Relays and Motor Loads

INTRODUCTION

When it comes to using a relay to control an inductive load such as a motor, there is often confusion and misinformation. We will attempt to reduce the confusion by addressing a few common misperceptions:

1) "All I need to do is pick a relay based on motor current."
2) "Relay contact material really isn't that important."
3) "I can protect the relay contacts from arcing by using an RC snubber / MOV / TVS."

Fortunately, there are some simple best-practices that can be implemented in order to address these misperceptions and achieve a high-confidence solution.

MISPERCEPTION #1: Select a Relay based only on Motor FLA Current

It is tempting to look at a motor's Full Load Amps (FLA) rating and then select a relay based on that. While this is a good start and may yield a working solution, there are a couple problems with this approach:

1) When the contacts first close to start the motor (rotor initially at rest), there is a high inrush current that is equal to the motor's Locked Rotor Amps (LRA). The LRA for a motor is typically in the range of 6 to 7 times the motor's FLA current.
2) While many relays are only rated for resistive loads, a motor is an inductive load. In short, once current is flowing thru an inductive load, the inductance will try to keep the load current flowing. This can have a significant effect on what happens to the relay contacts when they are opening (trying to turn off the load).

The simple solution in this case is to select a relay that is specifically rated for controlling motors like the one being targeted for the application. In the relay datasheet, look for a horsepower (HP) rating, or information that addresses both LRA and FLA rating.

MISPERCEPTION #2: Relay Contact Material Isn't Important

There are times when it may not be too important to understand what the relay contact material is. For instance, if the relay datasheet indicates that the relay is rated for controlling 1 HP motors, then the relay manufacturer by default is using a contact material that is suitable for an AC motor control application up to 1 HP. On the other hand, if the relay datasheet does not specifically call out ratings that are aligned with the application, then there could be cause for concern. Silver is generally the main metal used (at least for the portion of the relay contacts that actually touch each other), with small amounts of other metals added to provide hardness and improved contact wear. Here are some notes to be aware of regarding some typical contact materials:

1) Silver Nickel is a good general-purpose relay contact material. While it may not be quite as robust for inductive loads compared to some other materials, the main thing is to be aware of what the relay manufacture states in the datasheet regarding contact ratings.
2) Silver Cadmium Oxide (AgCdO) provides improved contact durability, but there are a couple downsides. First, AgCdO is not a great fit for DC applications due to the potential for contact material migration over the life of the product. Secondly, there is concern about cadmium from both a long-term RoHS standpoint as well as from a conflict mineral standpoint. So, while it may provide a good solution for AC motor control, it may be better in the long run to consider an alternative.
3) Silver Tin Oxide ($AgSnO_2$) provides good performance for either AC or DC applications without the other concerns associated with cadmium. Once again, the main thing is to make sure the datasheet ratings are aligned with the application.
4) Gold plating is typically used for switching very low-power signals. Gold provides a good solution for these applications since it does not corrode or tarnish.

Once again, the simple solution to this problem is to select a relay that is rated for the given application.

	AC Loads	DC Loads	High-Current / Inductive Load Durability	Low-Power Signals	RoHS / Conflict Mineral
Silver	✓	✓	GOOD		✓
Silver Cadmium Oxide	✓		BETTER		
Silver Tin Oxide	✓	✓	BETTER		✓
Gold Plating	✓	✓		✓	✓

Summary Table – Contact Materials

MISPERCEPTION #3: Contact Arcing Is Easily Suppressed with an RC Snubber / MOV / TVS

There are going to be some cases in which an RC snubber / MOV / TVS will provide some significant benefit, but unfortunately the user should probably assume that this will not be the case unless proven otherwise. There is much reference material out there regarding arc suppression and snubbers, but too often this material is based on the assumption that the electrical resistance of air is infinite from a practical standpoint. While this is a useful assumption in many cases, it is not correct for the air between relay contacts that are in process of opening. In fact, some simple testing can show that ionized air between relay contacts can actually allow motor current to continue to flow, imposing just a few Ohms of resistance!

