

## **Preventing Coil Burn-Outs**



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## Preface

Experienced motor control personnel find that 85% of all coil burn-outs are caused by low-voltage resulting from insufficient control power. The purpose of this white paper is to help field personnel identify or even prevent the death of contactor and/or relay coils.

### How To Select an AC Control Circuit Transformer

All too often we find that field installation personnel are under powering their selection of the control circuit transformer (often referred to as the CPT or CCT). The selection of a CCT for a single motor starter is a relatively straight forward process. Industrial control manufacturers usually provide coil consumption data (burden) in their catalog. Coil consumption is expressed in two values as follows:

1. Pick-up (coil inrush) expressed in VA and/or Watts
2. Hold-in (continuous current) expressed in VA and/or Watts

<b>Coil Data</b>		<b>CA7-9</b>	<b>CA7-12</b>	<b>CA7-16</b>
<b>Coil Consumption</b>				
AC: 50Hz, 60Hz, 50/60 Hz	Pickup	[VA/W] 70/50	70/50	70/50
	Hold-in	[VA/W] 8/2.6	8/2.6	8/2.6

Example: CA7-9..16 with an AC coil (reference CA7 Technical pages in Section A of catalog)

- Pick-up            70 VA (50 watts)
- Hold-in            8 VA (2.6 watts)

As contactors increase in size so does the burden of the coil on the available control power.

<b>Coil Data</b>		<b>CA6-95...180</b>	<b>CA6-95-EI...300-EI</b>
		<b>Conventional Coil</b>	<b>"EI" Coil</b>
<b>Coil Consumption</b>			
AC: 50Hz, 60Hz, 50/60 Hz	Pickup	[VA/W] 650 / 310	380 / 240
	Hold-in	[VA/W] 50 / 10	13 / 6
EI (B1-B2 24VDC Interface)		[VA/W] ~	15 ma

Example: CA6-180 with an AC conventional coil (reference CA6 Technical pages in Section A of catalog)

- Pick-up            650 VA (310 watts)
- Hold-in            50 VA (10 watts)

Sprecher + Schuh has already calculated the VA requirement of individual contactors based on the formulas provided by the manufacturer of control circuit transformers and this data is shown in the chart on page C67 of the SSNA9000 catalog.

For the CA6-180 conventional coil contactor we recommend a 150 VA control circuit transformer.

<b>Contactor (Relay) Coil Data</b>					<b>Minimum Recommended Transformer</b>
<b>Device</b>	<b>AC Coil Consumption</b>				
	Inrush (pick-up)		Sealed (holding)		
	VA	Watts	VA	Watts	<b>VA</b>
<b>CA6-180</b>	650	310	50	10	150
<b>CA6-180-EI</b>	380	240	13	6	100

### Is the CCT Under Powered?

#### Consider the basic formula: Power = Volts X Amps

If a 100 VA control circuit transformer were applied to a CA6-180 conventional contactor coil then the selection would be under powered. Here is an analysis for the events that will follow when the control circuit is under powered. When the control circuit is closed (voltage applied to the coil) then the coil burden demands the specified amperes, but since 100 VA isn't capable of producing the required power – the formula (Power = Volts X Amps) dictates that the voltage will drop in an attempt to provide the amperes demanded. This results in the fact that “low voltage burns out coils.”

Most conventional coils (non-electronic) will operate continuously between a minimum of 0.85 (85%) nominal voltage and a maximum value of 1.10 (110%) of nominal voltage without damage to the coil. If the application uses a Start/Stop momentary pushbutton (3-wire control circuit) then the contactor may drop-out and not burn out the coil (reference catalog Technical pages for Contactor or Relay in question). This means no coil burn-out unless the person pushing the Start button holds down or repeats the process. If a Hand-Off-Auto (HOA) selector switch (2-wire control circuit) is utilized, then coil burn out is much more likely. In a 2-wire control circuit with an under powered CCT, the voltage will drop when the contactor is energized and then the contactor will drop-out because of low voltage. When the coil drops-out, this removes the coil burden on the power source; therefore, the control power returns the voltage to the nominal value. With nominal voltage restored, the coil again closes and this process continues to cycle causing contactor chatter until the coil overheats due to repeated inrush currents. It's a vicious cycle that burns out coils and can weld main contacts as well.

