

Designing More Reliable 24VDC Systems

Redundancy, Buffer Modules, DC-UPSs & DC/DC Converters

Application Techniques

Control systems are becoming more complex and sensitive. In many cases, 24VDC power supply resulting in loss of data, loss of machine, loss of machine safety functions, down time and a long restart process. All of these conditions lead to lost production, higher costs, loss of safety function, and may shut the whole system down.

Basic requirements for more reliable 24Vcontrol systems start by using robust and sufficiently sized power supply units with a properly configured wiring scheme. Other devices such as: buffer, redundancy, DC/DC converters and UPS products can be added into a power supply system to help improve the reliability of the whole control system. This application note describes the way these additional devices function.

Following are the three most frequent causes for power supplies not being able to provide voltage to the load:

- Temporary failure of the input voltage such as a power outage or upstream protective device being triggered.
- Failure of the power supply itself.
- Temporary output voltage dip or loss due to short-term high power consumption loads such as motors.



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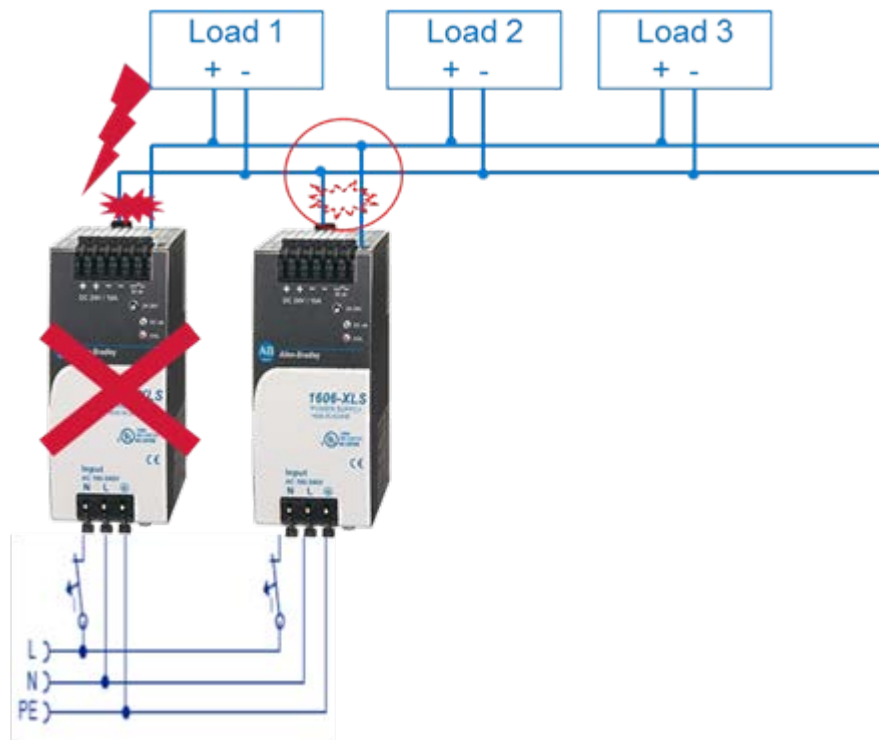
Redundant Systems

The uninterrupted supply of all 24V loads is becoming increasingly important, especially as industrial systems are becoming more intelligent.

Interruptions in a 24V DC supply voltage can often mean significant risks or economic losses. The uninterrupted supply of all 24V loads is becoming increasingly important, especially as systems are becoming more intelligent. This applies to industrial systems as well as telecom applications, process industry and power plant stations, where redundant power supply systems are common practice. In areas such as traffic control systems, tunnel monitoring and access control systems, redundancy is becoming more and more popular and important.

Parallel Power Supplies Versus Redundancy

Connecting two identical power supplies in parallel is a simple way to build a redundant system. However, this solution does not protect against failures such as an internal short circuit in the secondary side of the power supply. In such a case, the defective unit becomes a load for the other power supplies and the output voltages of good power supplies are then also shorted.



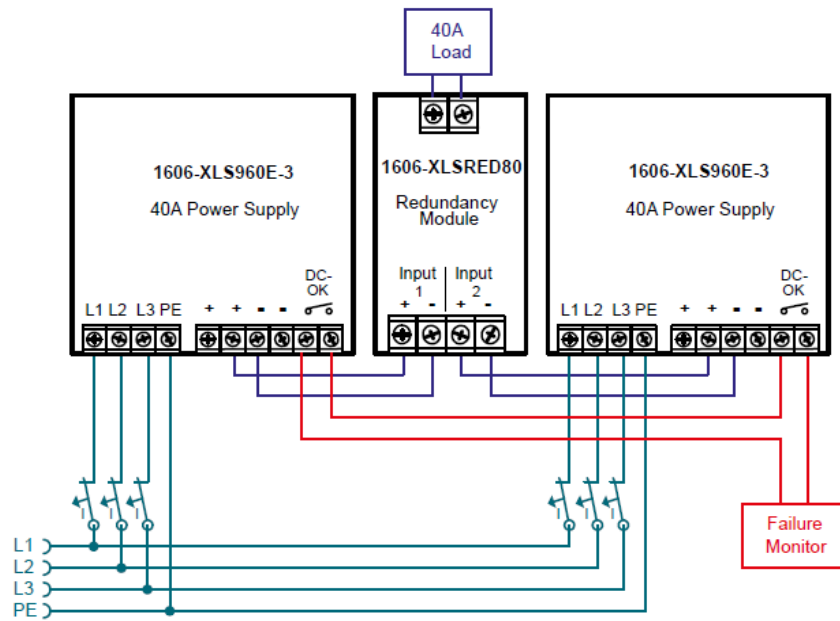
To achieve real redundancy the power supplies must be decoupled from each other.

