As lighting technology has changed, the use of multi-circuit extensions needs to be updated too

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SINCE THEIR INTRODUCTION in the early 1990s, multi-circuit extensions have become a common component of many lighting systems. The lighting extension design places a sufficient number of cables within a common jacket to conduct six circuits of power. In so doing, the multi-circuit extension saves clutter, weight, and money over the alternative: six individual cables of 12/3 (a quantity of three 12 AWG [American Wire Gauge] conductors within a common jacket). From the outset, the industry recognized the inherent conveniences of the multi-circuit extension and its use has gained widespread acceptance.

Multi-circuit extensions

Multi-circuit extensions, often referred to as "Socapex cables" or "Socas" in recognition of a brand name owned by Amphenol Socapex (www.socapex.com), are electrical extensions used in the location, studio, and theatre markets. Nineteen-pin plugs and sockets are joined by a multi-conductor cable of varied lengths. They consist of a multi-cable terminated by a plug (male) with pins and a connector (female) with sockets. When used for entertainment lighting, the individual conductors of the multi-cable are grouped in quantities of 14 or 18 within a common jacket. This jacket may be either a thermoplastic (e.g. TPR) or thermoset (e.g. SOOW) type.

Within the commonly used 19-contact devices that terminate the cable, six pins/sockets are designated as hot conductors, six pins/sockets are designated as neutrals, and six pins/sockets are designated as grounds. (See **Figures 1** through **3** and **Figure 4** for pinout assignments.) Pin/socket 19 is a spare.

In the case of an 18-conductor cable, the 18 pins of the plug (male) device are wired directly to the 18 sockets of the connector (female). When a 14-conductor cable is used, the hots and neutrals are wired directly between the plug and connector using the first 12 conductors. The grounds within the plug and connector are tied together with a ring and the remaining conductors are used to connect them.

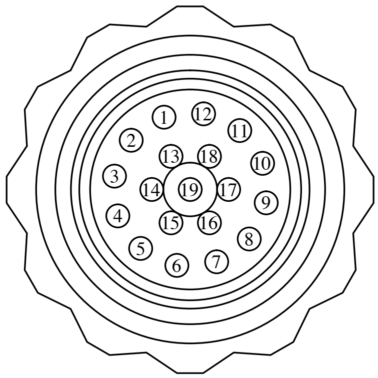

Figure 1 – Plug (male)

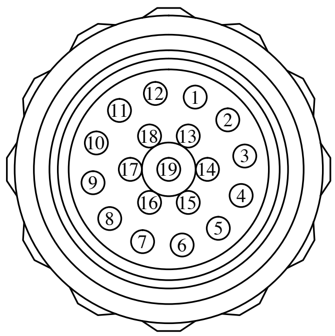

Figure 2 – Connector (female)

Figure 3 – Multi-circuit Extension

WIRING CHART	
CONTACT PIN	CIRCUIT
1	HOT 1
2	NEUTRAL 1
3	HOT 2
4	NEUTRAL 2
5	HOT 3
6	NEUTRAL 3
7	HOT 4
8	NEUTRAL 4
9	HOT 5
10	NEUTRAL 5
11	HOT 6
12	NEUTRAL 6
13 – 18	GROUND
19	NO CONTACT

Figure 4 – Multi-circuit extension pinout

FIGURES 1 – 4 COURTESY OF LES PRODUCTS

Multi-circuit extension rating

Loading a cable past its rating is an unsafe practice. During a system setup and testing, an overloaded cable will support loads in excess of its rating for some period of time. However, the length of time it will continue to do so cannot be calculated, so its failure may happen during the middle of show, perhaps at the worst possible time.

Pulling more amperage than a cable can support will eventually result in a failure; a good understanding of that cable's capacity is crucial to successful operation. It was in the interest of safe cable usage that the National Fire Protection Association created and maintains *NFPA 70, National Electrical Code.* The NFPA has published a series of tables in the *NEC* that show the safe usage ratings for electrical devices. Table 400.5(A)(1) of the NEC shows the following rating for 12 AWG (4.0 mm^2) cable, the most common conductor size used within multi-conductor cable for lighting purposes (see below).