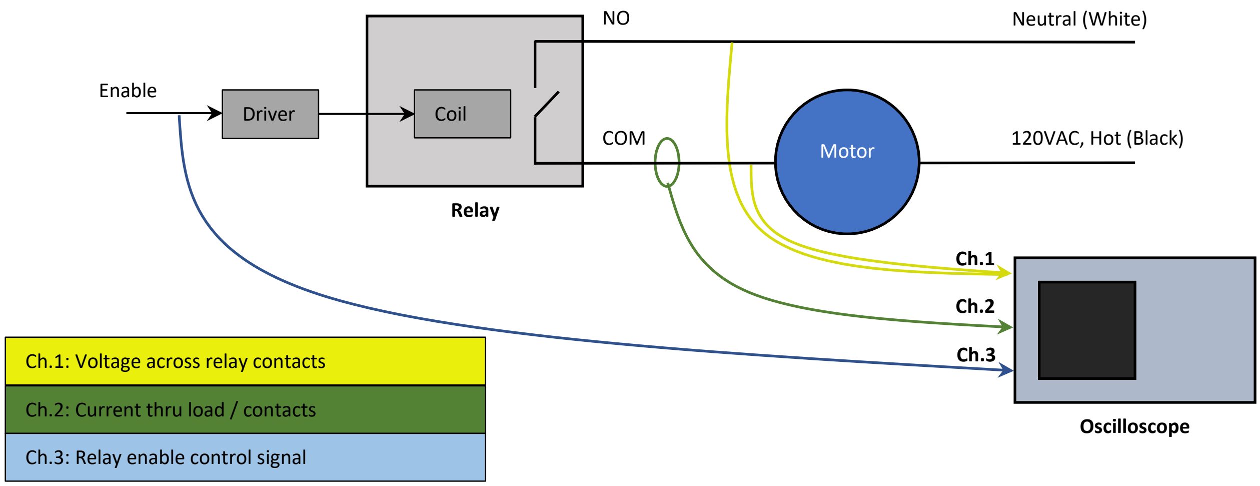
DEFINITIONS

An **RC snubber** is simply a resistor and capacitor (in series).

An **MOV** is a Metal Oxide Varistor. When its breakdown voltage is exceeded, it allows current to flow, acting as a clamp.

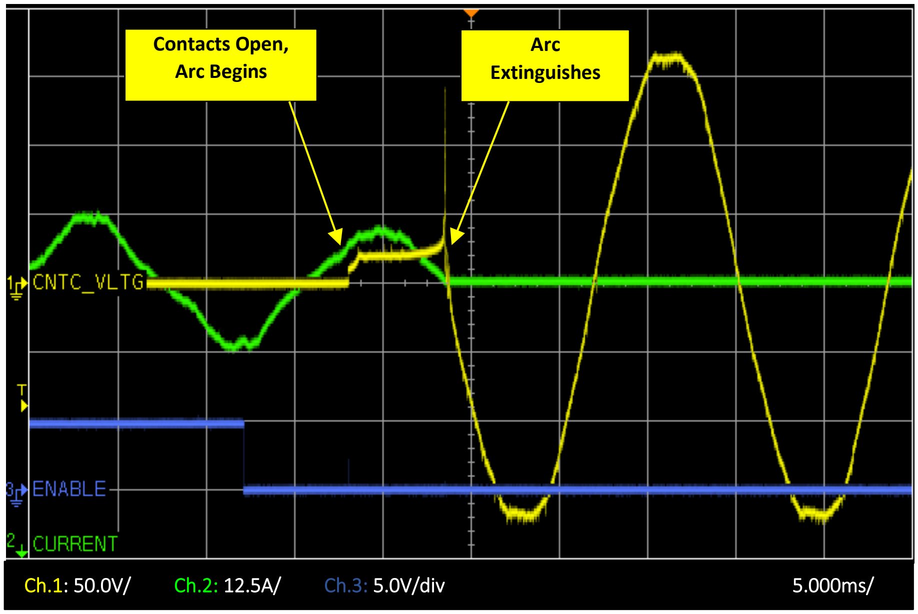
A **TVS** is a Transient Voltage Suppressor that is functionally similar to a MOV. It is comprised of one or two diodes that are rated to handle high-power transients.