Building Redundant Systems by Decoupling Power Supplies

To solve the parallel redundant system problem described above, we must decouple the power supplies from each other. In the simplest scenario, redundancy means that two power supplies are connected in parallel, both feeding into a Redundancy module (also known as Decoupling), and each is capable of handling the load by itself. This scheme is known as 1+1 redundancy.

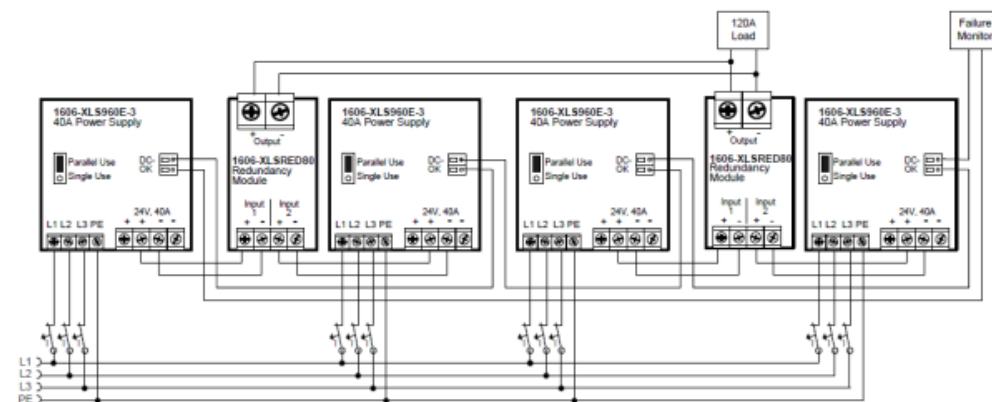
Each power supply should be monitored in a redundant system. This enables early fault detection and the initiation of maintenance routines. The DC-OK signal of the power supplies can be used for this purpose. In some cases redundancy modules can also monitor the incoming power via built-in contact on select redundancy modules.

For applications requiring one power supply to accommodate all load currents in a control panel, 1+1 redundant systems are used. The following illustration is an example of a 40A load current system, if one 40A power supply fails, the other power supply can continue to reliably supply power to the loads as the redundancy module decouples the faulted power supply.



1+1 Redundant System for 40A

For higher output currents, N+1 redundant systems are used. In the example of a 120A load current, shown below, four 40A devices are operated in redundant mode. If one device fails, the remaining three power supplies can continue to reliably supply the 120A system with power.



N+1 redundant system: 120A with four 40A power supplies

In summary, redundant power supply systems are individual power supply units connected in parallel but with output isolation. As standard power supplies do not normally have decoupling (isolation circuits) on the output, these devices must be connected together with the use of redundancy modules. This means that the system also remains redundant even if a short circuit or an anomaly occurs in a power supply output stage.

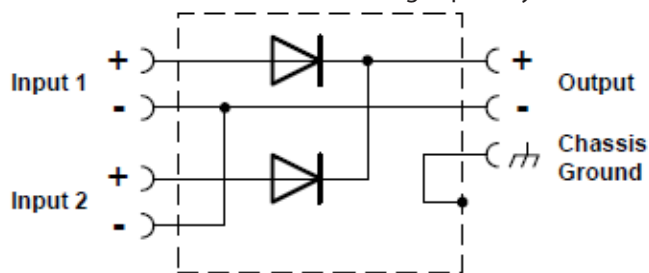
DNA of a Modern Redundancy Module - Technology

Diodes in standard redundancy modules cause voltage drops of 500 to 800mV between the input and output. Depending on the load current, the power losses can be very high and may result in heat problems. In the 1606-XLSRED40 (40A) and 1606-XLSRED80 (80A) redundancy modules, traditional diodes have been replaced by MOSFETs. MOSFET technology enables better protection against circuit problems such as, short circuits, and reversed polarity or back-feeding loads.