In many instances, when field maintenance attempts to investigate the reason for coil burn-out, they find that the control power is nominal when measured. What needs to be considered is “Was voltage measured when the coil was energized or NOT energized?” Measuring nominal voltage before being energized doesn't mean very much if the control circuit is under powered as described. The problems only start when the coils are energized. Even measuring voltage during coil inrush (start-up) is tricky as most digital or analog meters won't settle down in such a short period (30-50 milliseconds).

Sizing a CCT for a group of motor starters is a bit more complex than selection for a single motor starter. Sprecher + Schuh isn't a manufacturer of control circuit transformers (CCT's) and sizing of CCT product should be done by manufacturers' rules. Sprecher + Schuh does note that most of the CCT manufacturers use the following formula:

$$VA = \sqrt{(Inrush VA^2) + (Sealed VA^2)}$$

Where the inrush power ( $VA^2$ ) is the sum of all contactor coils required to pull-in at any one time plus the seal-in ( $VA^2$ ) power required of all contactors to be energized at the same time plus any additional burden of other control circuit devices. The formula results in a number (factor) which is then referenced to a regulation table that determines the actual VA of the CCT required. There is a simpler alternate method. Consider that a 50 VA transformer is a bit over sized for one CA7-9; so it isn't necessary for a group of (5) CA7-9 to result in  $50 VA \times 5 = 250 VA$  CCT but this is a simple and safe way to size if a CCT manufacturer's catalog is not available for reference of a regulation table or the square root function doesn't appear on a calculator (and using a slide rule is not conducive to current standards).

**How to Select DC Circuit Components**

Field installation personnel are often under powering their selection of the DC power supply for the type of electromechanical contactor selected. Most DC control circuits are applied at 24 VDC and there are several options with respect to selecting the contactor or relay when dealing with DC control circuits. The fact is that DC power supplies are larger and more expensive than CCTs and so field personnel select the smallest power supply they think they can get by with while largely ignoring the demand of power during coil in-rush. Power supplies also have some limitations that are not often carefully considered which further limit their ability to handle the demand (burden) of coils particularly on larger contactors. These factors lead to troubleshooting coil burn-out.

**Option #1  
True DC**

Single-winding conventional DC coil contactors and relays (sometimes referred to as ‘true’ DC devices) have pretty straight forward connections to A1 & A2 terminals and when power is applied to the coil terminals the coil in-rush power is demanded during pick-up (contactor closing) and an equal burden is required to hold-in the contactor. Single-winding conventional DC coils have more wire in the windings than their AC counterpart and therefore weigh more and cost more than their AC counterparts.

<b>Coil Data</b>			<b>CA7-9C</b>	<b>CA7-12C</b>	<b>CA7-16C</b>	<b>CA7-23C</b>	<b>CA7-30C</b>	<b>CA7-37C</b>	<b>CA7-43C</b>
<b>Coil Consumption</b>									
True DC Coils	Pickup	[W]	6.5	6.5	6.5	9.2	9.2	9.2	10.1
	Hold-in	[W]	6.5	6.5	6.5	9.2	9.2	9.2	10.1

The Sprecher + Schuh catalog number for a small contactor of this type would be CA7-9C-10-24D (selection typical for CA7-9C...43C). The advantage of single-winding conventional DC coil contactors is that the pick-up current demand is lower than with two-winding DC coil contactors.

**Option #2  
Two Winding DC**

Two-winding conventional DC coil contactors and relays (sometimes referred to as an ‘economy’ coil) differ slightly from single-winding conventional coil contactors which is they have two coil windings on the spool. Connections can vary slightly but the concept is simply that one winding is used to pull-in during closing (starting) and the run winding holds-in the contactor. The advantage of this method is that although the inrush wattage demand of the pull-in winding is high, the run winding (hold-in) requirements are lower than in single-winding conventional DC coils. This method requires milliseconds of time delay between energizing the start winding and switching to the run winding.

