

# Reducing Magnetic Interaction in Reed Relay Applications

Reed Relays are susceptible to magnetic effects which may degrade performance under certain conditions. This report presents a practical approach to reducing magnetic effects among and between Reed Relays. The guidelines can be applied to many cases.

With the trend toward reducing the size of electronic equipment, Reed Relays are typically placed in proximity to one another. Magnetic coupling between relays can affect parameters such as pull-in and dropout voltage. In some circumstances, adjacent relays will be adversely affected by their neighbors.

Experimental data is provided for some basic Reed Relay arrays under worst-case conditions. An analysis of the data is presented with equations. The data was gathered on single inline package (SIL) Reed Relays, but applies to most Reed Relay packages because the basic physical principles are the same.

A checklist for designing a relay array or matrix covers the factors necessary to minimize the electromagnetic effects most likely to be encountered. Systematically progressing through the checklist will aid in reducing or eliminating many troublesome variables.

## Factors Affecting Reed Relay Magnetic Interaction

A host of factors, internal and external, determine how a Reed Relay will perform when installed in a matrix assembly and subjected to electromagnetic interference (EMI).

**Internal Factors.** Early in the design phase, the user and the manufacturer must discuss the application and consider all the internal factors:

- Coil wire gauge.
- Coil resistance.
- Coil ampere-turns (AT).
- Coil winding direction.
- Coil winding terminations.
- Type of Reed Switch assembly.
- Number of Reed Switches in the relay.
- Internal magnetic shielding.

**External Factors.** Controlling external factors generally is accomplished by giving proper attention to the operating environment of the Reed Relay. How much effort is expended on these factors will depend on how strongly they adversely affect design performance. Consideration should be given to these factors:

- Nearby magnetic fields.
- Relay spacing in the relay matrix.
- Magnetic polarity arrangement.
- External magnetic shielding.

## Magnetic Coupling Between Reed Relays

To better understand the magnetic coupling between adjacent Reed Relays, consider this example. Figure 1 shows a portion of a relay matrix with two adjacent Reed Relays mounted on a PC board. The relays, K1 and K2, are identical in construction and the direction of current flow is the same in each.

Magnetic field lines are shown when both relays are energized. When K1 and K2 are energized, their opposing magnetic fields will adversely affect each other. This is shown where the field of K2 is extended into the body of K1.

When K2 is energized and K1 is not operating, the pull-in and dropout voltage of K2 is within the range of the manufacturer's specifications. Attempting to energize K2 when K1 is operating results in an increase of the pull-in and dropout voltage for K2, perhaps beyond the manufacturer's limits.

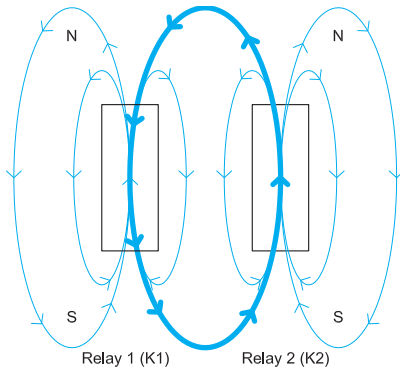


Figure 1. Magnetic Interaction Effects in Reed Relays

When K1 is energized with a current flowing opposite to that in K2, an attempt to energize K2 results in lower pull-in and dropout voltages.

### Experimental Data on Topical Relay Matrices

Relay matrices can be configured in a number of ways. In this analysis, data is presented on five typical configurations.

Polarity considerations also have been limited. The configurations and magnetic polarities presented demonstrate some worst-case effects of relay-magnetic interaction.

### Experimental Setup

Experimental data was gathered on 0.20" wide molded SIP relays. The test matrix configurations are shown in Figure 2 (Below).

Data was taken while all relays surrounding the relay-under-test (RUT) were energized with the same magnetic polarity. Once all relays were energized, the RUT (with the same magnetic polarity as its neighbors) was incrementally energized to the pull-in point. The dropout voltage data was taken in a similar manner.