Column A is the most commonly referenced segment of this table so "everyone knows" that 12 AWG wires are rated to 20 A.

Using this information, we can calculate the results if a multi-circuit extension were loaded to this rating, using the "West Virginia" formula: W = V x A (watts equals volts times amperes).

The maximum wattage on a single circuit would be:

- W = 120 VAC x 20 A
  - 120 VAC is considered the voltage standard for alternating current North America
  - 20 Amps is the rating of 12AWG cable from Table 400.5(A)(1)
- W = 2400 Watts

Therefore, a multi-circuit extension may be loaded with (24) 575W luminaires:

- (4) 575 W luminaires = 2,300 Watts/circuit
- (4) luminaires per circuit times (6) circuits = (24) 575 W luminaires

However, this kind of loading is not possible in practical application.

Multi-circuit extension rating – continued

Copper is the most commonly used material in the manufacture of cabling. It is a readily available material and easily worked into the forms needed for power distribution. However, while it is an excellent conductor, it is not perfect and will always present some resistance to the flow of electricity. This resistance results in the generation of heat that has the potential to damage the copper, the insulation material, or both over time. The *NEC* seeks to ensure that cables

Copper Conductor Size (AWG)	Thermoplastic Types TPT, TST	Thermoset Types C, E, EO, PD, S, SJ, SJO, SJOW, SJOO, SJOOW, SO, SOW, SOO, SOOW, SP-1, SP-2, SP-3, SRD, SV, SVO, SVOO, NISP-1, NISP-2 / Thermoplastic Types ETP, ETT, NISPE-1, NISPE-2, NISPT-1, NISPT-2, SE, SEW, SEO, SEOO, SEOW, SEOOW, SJE, SJEW, SJEO, SJEOO, SJEOW, SJEOOW, SJT, SJTW, SJTO, SJTOW, SJTOO, SJTOOW, SPE-1, SPE-2, SPE-3, SPT-1, SPT-1W, SPT-2, SPT-2W, SPT-3, ST, STW, SRDE, SRDT, STO, STOW, STOO, STOOW, SVE, SVEO, SVEOO, SVT, SVTO, SVTOO		Types HPD, HPN, HSJ, HSJO, HSJOW, HSJOO, HSJOOW
		Column A[a]	Column B[b]	
27[c]	0.5	—	—	—
20	—	5[d]	[e]	—
18	—	7	10	10
17	—	9	12	13
16	—	10	13	15
15	—	12	16	17
14	—	15	18	20
13	—	17	21	—
12	—	20	25	30
11	—	23	27	—
10	—	25	30	35
9	—	29	34	—
8	—	35	40	—
7	—	40	47	—
6	—	45	55	—
5	—	52	62	—
4	—	60	70	—
3	—	70	82	—
2	—	80	95	—

Table 400.5(A)(1) Allowable Ampacity for Flexible Cords and Cables Based on Ambient Temperature of 30° C (86° F)
(*NFPA 70 - National Electrical Code – 2017 Edition* by the National Fire Protection Association, page 70 – 248)
(+ The allowable currents under subheading A apply to 3-conductor cords and other multi-conductor cords connected to utilization equipment so that only three conductors are current-carrying.)

Number of Conductors	Percent of Value in Table 400.5(A)(1) and Table 400.5(A)(2)
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

Table 400.5(A)(3) Adjustment Factors for More Than Three Current-Carrying Conductors in a Flexible Cord or Cable (*NFPA 70 - National Electrical Code – 2017 Edition* by the National Fire Protection Association, page 70 – 249)

are used within their safe ampacity range.

In single circuit cables, airflow around the outer jacket allows the heat generated by this resistance to dissipate. With multi-conductor cable having so many current-carrying wires encapsulated within a single jacket, the opportunity for heat to radiate is reduced. This must be factored into load calculations.

Since a multi-cable has 12 current-carrying conductors (six hots and six neutrals), Table 400.5(A)(3) states the cable is only capable of supporting 50% of the rating shown on Table 400.5(A)(1). Therefore each of the six circuits in a multi-circuit extension is only capable of supporting 10 A or 1,200 W per circuit.

