable with an unknown connection scheme. This should not cause damage to the system.

It is foreseeable that devices intended to be powered from a supply located somewhere on the LAN could be plugged into 8 position modular jacks intended for non-LAN devices. These could include powered ISDN jacks or basic analog telephone circuits which commonly use 8 position connectors when 2 to 4 lines (RJ-13 ?) are terminated on a single connector. While it is unlikely that the LAN device would damage any of the power sources, these power sources may present voltages as high as 200 volts peak with output currents as high as 0.5 A and could damage the LAN device. To minimize potential damage, the LAN device must be polarity and over voltage protected. It would also be desirable for the LAN device not to power up unless it can determine that it is connected to a recognized power source. This would also allow the device to indicate to the user that it is powered and has a valid LAN connection.

3. Power Source/Sink Objectives and Characteristics

3.1. Easy Migration to LAN Powered Devices

To allow an easy migration to LAN powered devices, the proposed Source and Sink characteristics have been designed to limit the changes to the circuitry needed to support the addition of power to the LAN. Changes to existing MACs or PHYs have not been proposed to avoid making the wide range of existing parts obsolete. This is particularly important for new devices such as those for LAN telephones that are available now or in the near future that have single or dual embedded network interfaces.

An important factor in the migration to LAN powered devices is the ability to support higher powered or intermediate devices without placing a cost burden on the multitude of low power devices that will exist. This can be done by providing high and low power categories and a means of ensuring interoperability is provided. This contribution proposes three categories and a means of ensuring that only valid combinations of Sources and Sinks will inter-operate. Initially the three categories can be managed by the power Sources and Sinks themselves but migration to more intelligent management can be supported in the future

3.2. Maximize the power range.

In Table 1, the thermal limits of large bundles of cables limited the power that can be delivered to a device connected to a LAN were described. These maximums ranged from 102 W to 205 W and were dependent on the powering configuration and wire gauge. To simplify the safety requirements for lower power, cost sensitive devices, this has been divided into a low voltage and high voltage category. Based on the maximum 60 volt limit for SELV circuitry the low voltage source category must have an upper limit of 60 volts. It is proposed that the nominal voltage therefore be set at 55 ± 5 volts. Allowing reasonable tolerances, the proposed high voltage category source voltage is 135 ± 15 volts. To ensure that the temperature rise for #26 AWG wire is reasonable a maximum load current of 1.2 A or 0.6 A per conductor has been assumed. This limits the Source Power to 66 W for the low voltage category and 162 W for the High Voltage category. Assuming that the cable can be 26 AWG, the maximum power that will be delivered and therefore the limit to be consumed by the Sink device is 45 W for the Low Voltage category devices and 141 W for the High Voltage category. This is summarized in the table that follows.

Parameter	**Phantom Power (2 pair) Low Voltage**		**Phantom Power (2 pair) High Voltage**	
Conductor Size	24 AWG	26 AWG	24 AWG	26 AWG
Supply Voltage	55 Volts	55 Volts	135 Volts	135 Volts
Supply Current	1.2 A	1.2 A	1.2 A	1.2 A
Supply Power	66 W	66 W	162 W	162 W
Cable Resistance	9 Ω	14.3 Ω	9 Ω	14.3 Ω
Voltage Drop	10.8 V	17 V	10.8 V	17 V
Cable Loss (100 M)	13 W	20.6 W	13 W	20.6 W
Load Power (Max)	**53 W**	**45 W**	**149 W**	**141 W**

Table 2 Practical LAN Power Capabilities

For many devices, the power that can be delivered and what is actually required will be very different. Many devices, such as telephones will only require power levels below 5 watts so the Source should not always be required to support higher power levels. To recognize this, a Low Power, Low Voltage category is proposed. The characteristics of the three categories proposed are:

Characteristic	**Category**		
	1	**2**	**3**
Source Voltage	55 V	55 V	135 V
Source Power (max)	5.1W	66 W	162 W
Cable Loss (100 M)	0.12 W	20.6 W	20.6 W
Sink Power (max)	5 W	45 W	141W

Table 3 Proposed Source and Sink Power Categories

3.3. Power Management Considerations

When considering a power management methodology a wide range of requirements including design practicality and cost must be evaluated. Some of the factors that were considered for the power management scheme proposed were:

a) For safety and reliability reasons, power should only be provided when the Source has determined that a valid Sink has been connected. Due to the unknown characteristics of the wide variety of products that use 8 position modular connectors, this can only be done by looking for a unique Sink signature.

b) For reliability reasons, It is desirable that the Sink only accepts power when it is connected to a recognized Source. This can be done by requiring the Sink to only respond to a recognized power up sequence.

c) It should not be assumed that all devices will be able to support management protocols. This complicates the administration of any product such as LAN telephones and adds a cost burden that may be unacceptable on low cost (under $30) devices.

d) Higher power devices should be supported without any burden being placed on the more common low power devices.

e) Power may be inserted and removed by devices that are separate from the network interface. As such the power management methodology should be independent from the MAC or PHY. This is also important because it avoids making the wide range of low cost LAN silicon in use now obsolete for powered devices. It is also important because it provides the ability to move the burden that high currents will place on LAN isolating transformers to external devices that are only provided when more power is required. This is most applicable to applications where the power provided by the LAN wiring exceeds 5 watts.

f) LAN connections are isolated so it is expected that Sinks and Sources will also have to be isolated. As a practical design consideration the basic Sink and Source management should be located on the cable side of the connection so that the need to provide more costly isolated control lines for these devices can be avoided.

g) LAN power Sources will be provided as primary power and as backup power to devices that may be locally powered. When a Source is used for backup power, its removal and application must be able to be accomplished while the device is operating and should not impair normal operation.

h) It should be assumed that some ports could be a Source or a Sink and that the functional determination could be automatic.

i) A power management methodology should not require system intelligence nor should it preclude its use.

j) Continuous operation of a power management system should not be dependent on the device operating system. For example, a reset or reboot should not affect normal operation of the power management system unless this is a specifically intended interaction.

k) The 8 position modular connectors were designed primarily for low current applications and some designs may not tolerate the high inrush current currents that can be caused when capacitor is charged from a voltage source. The power management system should ensure that these inrush current do not occur.