Consider the following application example in which relay contacts are being used to provide power for an AC motor (a bit less than ½ HP).



You probably would expect that since the motor is an inductive load, there should be a high-voltage inductive spike that occurs when the contacts open. However, looking at captured scope traces, it can be seen that this actually is not the case. In the trace shown below, after the relay contacts open, current keeps flowing for another 4ms or so! During this time, although the contacts are open, current is flowing thru the ionized air between the contacts. This current arc continues until the arc is extinguished due to approaching the zero-crossing point of the AC current, at which point the remaining current is interrupted and the inductive spike occurs.

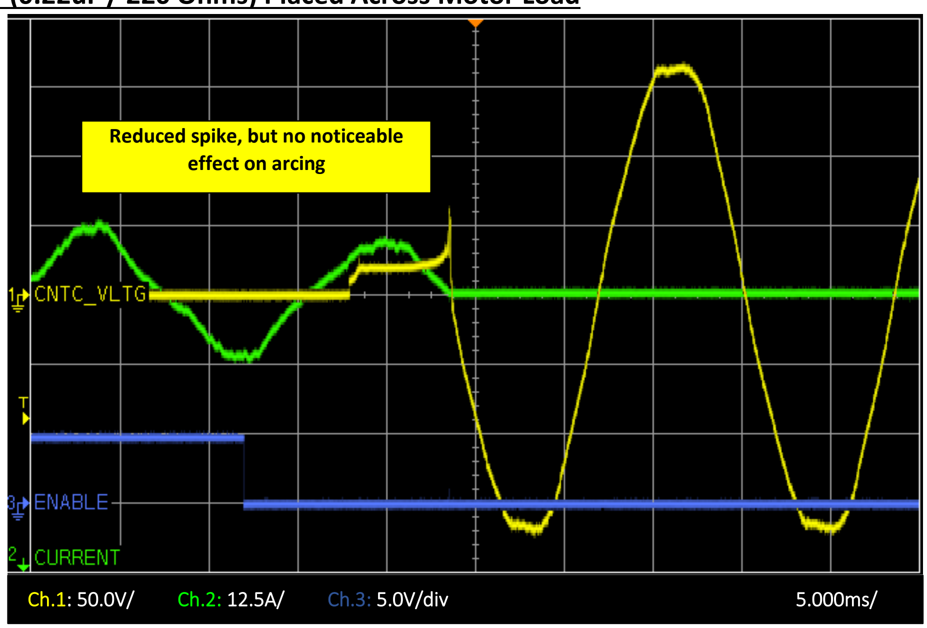
No Arc Suppression Implemented



Note that during the 4ms of arcing, the voltage across the contacts is only about 25 to 30V, so a clamping device (e.g., MOV, TVS) would not even be activated during that time.

An RC snubber also has very little effect on contact arcing, as shown below for the following case in which a snubber device (C=0.22uF, R=220 Ohms) was placed across the motor load.

RC Snubber (0.22uF / 220 Ohms) Placed Across Motor Load



It can be seen that there is some benefit in knocking down the magnitude of the inductive spike, so one would expect some EMC improvement. However, as far as reducing or eliminating the arcing, there is no significant benefit in this application.

It would be an overstatement to claim that snubbers and clamps are never effective. The point of this example is to show that the calculated effectiveness of these devices is too often based on an incorrect assumption that the resistance of air is infinite. In short, the user would do well to perform actual testing to confirm the effectiveness of whatever solution is selected for a given application.

Once again, the simple solution to this problem is to start out by selecting a relay that is rated for the given load. After that, there may be additional benefit to be gained by investigating arc suppression solutions, but the user probably should not be depending on arc suppression as a way to achieve a reliability target. The reliability target should be achieved by selecting a relay that is designed and rated for the application use case.