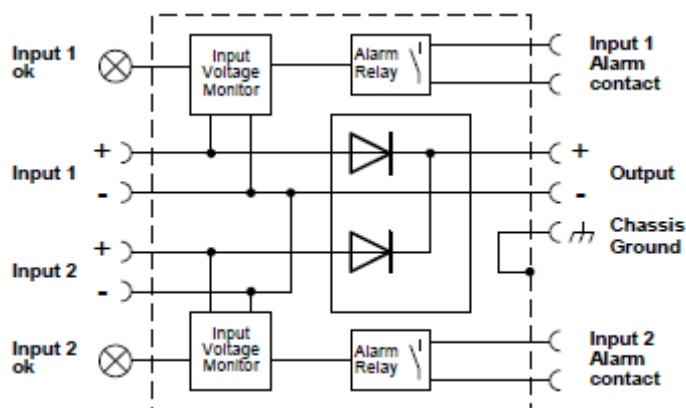
In addition to these two high-current redundancy modules, Rockwell Automation also offers redundancy modules with diodes for small and moderate output currents. These modules are available with or without integrated monitoring function. The monitor function recognizes an output voltage of the power supply which is below a fixed threshold value and opens a signal contact in such cases. This is an important feature when the power supply itself does not have a DC-OK signal included.

Redundancy Module Circuit Options

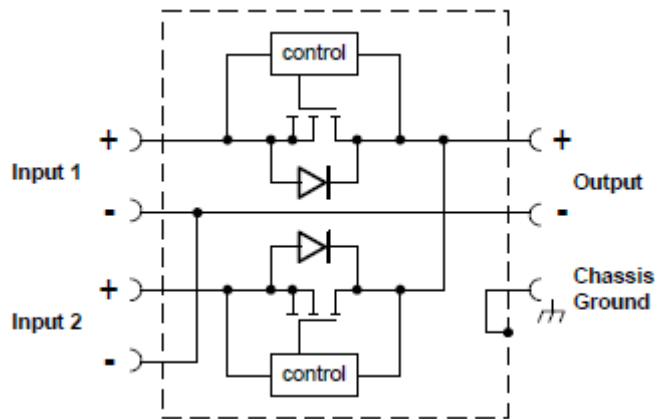
Redundant module selection depends on Power Supply size (current) and the monitoring capability of a given power supply. Generally lower current (e.g. Power Supplies rated 20A and under) systems can use Diode based redundancy modules and for higher current (e.g. Power Supplies with 20A or higher) systems MOSFET based redundancy modules can be used. Below are a few examples of available redundancy modules with and without monitoring capability:



1606-XLSRED, Diode Based, Functional Diagram (No input power monitoring, use Power Supply DC-OK contact for monitoring)



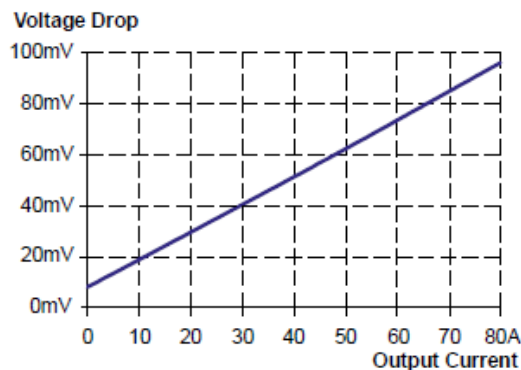
1606-XLERED, Diode Based, Functional Diagram (with input power monitoring, useful for power supplies without DC-OK Contacts)



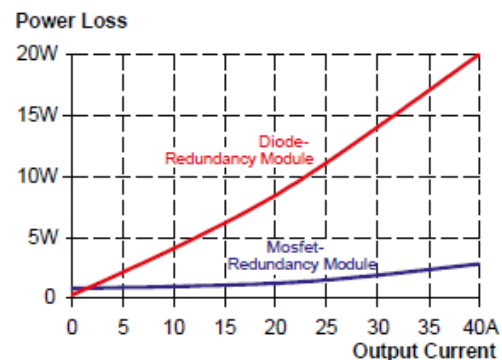
1606-XLSRED40 & 1606-XLSRED80, MOSFET Based, Functional Diagram (No input power monitoring, use Power Supply DC-OK contact for monitoring)

MOSFET Redundancy Module with Low 50mV Voltage Loss and no Heat Sinks

The benefits of the MOSFET redundancy module are clear. The low on-resistance of the MOSFETs causes a considerably lower voltage drop than diodes. This also means that heat sinks are no longer required for the MOSFET based Redundancy Modules. At 40A output current, only 50mV difference is present between the input and output terminals with the 1606-XLSRED80. With a traditional diode module at least a drop of 500mV is likely to occur in that scenario.



1606-XLSRED80:
Typical voltage drop between the input and output



1606-XLSRED80:
Power losses of diode and MOSFET redundancy modules

MOSFET redundancy modules are compact, saving panel space

Until recently, a single 40A power supply required more space on the DIN rail than a fully redundant system consisting of two 3-phase 40A power supplies (1606-XLS960E-3) and one 1606-XLSRED80 redundancy module. A total width of 266mm is needed on the DIN Rail. For single phase systems, 1606-XLS960E power supplies can be used. This increases the total width to 296mm.

Recommendations for More Reliable Redundancy Operation

- Use separate input circuit protection for each power supply.
- If possible, connect the power supplies to different phases or mains circuits.
- Use three-phase power supplies to gain functional reliability if one phase fails.
- Always use redundancy modules or decoupling diodes.
- All power supplies must be monitored individually. Faults need to be detected early and immediately corrected. For this purpose, the DC-OK signals of the power supplies can be used. Facilitates remote monitoring and alarming allowing faster response by maintenance personal.
- Set all output voltages as evenly as possible and set the device in “Parallel Use” mode if this feature is available.