All data was gathered using a 5-V coil drive. With higher voltage coils that generate equivalent ampere turns, the

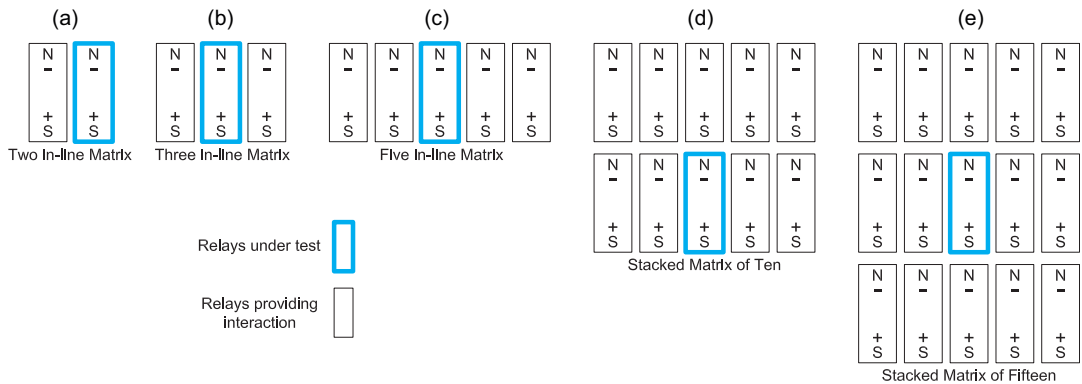


Figure 2. Relay Test Configurations: (a) Two In-Line Matrix; (b) Three In-Line Matrix; (c) Five In-Line Matrix; (d) Stacked Matrix of 10 and (e) Stacked Matrix of 15.

results are similar. Higher ampere-turn coils produce slightly higher interaction effects.

For data presented on magnetically shielded relays, the magnetic shielding is internal and an integral part of the relay (Figure 3).

## Data Analysis

In general, near worst-case magnetic interaction conditions for pull-in voltage in a matrix exist when all relay fields have the same polarity and all the fields are from adjacent relays (**Figure 2**). The interaction is somewhat reduced when the matrices have relays mounted end-to-end (Figure 2d and 2e). This effect can be seen in Figure 3b, showing the reduced interaction for the 10- and 15-relay matrices.

Under the expected worst-case conditions presented, dropout voltage is not really a concern since it increases and tracks the pull-in voltage, maintaining approximately the same voltage change. The dropout voltage may become a major concern if the magnetic polarity of

adjacent relays is opposite to that of the RUT (aiding). This situation can be avoided by assigning appropriate voltage polarities to the relays and using relays of consistent manufacture.

The change in pull-in voltage ( $\Delta PI$ ) is defined as the pull-in voltage with interaction effects minus the pull-in voltage without interaction effects. Percent increases for the pull-in voltages presented were calculated at the 5-V nominal coil voltage. Stated mathematically,

$$\% \Delta PI = \Delta PI(100)/5 \text{ volts} \quad \text{Equation 1}$$

For a given matrix, the change in pull-in voltage essentially remains the same for all relays having pull-in voltages of various levels. If one relay without interaction, for example, has a pull-in voltage of 2.3 V, it will shift to 2.7 V with interaction ( $\Delta PI$  of 0.4 V).

Now consider a second relay in the same matrix under the same conditions that has an initial pull-in of 2.6 V. With interaction, the pull-in voltage will rise to 3.0 V (again the  $\Delta PI$  is 0.4 V).