Yet, "everyone knows" that 12 AWG conductors are rated to 20 A. While it is true that as a manufacturer, Lex Products has repaired examples of overloaded cables, these examples are not numerous and rarely resulted in catastrophic failure. If cables are being loaded in excess of the table-rated capacity based on a misunderstanding, why is there not an epidemic of overheating failures?

Diversity of Load

While the sum of individual loads (e.g. lighting luminaires) will exceed the total rating, Diversity of Load (DOL) assumes all the loads are not operating simultaneously or are operating at less that their maximum rating. The Diversity Factor is a measure of probability that a particular system component will be drawing power at the same time as another component.

In the early days of multi-circuit extension service, loads were luminaires using incandescent lamps. Multi-circuit extensions loaded well past their actual rating were able to continue to support the lighting since all 24 luminaires being on at full at the same time was a rarity and, even should it occur, was not for a sustained period of time. By taking advantage of the diversity of loads through the variety of lighting levels across the six circuits, overloads were avoided.

Changing loads, changing demands

With advances of lighting technology over the last few years, a single LED or moving light source is able to provide colors and effects that once required numerous incandescent luminaires. There is an understandable inclination towards getting the most "bang for your buck." This is true not only with luminaires but also the power distribution system supporting them.

As lighting technology has changed, so too has the purpose of the multi-circuit extension. In the beginning, multi-circuit extensions were part of controlling an incandescent luminaire's output through varying the flow of power. LEDs and moving lights, on the other hand, require constant power, and while far more efficient than their incandescent predecessors, the manner in which LEDs and moving lights consume power has become a growing concern with multi-circuit extensions.

Now in much the same way that DOL would be used for incandescent luminaires, the inclination would be to assume the same for modern luminaires. Since the assumption is that all the luminaires would not be on at the same time, diversity of load would apply, wouldn't it?

While LEDs and moving lights may be "off," unlike incandescent luminaires they continue to draw power to maintain their control electronics and lamps. This background power draw must be taken into consideration when doing load calculations.

Loading a cable past its rating is an unsafe practice.

In light of these changing demands and changing dynamics, what is needed is an understating of how multi-circuit extensions are used in the field and create a standard for their safe and practical use.

Regulation and listing

The safe use of cabling is in the best interest of everyone, from the manufacturer to the consumer. It is no coincidence that the ampacity ratings outlined in the above tables were drawn from the *National Electrical Code (NEC)* written by the National **Fire Prevention** Association. While not codified into federal law, the *NEC* has been adopted by states and municipalities in an effort to standardize the enforcement of safe electrical practices ("Adoption of the National Electrical Code," NEMA.org). A Nationally Recognized Testing Laboratory, or NRTL, is responsible for creating the conditions of proper operation for a device that is seeking a certification mark. Provided the consumer uses the listed product within the associated guidelines, the consumer may be assured that the product will operate properly.

Buyers desire assurances that they are making good choices in their product selection. Manufacturers want to assure their customers that their goods meet a level of functionality that the customer expects. By working with an NRTL, manufacturers are able to place a stamp on their products that indicate the consumer has purchased a product that is compliant with industry-established standards. Examples of NRTLs include Underwriters Laboratories (UL) and Electrical Testing Labs (ETL), some the oldest NRTLs in North America. The marks, "listings," passed on by these NRTLs demonstrate a product's compliance with the requirements of widely accepted product safety standards, as determined through independent testing. At the same time, the NRTL will create guidelines for the safe usage of the listed product.

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The case of the multi-circuit extension presents a unique challenge for NRTLs. This is the result of a number of factors:

- Calculating the application of diversity of load apply in a current entertainment setting.
- When dealing with the constantly changing sine wave of alternating current power it is difficult to simulate diversity of load.
- Plugging diverse loads into a common circuit leaves no way of determining if each device will share a common demand at the same time.
- Without a means of establishing a controlled diversity of load scenario, NRTLs are unable to create a standard to test against.

Prior to creating a listing, an NRTL requires guidelines on how a product is to be used. Once they have been established, identifiable and repeatable tests are used to determine if a submitted product meets those guidelines. The resulting listing assures a level of product performance provided it is used in the proper manner.