Redundancy Modules Solution Options

Diode Modules

- 1606-XLSRED for 20A output current (2x 10A input)
- 1606-XLERED for 20A output current with monitoring (2x 10A input)
- 1606-XLPRED for 10A output current (2x 5A input)

MOSFET Modules

- 1606-XLSRED40 for 40A output (2x 20A input)
- 1606-XLSRED40HE for 40A output (2x 20A input) (not suitable for 1606-XLS480E-3 and 1606-XLS480E-D)
- 1606-XLSRED40HF for 40A output (2x 20A input)
- 1606-XLSREDS40HE for 40A output (1x 40A input)
- 1606-XLSRED80 for 80A output current
- 1606-XLSRED80HE for 80A output current (not suitable for 1606-XLS960E-3 and XL power supplies)



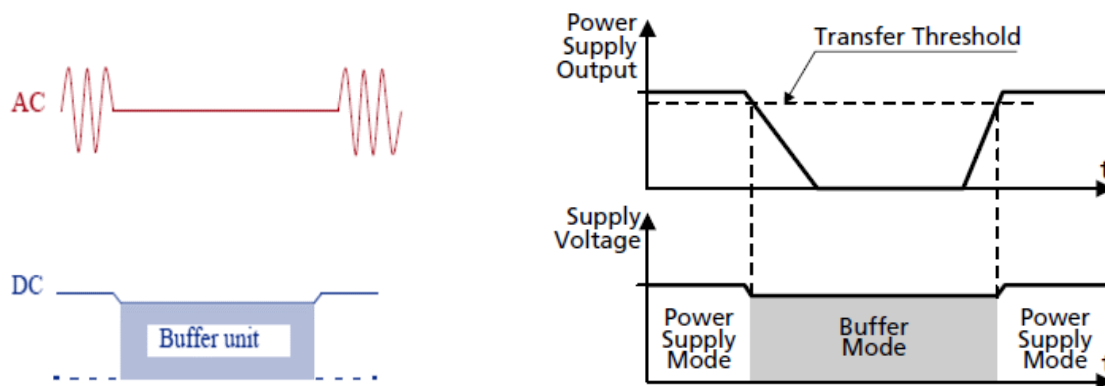
High Availability Systems

Capacitor-supported Buffer Modules

Provides uninterrupted ride through during momentary power anomalies

Statistically, 80% of mains power failures are interruptions in the voltage lasting less than 200ms.

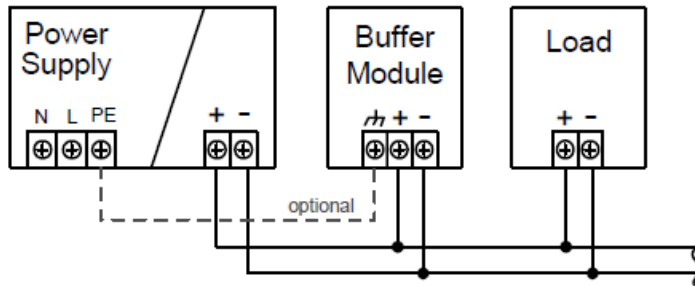
Statistically, 80% of mains power failures are interruptions in the voltage lasting less than 200ms. These are caused by switching operations in the power networks, by overloads in adjacent circuits or as a consequence of lightning strikes. These short failures do not matter for non-sensitive loads such as light bulbs, but they can cause electronic equipment (for example DC coils of a contactor, drives, safety relays, controller inputs) to drop out completely. These short failures can be bridged by means of capacitors and handled without the maintenance of batteries.



While the power supply unit is providing voltage, the internal electrolytic capacitors are charged to approximately 200Vdc and stores the energy. If there is a mains voltage failure, this stored energy is then released in a regulated process to the load. Both 1606-XLSBUFFER24 & 1606-XLSBUFFER48 can provide load currents fully rated 20A with a minimum buffer time of 200ms (typically 310ms). This time is even longer for lower load currents. Buffer modules are a cost-effective solution for situations where power interruptions are mostly momentary power anomalies.

The 1606 buffer modules are maintenance and service free due to electrolytic capacitor advantages, simple to operate and do not need cumbersome control wires. The units are simply connected in parallel to the load. To gain longer buffer time or to increase the buffer current, multiple units can be connected in parallel.

Buffer modules supply energy in addition to the power supply unit. If for example, a device is connected and draws a high starting current, the additional stored energy from the buffer module helps prevent the voltage from dipping. This is helpful for high inductive load start ups.