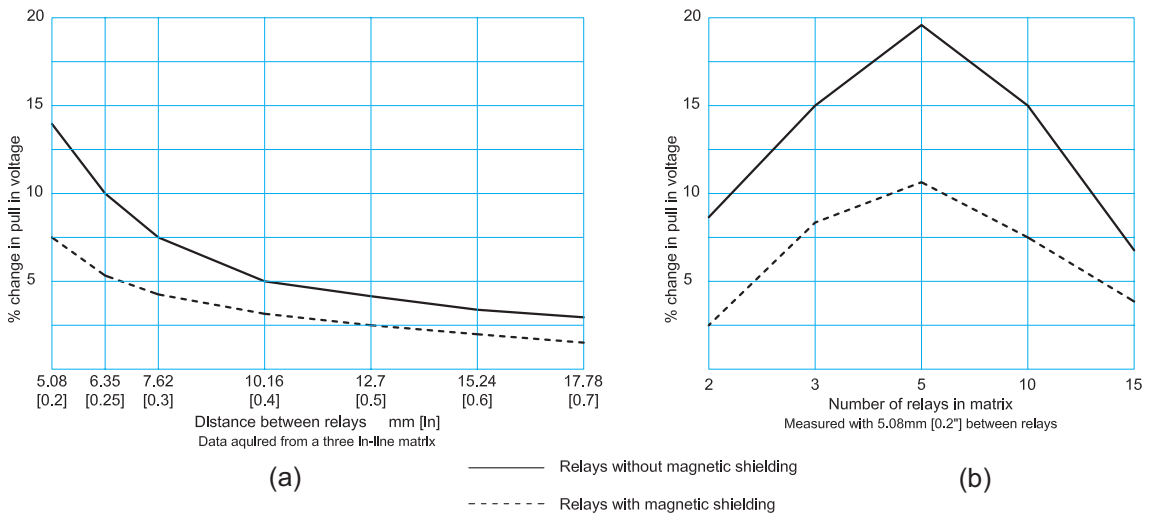


Figure 3. (a) Percent Pull-In Voltage Increase vs. On-Center Distance Between SIL Relays. Data was taken using the three-relay test matrix (see Figure 2b). (b) Percent Pull-In Voltage Increase vs. the Number of Relays in the Test Configuration. (Data was taken with the relays mounted on 0.20" width centers for all test configurations presented in Figure 2; and the 10 and 15 relay test configurations were butted end-to-end).

## Calculating the Effects of Magnetic Interaction

To further examine the magnetic interaction effects on Reed Relays, consider an example using the three-relay matrix of 5-V SIL relays in **Figure 2b** on 0.20" centers (no magnetic shielding). All testing will be performed on the center relay which has an actual pull-in voltage of 2.6 V by itself. The outer two relays are activated with 5 V applied to the coil.

The center relay will be energized and the expected pull-in voltage change can be calculated.

First calculate the pull-in voltage change. For the example, these equations will be used:

$\Delta PI = (\% \Delta PI \times V_{nom}) / 100$  **Equation 2** where:

$\Delta PI$  = the expected pull-in voltage change.

$\% \Delta PI$  = the percent interaction calculated at the nominal voltage and shown in the graphs of experimental data.  
 $V_{nom}$  = the nominal coil voltage as specified by the manufacturer.

$PI_{wc} = PI_{act} + \Delta PI$  **Equation 3**

$PI_{wc}$  = the worst-case increased pull-in voltage under interactive conditions.

$PI_{act}$  = the actual pull-in voltage without external magnetic interference.

Referring to **Figure 3a**, at a nominal coil voltage of 5 V, the magnetic interaction is 14.2%. Using equation 2 to calculate  $\Delta PI$ :

$$\Delta PI = (14.2 \times 5) / 100 = 0.71 \text{ volts}$$

The relay has an actual pull-in voltage of 2.6 V. Therefore, the near worst-case pull-in voltage can be calculated using Equation 3:

$$PI_{wc} = 2.6 + 0.71 = 3.31 \text{ volts} \text{ **Equation 3**}$$

The value calculated for  $PI_{wc}$  is perhaps the worst case for the given matrix under all possible polarity (magnetic and electrical) conditions. The value calculated for,  $\Delta PI$

is a close approximation over the entire pull-in voltage range.