3.4. Outline of a Proposed Power Management Methodology

Adding the three power categories proposed in Table 3, places even more requirements on the power management system. For example, a device with a type 1 Sink could be powered from a type 1 or 2 Source. If designed with an adequate input voltage and insulation system, it could also be powered from a type 3 Source. A type 2 device could be powered from a type 2 Source or if designed with an adequate input voltage and insulation system from a type 3 Source. A type 2 device cannot be used with a type one Source because it requires more power than the Source may be able to provide. Due to the high power requirement for a type 3 device, it can only be powered from a type 3 source. In the future, an intelligent power management methodology could be used to allow a device to power up as a type 1 or 2 device and then request and confirm that a specific power be allocated to it before switching to a high power category.

This contribution proposes the use of a DC signature to identify the Sink type and the Sink may use the specific power up sequence characteristics of the Source to determine if it should draw power. While this may seem complex, these functions can be performed with simple Source and Sink circuitry that doesn't require changes to the existing integrated circuits used in most LAN circuitry. An intelligent system based management is also not required but the use of such systems is not precluded. In the case of the Sink, the power management function is envisioned as a functionality that could be added to the switching regulator that will be used to pass power over the isolation barrier required in most products.

As proposed, the signature for a Sink circuit consists of three parts. At low voltages (less than 5 volts) the Sink must present a high resistance (greater than 10K) to the Source. During a transitional phase from low voltage to operating voltage it must preset a constant current load or pilot current that is used to identify the type 1 or 2 category of the Sink. A voltage clamp in type 1 and 2 Sinks is used to separate them from type 3 Sinks. This clamp is also required to ensure that the SELV circuit characteristics of type 1 and 2 devices cannot be exceeded in the event of a single fault. The fault could be the result of a failure in a type 3 Source.

The low voltage characteristic of the Sink is provided to allow the source to detect devices such as termination resistors that could be damaged by the Source. The pilot current is used to detect other types of power sinks such as power supplies or surge protectors that may exist in non-LAN devices.

To detect the signature of the Sink, the Source and Sink go through a specific power up sequence. The basic sequence includes the following steps;

With no current flowing from the Source, it reverts to a 6 volt (the actual voltages current used could vary from those used in the example) with the output current limited to 2 mA at 3 volts or higher and but decreases to 0.5 mA at 0 volts. When a 1 mA pilot current is detected by the Source, the output voltage starts a transition to the operating voltage. During this transition, the pilot current must remain within a valid range. If the pilot current goes outside the valid range the output is reset to the 3 volts. It remains there until the load current is removed. If the pilot current remains within the valid range the Source output rises to the normal output voltage and the current limit is increased to the normal running current that the source is capable of providing. The Source is now in full power mode and will remain there until the load current falls below the pilot current or exceeds the maximum output current for more than a few hundred milliseconds. If this happens the Source resets and starts the initialization sequence again.

A Sink starts to power up when a voltage is applied by the source but remains in the low pilot current state for a few hundred milliseconds after the nominal operating voltage is reached. It then switches run state and latches. It will stay in the run state as long as the operating voltage remains in the valid range. If the input voltage drops below the minimum for more than a few hundred milliseconds, the Sink will reset and reapply the pilot current until the operating voltage returns to normal.

If it is desirable to have the Sink only draw power from a recognized Source, the slew rate of the transitional phase used to measure the pilot current can be define by the standard and used as a Source signature.

A type 2 device is distinguished from a type 1 device by the pilot current. The type 2 Sink has a higher pilot current and will cause the transitional Current limit of a type 1 Source to be exceeded. When this happens, the Source will reset to the low voltage state. However, the lower pilot current of a type 1 device will allow it to operate from a type 1 or 2 Source. To comply with the requirements for an SELV circuit, a Sink must be able to maintain the SELV voltage limits at all times. This includes conditions where a single fault has occurred. One way of doing this is by providing a voltage clamp (such as a zener or thyristor protection device) at the input of a type 1 or 2 device that does not have an adequate insulation system to qualify as a type 3 Sink. While provided as part of the basic safety system, this clamp limits the transition voltage (causes the pilot current to be exceeded) which causes a type 3 source to reset to the low voltage state if an incompatible type 1 or 2 device is connected.

While not suggested as a requirement, a single connection can be designed to act as a Source or as a Sink. When a device is powered via the mains connection, the port functions as a Source. When mains power is not available, the port acts as a Sink and may draw power from a unit that has central battery backup. If both devices are mains powered, the ports both function as Sources and will remain that way until one port starts to draw pilot current

While basic, this power management methodology will facilitate the use of different power category Sink and Source devices without placing a cost burden on the low power devices while allowing applications that do need considerably more than 5 or 6 watts to obtain it via a compatible powering system.