1606-XLS BUFFER Modules for Momentary Backup Power

- 1606-XLSBUFFER24, for 24VDC circuits, up to 20A
 - Buffer time
 - 310ms at 22.5V, 20A
 - 670ms at 22.5V, 10A
 - 43s at 22.5V, 0.1A
- 1606-XLSBUFFER48, for 48V DC circuits, up to 20A
 - Buffer Time
 - 150ms at 45V, 20A
 - 300ms at 45V, 10A
 - 21s at 45V, 0.1A



EDLC Uninterruptible Power Supplies (DC-UPS without batteries)

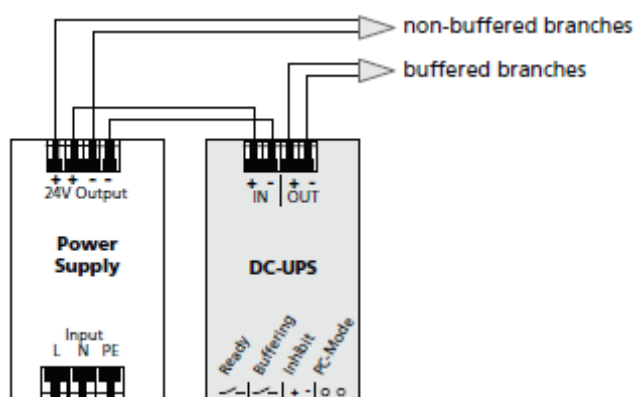
Provides Uninterrupted Optimized Ride Through for Network Infrastructure

EDLCs are more age resistant than lead-acid batteries, in regard to both service life and temperature.

EDLC (Electrochemical Double Layer Capacitor) are double layer capacitors that are also known as super capacitors or ultra-capacitors. No chemical reaction takes place within these capacitors. The charge is stored in an electrochemical double layer (known as the Helmholtz double layer), where positive and negative ions of electrolyte shift through the electric field to the corresponding electrode. As a consequence these are more age resistant than lead-acid batteries, in regard to both service life and temperature.

Although this technology can achieve very high capacitance values it is, however, limited to a nominal voltage of 2.7V, and as a result a series circuit of multiple capacitors is necessary. EDLC have approximately 40 times the energy density of electrolytic capacitors and are suitable as an energy store in buffer modules. In contrast to lead-acid batteries, EDLC modules have a service life expectancy similar to power supplies and do not need to be replaced during the period of operation.

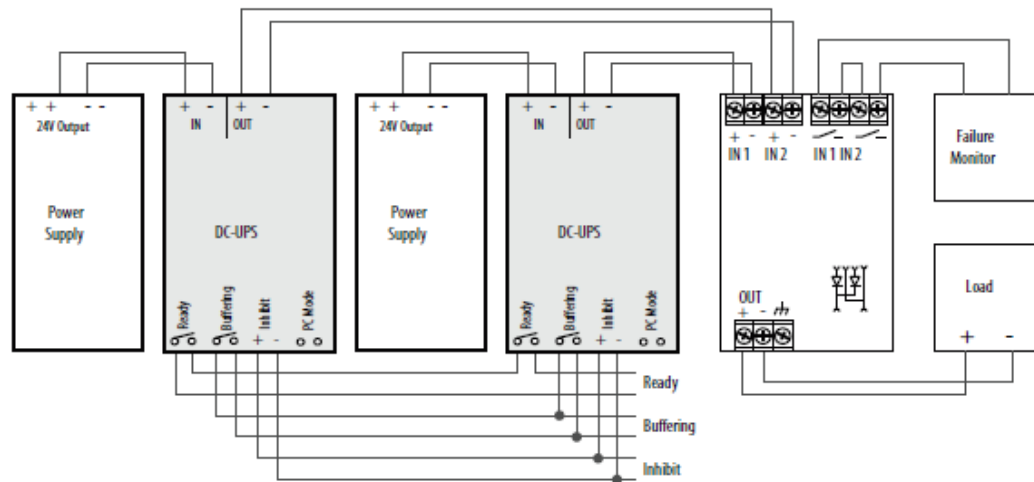
The wide temperature range from -40°C to +60°C makes the unit suitable for many applications.



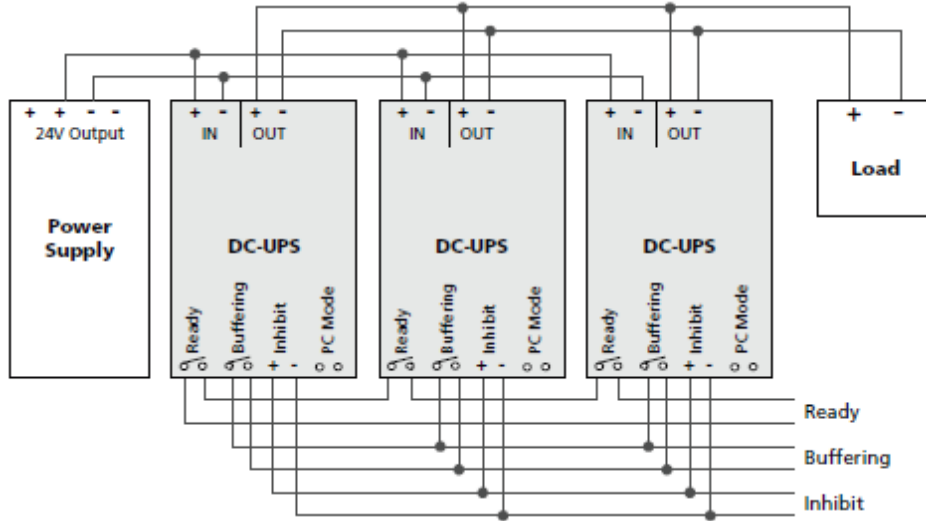
1606-XLSCAP modules are based on Electrochemical Double Layer Capacitor technology. They can bridge power failures or voltage fluctuations and supply voltage to the DC 24V bus for a certain period, which allows for a controlled shut-down of the system. Expensive downtimes, long restart cycles and loss of data can be avoided. In times when the power supply provides sufficient voltages, the DC-UPS stores energy in the capacitors. In case of a mains voltage fault, this energy is released to the DC bus in a regulated process.