<b>Coil Data</b>			<b>CA7-60D</b>	<b>CA7-72D</b>	<b>CA7-85D</b>	<b>CA7-97D</b>
<b>Coil Consumption</b>						
Two Winding DC Coils	Pickup	[W]	200	200	200	325
	Hold-in	[W]	4.5	4.5	4.5	5.5

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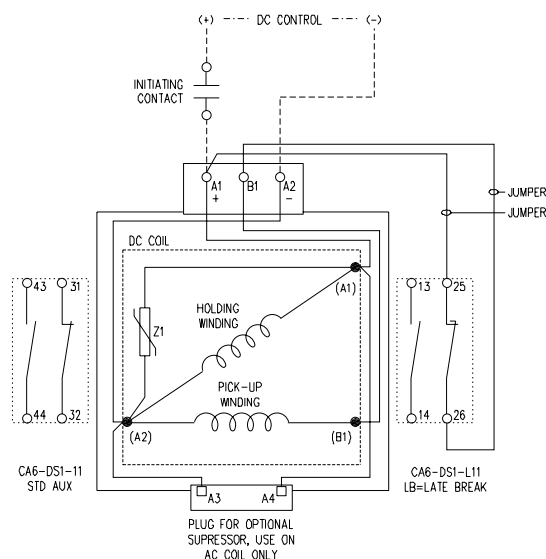
In the Sprecher + Schuh catalog number CA7-60D...97D, a set of internal contacts switch from the pull-in to the hold-in coil winding. The contactor closes if power is applied and opens if power is removed from the A1 and A2 terminals. This switching between the pull-in coil and hold-in coil occurs inside the body of the device with a delayed auxiliary mounted on the coil. The concept of the two-windings is that hold-in burden is less than the pull-in demand and the customer still makes connections only to the A1 & A2 terminals.

Coil Data		CA6-95...180 Conventional Coil	
<b>Coil Consumption</b>			
Two Winding DC Coils	Pickup [W]		540
	Hold-in [W]		8

Sprecher + Schuh also offers a two-winding conventional coil design on CA6-95...180 for DC coil devices. Like described before, the pull-in coil winding is switched out and the hold-in coil winding takes over after milliseconds, using a late break contact mounted on the side. Customer connections to A1 & A2 remain simple. The detailed wiring diagram below shows how the two-windings and three coil terminals are interconnected. It is an electrical fact that when contactors increase in size so does the burden of the coil on the available control power.

### Notes

- 1) The CA6 conventional DC coil has dual windings with three leads brought out. One winding is the "pick-up" winding and the other is the "holding" winding. The coil also has a built-in voltage limiting varistor (Z1).
- 2) The pick-up winding has low resistance while the holding winding has a higher resistance.
- 3) When the control circuit is energized, the contactor "pulls-in" through the lower resistance pick-up winding and the NC late break auxiliary contact. After the contactor seals in, the late break contact opens and the contactor is held in through the holding winding.
- 4) The pick-up winding is not designed for continuous operation and must be disconnected by the "late break" contact immediately after the contactor pulls-in.

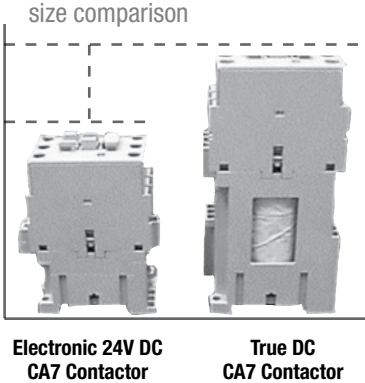


### Option #3 Electronic DC

Electronic DC coil contactors and relays are the newest option which provides reduced power demand and a wider range of continuous duty, making the contactor less vulnerable under a voltage variance condition. Another advantage of the Electronic DC design is a lower profile equal to that of AC coil contactors. Most small HP electronic coil contactors

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like CA7-9E-10-24E are limited to applications at 24 VDC; which means if 125 VDC or 220 VDC needs to be applied, then Option #1 must be selected as described above. Option #2 for mid-range or large HP contactors can be used. Most conventional coils (non-electronic) will operate continuously between a minimum of 0.85 (85%) nominal voltage and a maximum value of 1.10 (110%) of nominal voltage without damage to the coil. CA7 electronic DC coil contactors have a continuous duty range of .70 (70%) minimum and a maximum voltage of 1.25 (125%) which is important when operating at just 24 VDC. The hold-in values of electronic coil contactors are much reduced in comparison to single-winding versions.



Coil Data		CA7-9E...37E	CA7-43E
<b>Coil Consumption</b>			
24 VDC, Electronic Coil	Pickup Avg	[W] 10	12
	Pickup Peak	[W] 22	28
	Hold-in	[W] 1.5	2.5

Larger HP electronic DC coil contactors, like CA6-95-EI-11-24D, offer a complete selection of DC voltages. Sprecher + Schuh CA6-EI (electronic interface) contactors offer the customer reductions in the pull-in demand and hold-in wattage burden when DC coils are required. For example, on the CA6-95 the inrush demand drops from 540 watts for the conventional coil version to 265 watts average for the electronic coil version in the 'EI' mode. However, one must take into account the peak demand of the electronic 24 VDC coil since it requires 25 amps at peak for 10 ms then reduces to 11 amps for 100ms and finally settles down to 0.5 amps average continuous duty (25 amps X 24 volts = 600 watts for 10ms).