RELAY BOARDS FROM WINFORD ENGINEERING

RLY202 (2 channels) and RLY204 (4 channels)

- Suitable for general-purpose applications and small AC motors up to 1/3 HP
- Silver Tin Oxide contacts
- LINKS:
  - http://www.winford.com/products/rly202.php
  - http://www.winford.com/products/rly204.php

RLY302 (2 channels) and RLY304 (4 channels)

- Suitable for resistive loads from 10uA to 2.0A
- Gold-plated contacts
- LINKS:
  - http://www.winford.com/products/rly302.php
  - http://www.winford.com/products/rly304.php

RLY402 (2 channels)

- Suitable for general-purpose applications and AC motors up to 1 HP
- Silver Tin Oxide contacts
- LINKS:
  - http://www.winford.com/products/rly402.php

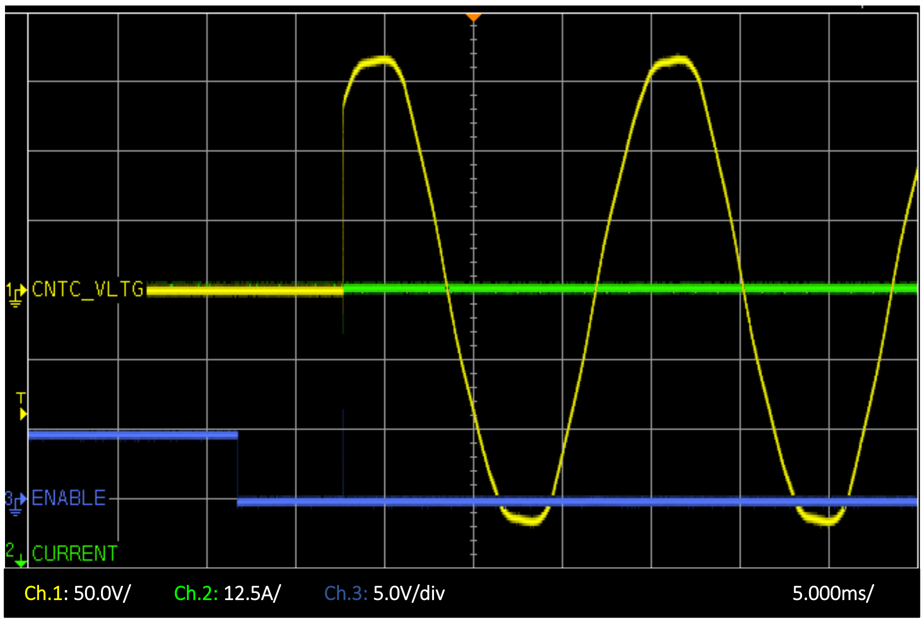
RLY501 (1 channel)

- Suitable for general-purpose applications and AC motors up to 1 HP
- Silver Tin Oxide contacts
- LINK:
  - http://www.winford.com/products/rly501.php

APPENDIX A

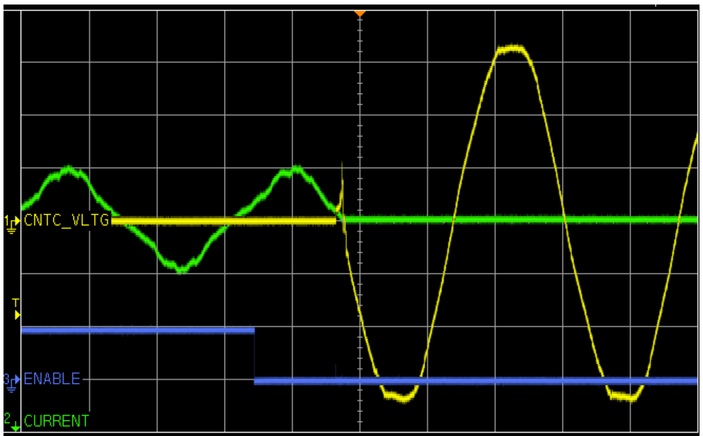
In the scope plots shown previously, there may be some questions regarding when the contacts open. Are they really opening at the time indicated in the plots, or are they actually opening when the high-voltage spike occurs? There are two methods that may be used to better understand when the contacts actually open.