EDLC DC-UPS Application Examples

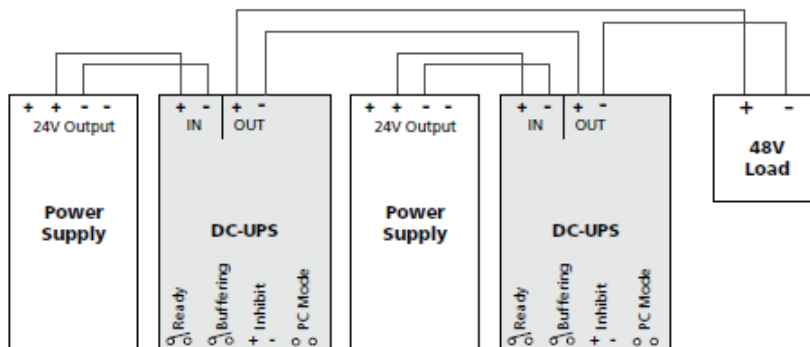
Wiring example for a fully redundant system that includes power supplies and DC UPSs (EDLC) modules with a redundancy module.



DC-UPSs can be paralleled to extend the buffer time, as shown below.



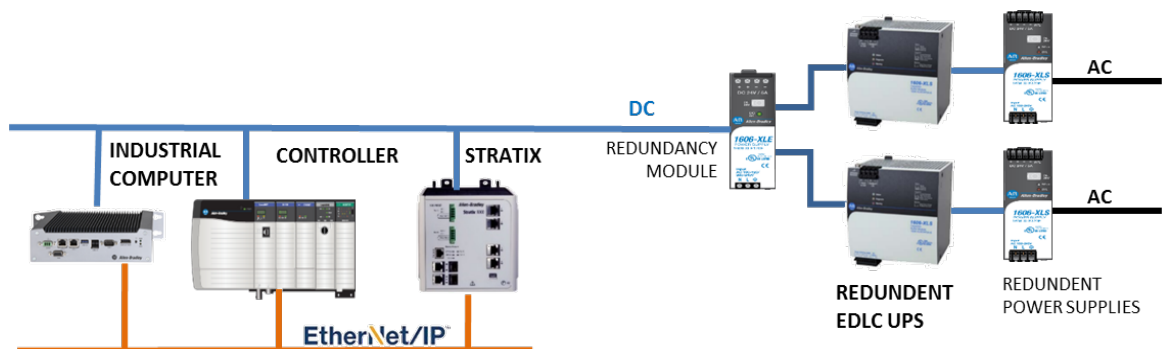
A series connection for 48V applications is allowed when using two individual power supplies and two DC-UPSs, as shown below.



EDLC DC-UPS Provides Backup Power to the Network Infrastructure

EDLCs provides backup power to ride through most power interruptions and enough time to perform an orderly shutdown, thus reducing productivity losses.

Redundant EDLCs (DC-UPS) with redundant power supplies improve reliability of a system even when a power supply or an EDLC goes through a fault. This provides backup power to ride through most power interruptions and enough time to perform an orderly shutdown, thus reducing productivity losses.



1606-XLSCAP EDLC UPS Modules for Extended Momentary Backup Power

The EDLC DC-UPSs come in two versions:

- 1606-XLSCAP24-6
 - 24VDC, 15Amps, 6kW
 - Buffer time (typical)
 - 15A for 9s
 - **10A for 16.5s**
 - 1A for 200s
- 1606-XLSCAP24-12
 - 24VDC, 15Amps, 12kW
 - Buffer time (typical)
 - 15A for 18s
 - **10A for 33s**
 - 1A for 400s



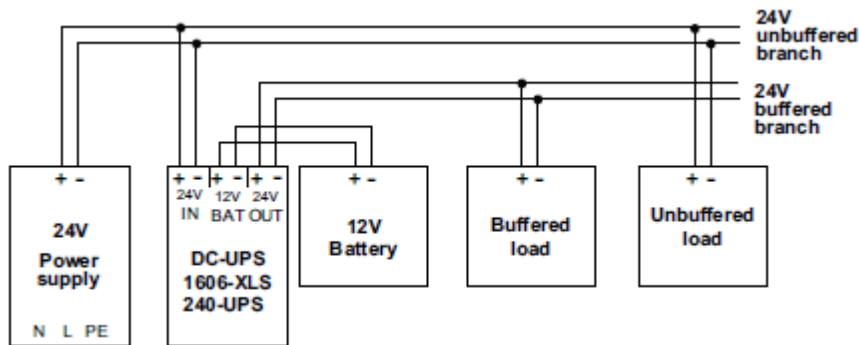
Uninterruptible Power Supplies (DC-UPS with batteries)