Coil Data		CA6-95 Conventional Coil	CA6-95-EI...300-EI	CA6-420-EI	CA6-630-EI...860-EI
<b>Coil Consumption</b>					
Electronic DC Coil	Pickup	[W] 540	265	340	1980
	Hold-in	[W] 8	6	7	30
EI (B1-B2 24VDC Interface)		[VA/W]	15 ma	15 ma	15 ma

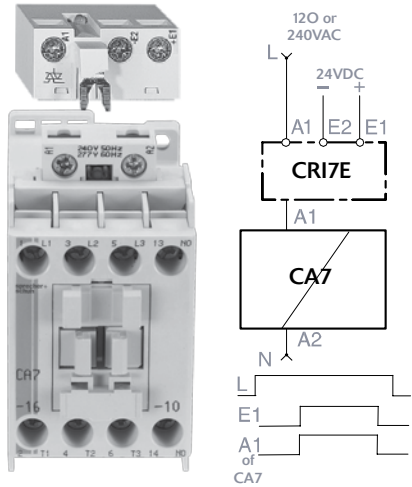
**Option #4  
Electronic Interface**

There is one more option for DC control circuits and that is an external electronic interface. The CA7 contactor family includes a CRI7E-\* accessory (see diagram below). This device allows the customer to use a 110 or 240VAC coil which can be taken from the line voltage or a CCT and still use 24 VDC in the control circuit to determine when the contactor should pull-in (start) or drop-out. Simply connect the CRI7E-24 to the CA7 coil terminal A1 and then connect 120 VAC (Hot) to the CRI7E-24 terminal A1 and 120V(N) to A2 as normal. The device will not conduct the 120 VAC to the contactor A1-A2 terminals and nothing will happen until 24 VDC is applied to terminals E1 and E2. The E1-E2 terminals of the

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CRI7E-24 are connected internally to the gate of an SCR which only conducts when the 24 VDC gate is energized. This method places the coil burden on the 120 VAC and everyone knows that a CCT is much less expensive than up-sizing a 24 VDC power supply. There is only a 15ma burden placed on the DC power supply or PLC card connected to E1 & E2 terminals of the CRI7E-24. Now that represents advancement in DC control circuit design for small HP contactors!

### CRI7E Accessory



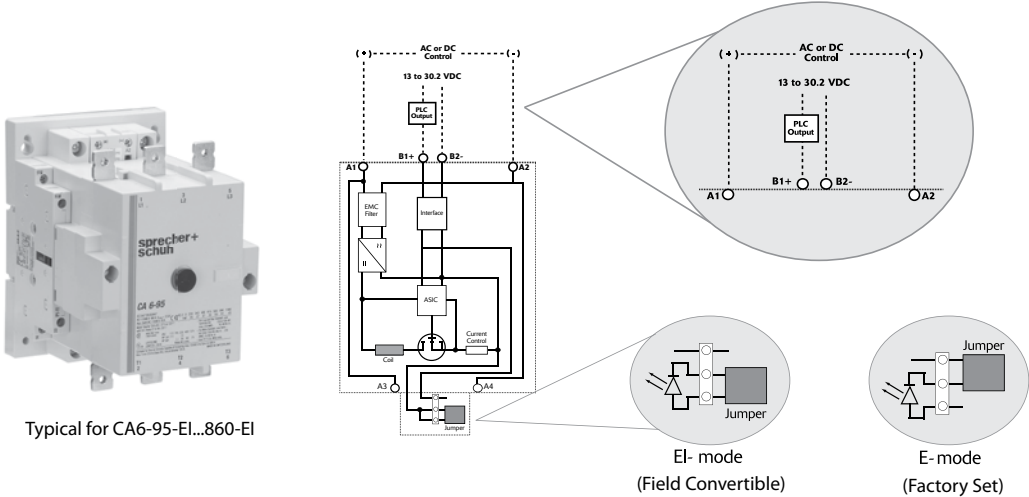
**Electronic Interface –**  
Interface between the DC control signal from a PLC and the AC operating mechanism of the contactor.