Creating benchmark guidelines that are practical and useful to the industry is a crucial first-step in creating a "level playing field" for manufacturer and consumer alike. This is especially important in the case of multi-circuit extensions in the entertainment industry where no applicable standards exist. Creating guidelines establish the proper expectations of and from a multi-circuit extension for service life and safe usage. It is these very guidelines that have eluded the entertainment industry since the product's introduction.

Setting the expectation

The Entertainment Services and Technology Association (ESTA)'s members support increasing safety through the development of standards and certifications. One of the many working groups within ESTA's Technical Standards Program is the Electrical Power Working Group. The EPWG does not perform tests or create listings, but they create technical standards against which NRTLs may test products for acceptable operation. One effort currently underway within the EPWG is the creation of a technical standard for multi-circuit extensions.

By taking up the issue of creating a multi-circuit extension standard, the EPWG must weigh a number of factors:

- The ongoing change in demands of multi-circuit extensions
- The changes that will occur in the expectation of these cables
- The physical limitations of copper cable and safe usage
- The industry expectation of multi-circuit extensions

It is likely that the resulting standards will require a change in the way the industry thinks of the multi-circuit extension. The current design cannot support six circuits of continuous 20 A power at 120 VAC or 208 VAC. But if the demand is for a cable capable of supporting six circuits of this much power, design concessions will need to be made. What form might these concessions take?

- Change the voltage?
  - By increasing the voltage rating of the cable, to 600 VAC for instance, amperage drops and the cable may be safely used for larger wattages
  - However, this requires finding 600 VAC power sources and devices that use the higher voltage
  - This concession may be difficult to accept owing to the current North American power gird and luminaire availability
- Increase the cable size
  - By increasing the conductor diameter, this increases the amperage rating
  - The *NEC* tables does not tell you what cable to use, only its capacity at a given size in a given situation
  - This concession increases weight and expense
- Change the connector
  - The current design of the 19-pin device is a gating consideration
  - Increasing the pin/socket dimensions
  - This concession would render previous 19-pin devices unusable

As with any attempt at creating a new standard, the EPWG must balance numerous issues in creating a standard that is acceptable to manufacturer and consumer alike. At the forefront of any guideline effort is creating one that is both practical and safe.

The challenges are numerous. Take the issue of voltage. If the voltage coming into the building and the voltage accepted by the luminaire is locked in, what kind of change can the EPWG make? As lighting schedules increase in luminaire complexity and quantity, the demand on power distribution also increases. Multi-circuit extensions remain one of the most convenient means of addressing those needs. Establishing a standard is only the first step in creating a safe working environment. The EPWG must then approach the NRTLs and establish a practical rating and listing for these cables. Once those standards are in place, they must be accepted and put into practice at all levels.

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A NRTL-listed multi-circuit extension standard at a practical voltage rating is long overdue. Manufacturers and users alike desire a series of guidelines for the proper and safe use of these cables. The final results of those diligently working on this issue cannot come soon enough.

But no guideline, no standard, no listing is useful unless they are put into practice. The real work will begin once the standards have been created. Diligent promotion and education will be required in order to make all these efforts worthwhile.

"Everyone knows" that. ■

As a leading North American manufacturer of power distribution solutions for demanding markets, including entertainment, Lex Products has been in a unique position to observe the growing use of multi-circuit extensions. Founded in 1989, the company specializes in the production of products designed to withstand the rough use and harsh environments where these devices are used. Headquartered in Connecticut, the company also has offices in California, Florida, and Scotland.

John Valus Jr. is the Custom Products Engineer and one of the main Product Development Engineers at Lex Products. He designs power distribution and control equipment for the entertainment and industrial market. John is one of the main engineers behind PCS Trio Touring and Lex's new PowerData Cable. He has a BS in Electrical Engineering with a robotics option from Rochester Institute of Technology. He is also an Eagle Scout with 4 Palms.

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References:

Amphenol SOCAPEX, www.socapex.com

NFPA 70 - National Electrical Code – 2017 Edition by the National Fire Protection Association, page 70-249

"Adoption of the National Electrical Code," NEMA.org

"Welcome to ESTA," http://esta.org/