Method 1: Use a Low-Current Resistive Load
For a low-current resistive load, the point at which the contacts open can be clearly determined since there will be practically no arcing. The plot below shows what happens when the motor load is removed and replaced with a low-current resistive load (68k resistor). This clearly shows that the contacts open about 6ms after the enable signal goes low, which is consistent with what was determined previously.



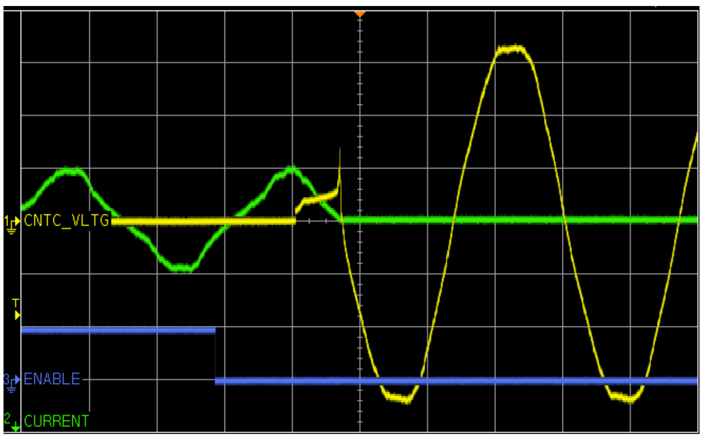
Method 2: Capture Multiple Plots and Compare

Multiple plots shown below (with the motor-load test configuration, including the RC snubber) show that no matter when the enable signal goes low during the AC current cycle, the voltage across the contacts always bumps up after 6ms elapses. However, the current always continues to flow until it approaches its zero-crossing point.



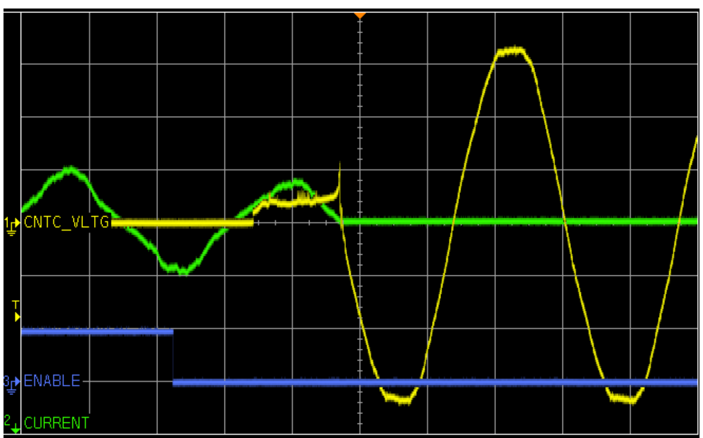
There are about **6ms** between enable signal falling edge and relay contacts opening.

Arc lasts only about **1ms** before it is extinguished by the current approaching the zero-crossing point.



There are about **6ms** between enable signal falling edge and relay contacts opening.

Arc lasts about **3ms** before it is extinguished by the current approaching the zero-crossing point.



There are about **6ms** between enable signal falling edge and relay contacts opening.

Arc lasts about **7ms** before it is extinguished by the current approaching the zero-crossing point.

APPENDIX B

One additional misperception (not addressed in the main body of this paper) is that arcing will only occur with an inductive load. The unfortunate reality is that arcing may also occur with a resistive load. Consider the plot below, which was captured by replacing the motor load with a 75-Ohm resistive load (no snubber). Even though the current is not even 3A, arcing occurs until the current approaches the zero-crossing point.

75-Ohm Resistive Load (no snubber)