- Requires no additional surge suppression for the coils
- Switching capacity 200VA
- Suitable for all CA7 with AC control

**Input:** 24VDC  
**Output:** 110...240VAC

**Catalog Number:** CRI7E-24

Once again larger HP contactors increase the pull-in (pick-up) demand on DC power supplies and this factor is often overlooked by designers who focus on the hold-in or continuous current requirements which leads to coil burn-out. The Sprecher + Schuh CA6-EI contactor incorporates a 24 VDC electronic interface which can be used to avoid high power demands on the DC power supply and therefore reduce cost while increasing the reliability of the system. When the CA6-EI option is chosen for a 24 VDC application, an electronic interface option (similar to CRI7E) is built-in to every CA6-EI contactor. The concept is the same as CRI7E for smaller CA7 contactors but the line voltage flexibility is increased for CA6-EI, no matter if the available line voltage to be switched is 120, 208, 220, 277, 380, or 460 VAC. The available line voltage can be directly connected to coil terminals A1 & A2 but when the contactor is set to the EI mode (as illustrated below) it will



Typical for CA6-95-EI...860-EI

not close until the 24 VDC signal from your PLC (or other electronic source) applies power to B1 and B2. Similar to the CRI7E-24; the CA6 terminals B1 & B2 are connected internally to the gate of a SCR which allows the contactor to conduct AC voltage from A1 & A2 to the coil when the 24 VDC gate is energized. The burden to the DC source is only 15ma maximum (reference Coil Data page 7). The burden of the coil remains on the line source or CCT which results in a huge reduction in the money spent on the 24 VDC power supply or the space required for the up-sized power supply.

### Is the DC Power Supply Big Enough?

Customers often select a marginally sized 24 VDC power supply because a power supply is relatively expensive in comparison to a CCT. We aren't going to tell you how to size a 24 VDC power supply in this article. Reference additional white paper posted to the Distributor Extranet on sizing power supplies for CA6-EI. We are suggesting that the power supply must produce 25 amps X 24 volts = 600 watts for 10 ms for just one CA6-EI contactor with a 24 VDC electronic coil or the power supply will be under powered. It should be noted that although 600 watts is a significant power requirement, the CA6-EI is still much less than competitive conventional coil 'power hungry monsters'. If a power supply is under powered for the control circuit then most power supplies will shut-down for a few milliseconds (the technical term is 'hiccup'). Since most 24 VDC circuits are essentially maintain circuits (2-wire control), then after the 'hiccup' the power supply tries again and the 24 VDC coil experiences repeated inrush. It's a vicious cycle that burns out coils and can also weld main contacts.

Some power supplies use "fold-forward" technology in lieu of the 'hiccup' method of self-protection. "Fold-forward" is technical speak for reducing the voltage for interim periods in order to deliver excess transient current demand. Early in this paper we asked you to consider the formula Power = Volts X Amps. This formula is more critical to a 24 VDC power supply than in an alternating current CCT. Applications involving 24 Volts is critical since most coils only operate continuously at a minimum of 0.85 (85%) nominal voltage without damage to the coil. Let's do a little math (24 volts x .85 = 20.4 volts minimum) which shows that a drop to just 20 volts is too low for operation. Further, most power supplies have a 60° C upper temperature limit and performance degrades above that temperature limit. Contactor coils, overload relays, softstarters, VFD, power supplies, and ambient temperature in the summer are sources of additional heat which can raise the enclosure temperature above the limits of the power supply, resulting in reduced ability to produce the current demand at the prescribed 24 VDC. A minimum of 20.4 volts doesn't leave much room for variance from 24 volts nominal and we already know "low voltage burns out coils."

### Conclusion

Coils can become inoperable for a number of reasons. It is quick to find the answer to most coil burn out mysteries if it is assumed that 85% of coil burn-out is due to low voltage resulting from an under powered control circuit. This was the primary purpose of this white paper. If this assumption proves incorrect, then the primary suspect for coil death has been eliminated and an alternate cause for the problem can now be researched (see Appendix).