Provides time for orderly shutdown to reduce recovery time and scrap

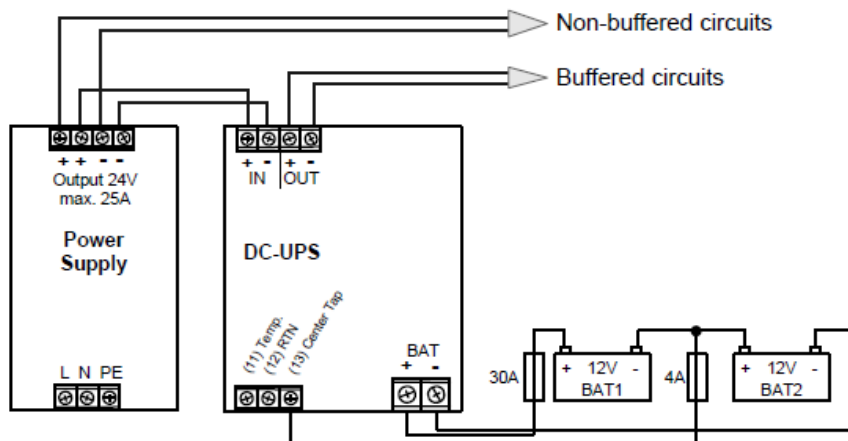
DC UPSs bridge temporary mains failures, voltage fluctuations or unexpected system shutdowns. If the mains voltage fails, the DC UPS along with a battery, takes over the load current and can buffer it for a settable length of time. The duration (buffer time) depends on the size of the battery and load power. The most popular type of battery for this purpose is the lower-maintenance AGM (Absorbent Glass Mat) battery because of its low cost and worldwide availability. However, lower maintenance doesn't mean you can ignore them. These AGM based VRLA batteries can age very quickly and must be replaced periodically. Regular battery inspections are required to help insure proper operation during power outage events.

Understanding battery parameters can help the batteries reach their maximum possible service life – Essential for a scalable UPS system.

When selecting a DC UPS, it is important to understand the following functions of a DC UPS; specification of the batteries with an exact end-of-charge voltage, deep-discharge-protection, and whether it is equipped with a buffer time limit which helps prevent the battery from being discharged too much. These functions help the batteries reach their maximum possible service life.



1606-XLS240-UPS* modules only need a single 12V battery to buffer 24VDC to the loads. The “single battery concept” for 10A solutions allow even more precise battery management, which provides the longest battery service life possible.



1606-XLS480-UPS module requires two 12V batteries to buffer 24VDC to the loads.

1606-XLS DC-UPS Modules for Scalable Backup Power Runtime Solutions

The DC-UPSs (battery supported) come in two versions.

240watts, 10A options:

- 1606-XLS240-UPS (Standard UPS Controller and Charger only)
 - Battery options 3.9Ah – 40Ah (Sold Separately)
- 1606-XLS240-UPSC (UPS Controller, Charger, & 5Ah Battery)
- 1606-XLS240-UPSE (UPS Controller and Charger only)
 - Battery options 17Ah – 130Ah (Sold Separately)
- 1606-XLS240-UPSD (UPS Controller and Charger only, 12VDC and 24VDC outputs)
 - Battery options 3.9Ah – 40Ah (Sold Separately)

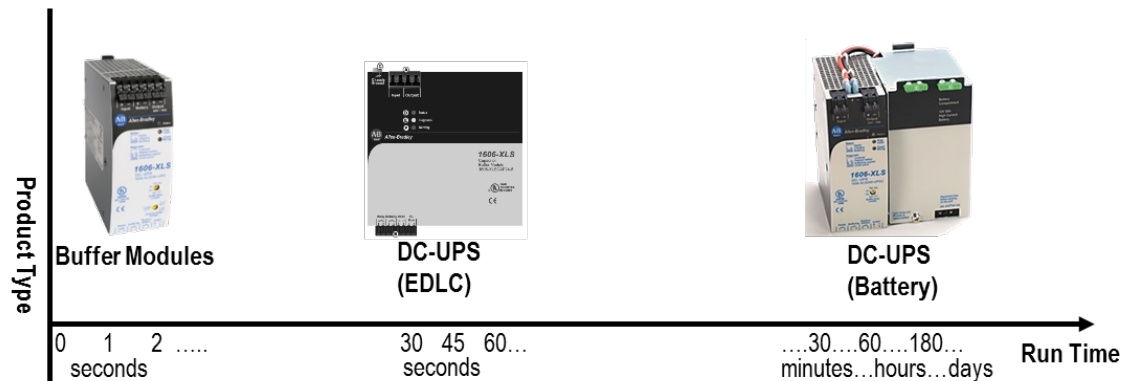


480watts, 20A option:

- 1606-XLS480-UPS (20A, Standard UPS Controller and Charger only)
 - Battery options 3.9Ah – 130Ah
 - Requires 24VDC Battery, 12V +12V in series (Sold Separately)

Buffer/DC-UPS Selection Depends on Applications

Depending on the nature of application and desired runtimes during brownout or blackout events, select the right solution:



Ride Through to Orderly Shutdown

DC/DC Converter Modules

Applications with long wires often fall victim to line loss, resulting in reduced voltage at the loads. In these cases, neither a buffer module nor a DC UPS would help. DC to DC converter, such as 1606-XLDC92D can help restore (from lower than 24VC) line voltage back to 24VDC.