Overvoltage	<p><b><u>Can a coil burn-out occur due to overvoltage?</u></b></p> <p>Certainly 480 Volts or 240 Volts AC on a 120 volt AC coil will cause the coil to burn-out quickly. Further, a continuous 140 volts on a 120 volt coil exceeds the specified <math>120 \times 1.10 = 132</math> volts maximum and so 140 volts AC will burn out a coil if it is applied continuously.</p>
Erratic Operation	<p><b><u>Can a float switch opening and closing quickly under erratic operation (intermittent operation possibly during system start-up) cause coil burn-out?</u></b></p> <p>Yes. Any 2-wire (i.e.: Auto mode of an H-O-A) control circuit contact provided by the customer that is opening and closing multiple times per minute will cause repeated coil inrush resulting in excessive heat which will burn-up coils and may cause main contact welding.</p>
Timer Adjustment	<p><b><u>Can a coil burn-out if a wye-delta timer is set to zero?</u></b></p> <p>Yes. A wye-delta starter should be set in the field to match the torque of the motor and load. Wye-delta timers are usually set for 3 seconds when wye-delta starters are shipped. If the timer is later set to zero, the whole sequence of the wye-delta transition is blundered. Not only will coils burn-out but auxiliary contacts and power contacts will weld due to contactor opening and closing rapidly and out of sequence. Not good!</p>
Undersized Site Power	<p><b><u>Is it possible, even if a CCT is selected properly, to burn-out coils from under-voltage if the customer's large HP motor overloads the site power system during starting because the utility company undersized the power transformer feeding the facility?</u></b></p> <p>Yes. In fact this frequently happens with softstarter applications that are connected to generators. Owners (or their advisors) often fail to consider the inrush current of a large HP motor that occurs during starting and as a result under power the entire system. This happens because generators are expensive and everyone attempts to get by with the minimum KW generator they can. Even under reduced voltage electromechanical or solid state methods, a large HP motor demands additional current during starting. If the power system is under sized then the formula <math>\text{Power} = \text{Volts} \times \text{Amps}</math> plays exactly the same role as outlined for under powered CCT. The sequence of events are: Start the motor and the current is demanded. As a result of under powering, the voltage drops off. Maybe low voltage for a short duration doesn't hurt most of the customer equipment, but it plays havoc with contactor coils and softstarter control boards that expect the right voltage to be supplied. This leads to an attempt to identify the guilty party since large amounts of money is involved.</p>
Know the Contactor Safety Features	<p><b><u>When maintenance personnel are inspecting the contactor, the contacts are locked. Did this cause the coil burn out?</u></b></p> <p>CA6 contactors have an interlocked arcing chamber. The main contacts can be inspected for wear and tear with a simple quarter-turn of two screws located in the top of the arcing chamber. When just one of these two quarter-turn screws are turned to the open position then the main contacts are then locked-out from closing as a safety feature. Contacts should not be inspected, when the contactor is actively carrying current and might open under load resulting in 'arc in your face.' If so, maintenance personnel will find a locked</p>

contactor when investigating inside. The field person is then likely to incorrectly assume the contactor is locked up. Wrong! The problem is most often the improper application of the electronic interface of the CA6-EI contactor combined with under-sizing of the 24 VDC power supply which leads to coil burn out.

Improper use of “EI”  
Function

**If a CA6-420-EI-11-24D contactor (typical for CA6-95-EI...CA6-860-EI) is used where the 24D represents a 24 VDC coil this means the EI feature isn’t being utilized.**

The Sprecher + Schuh 9000 Catalog has several footnotes warning against selecting a 24 VDC coil and suggesting the use of the 24 VDC electronic interface (EI) functionality of the device; this scenario still occurs all too often. There is a high potential for a coil to burn-out in this situation.

Wiring Tips & Tricks

**Use the right wire gauge.**

The wire gauge should be 10 or 12 AWG for the A1, A2 circuit. 10 AWG is preferred.

**DO NOT Daisy Chain control power wiring if using multiple contactors.**

The wiring for A1, A2 on each contactor coil should be direct (Home Run) to the 24VDC Power Supply.

**If using multiple contactors, the Contactors should NOT energize at the same time.**

PLC programming can adjust short time delays in certain instances.

**Electronic coil contactors do NOT like unfiltered half-wave DC.**

OEMs assembling electronic components into a Do-It-Yourself half-wave rectifier to avoid the cost of a 24 VDC switching power supply; “Don’t do it!” Electronic contactor coils expect a smooth wave form, and the “choppy” wave form from the half-wave rectifier destroys the IC in electronic coils. Use a manufactured switching power supply.

**Terminals connecting to the wrong leads.**

In most DC devices, including contactors and relays, it makes a difference to which terminal you connect the positive (+) and the negative (-) wire leads. If + and – are mixed-up on electronic devices the result is burnt-up equipment.

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