In many cases the converter modules pay for themselves just after a single fault event

The costs of procuring these converter modules outweighs the costs and consequences of down time, in many cases the converter modules pay for themselves just after a single fault event. Increasing the reliability of the 24V system saves money and the inconveniences of down time.

DC/DC Converter for NEC Class 2 Circuits

Since 1606-XLDC92D provides NEC Class 2 output, it can also be used to power NEC Class 2 loads within a panel with a bigger capacity power supplies (e.g. 20 or 40A.) This is desirable in situations where line loss is an issue and loads require Class 2 power.

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1606-XLDC Modules for Line Loss Correction

- 1606-XLDC92D
 - Input: 24VDC
 - Output: 24VDC, NEC Class 2 rated
 - Output Limited to 3.8A or 92Watts
- 1606-XLDC40A
 - Input: 18...36 VDC
 - Output: 5.1 V / 8 A



A Note about NEC Class 2 Circuits

What is a NEC Class 2 DC power source?

The "National Electrical Code" (NFPA 70) defines special safety requirements for low voltage circuits. The NEC refers to such circuits as Class 2 circuits.

To minimize electric shock hazard the standard in Article 725, requires that low voltage DC circuits have a maximum voltage limit essentially the same as that defined in IEC 60950-1. The big difference is that, to eliminate the risk of fire hazard, Article 725 also requires that the maximum power potential of these circuits to be limited to 100VA. As a consequence of the 100VA max capability requirement, power sources meeting Class 2 requirements generally have lower current capability than non-Class 2 power sources.

When must a Class 2 power source be used?

Class 2 is exclusively a NEC category. The short answer for the “...when to use a Class 2 power source?” question is for any circuit powering any device that is UL certified with a requirement of a Class 2 power source.

Most DC sensors, from any provider, when UL certified, are certified for use in Class 2 circuits (e.g. powered by a Class 2 Power Source). Most Rockwell Automation DC sensors including IO-Link, Zone Control and DeviceNet sensors are UL certified for Class 2 circuits. SensaGuard™ products are UL Certified for Class 2 circuits. Safety Relays, the MSR42 for instance, are UL Certified for Class 2 circuits. Many condition sensing devices from Rockwell Automation are UL certified with Class 2 circuits.

Whenever the connected component(s) require a class 2 circuit, it is the installer’s responsibility to power that device with a Class 2 power source.

NEC Class 2 Circuit Guidelines

When there is application of components in regions other than US, the NEC Class 2 requirements do not carry any authority. However, the application designer must consider the component product design requirements when designing power sources for those components, wherever they are applied.

Class 2 power sources can be designed in from the beginning or a Class 2 source can be integrated into an existing system.

There are two basic scenarios for implementing Class 2 power sources into a system: Class 2 power sources can be designed in from the beginning or a Class 2 source can be integrated into an existing system. Rockwell Automation has products suited for either situation.

In the case of a new system using Class 2 power sources, when required, from the start is simplest. Due to the relatively limited power available from a Class 2 source it is not uncommon for a new system to include both Class 2 and standard non-Class 2 power sources. While non-UL Certified Class 2 DC powered devices may be included in a Class 2 circuit; generally the Class 2 power source is sized to handle the power requirements of only the Class 2 devices only. A standard supply with a higher current capacity is provided to power devices that do not require a Class 2 power source. The Bulletin 1606-XLP series has a wide selection of Class 2 power supplies.

There can be a third way. In many instances the combination of a larger “standard” power supply and the Bulletin 1692 ECP may offer another alternative.

NEC Class 2 Solutions

■ 1606-XLP family

- 1606-XLP15A
- 1606-XLP15B
- 1606-XLP15E
- 1606-XLP30E
- 1606-XLP25A
- 1606-XLP30B
- 1606-XLP36C
- 1606-XLP30EQ
- 1606-XLP50E
- 1606-XLP50B



- 1606-XLP50F
- 1606-XLP50EZ
- 1606-XLP60BQ
- 1606-XLP60BQT
- 1606-XLP60EQ
- 1606-XLP60EQT
- 1606-XLP72E
- 1606-XLP90E-2
- 1606-XLP95E
- 1606-XLP90B



■ 1606-XLE and XLS family

- 1606-XLE80E
- 1606-XLE96B-2
- 1606-XLSDNET4



■ 1692 ECP Options for NEC Class 2

- 1692-ZR1111
- 1692-ZR2222
- 1692-ZRCLSS



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