Furthermore,  $\Delta PI \sim \Delta DO$ ; that is, the dropout voltage change in the matrix closely follows the change in pull-in voltage. For example, in the calculation for  $PI_{wc}$ , if the dropout voltage was measured to be 1.4 V without magnetic influence, its value will change to 2.11 V for the conditions described. Except for rare cases where special dropout conditions are required, dropout voltage changes as described do not present a problem.

## Ways to Reduce Magnetic Effects

- Specify Reed Relays with internal shielding.
- Use external magnetic shielding on the matrix.
- Provide for larger spacing between relays.
- Avoid simultaneous operation of adjacent relays.
- Design a special matrix configuration.

## Special Conditions

For conditions presented in **Figure 3**, the data was taken on single unenergized relays surrounded by energized relays. In many actual applications, the relays are energized under a host of different circumstances. Typically, banks of relays are energized together.

For example, the data gathered in **Figure 2a** will be reduced by approximately a factor of two by energizing the relays in the same matrix in this manner: energize all relays simultaneously with a ramping voltage while monitoring the center relay.

Here the interaction effects will be reduced by a factor of two. This same effect will be observed with faster and faster ramp speeds (approximately a step function) if the relays are still energized simultaneously.

This reduction in interaction occurs because of the reduced surrounding magnetic fields present at the time of contact closure, where the actual pull-in voltages are typically half the nominal voltage.

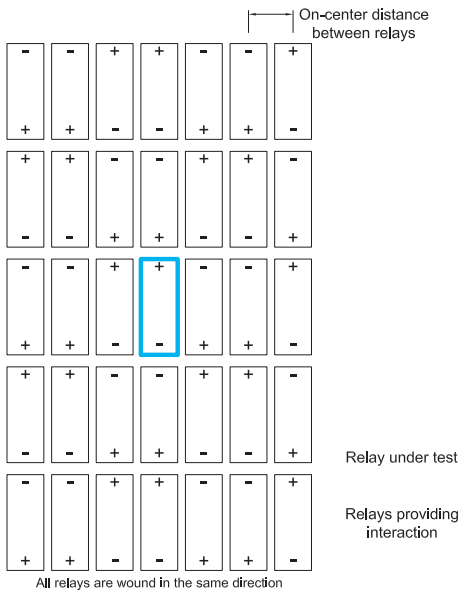


Figure 4. Alternative Pairs Relay Test Configurations.

## Special Matrix Applications

Under certain conditions, the consistent direction in which the coils are wound and terminated, particularly when mounted close together, can reduce the magnetic influence.

The matrix shown in Figure 4 uses the opposing magnetic polarities and consistent coil manufacture to reduce interaction without the added cost of magnetic shielding. This effect (Figure 5) is achieved by wiring the matrix as shown in Figure 4.

The data presented in Figure 5 can be compared to the data presented in Figure 3 for a similar nonmagnetically shielded SIL matrix of 15 where the polarities are in the same direction. The improvement or reduced interaction is 2.5 % in Figure 5 compared to 6% in Figure 3.

## Checklist for Designing a Relay Matrix

- These items should be considered:
- The applied coil voltage for each relay.
- The temp. characteristics.
- Available PC board space.

- Distance between adjacent relays.
- Scheme for energizing the relays in the matrix.
- Added cost required for shielding.
- Relay life characteristics.

## A Relay Matrix Design Example

Using the checklist, an example of a 50-relay SIL matrix design is presented. This analysis presents most of the factors affecting magnetic influence that should be considered during the design phase.

1. **Applied Voltage.** The power supply under maximum load and at 50 0C can be as low as 4.9 V minimum. Under some circumstances, the load voltage may be in series with transistor/diode drops of 0.6 V maximum over the operating temperature range. The working voltage of the power supply is reduced to 4.3 V, the actual voltage applied to the relay coil.

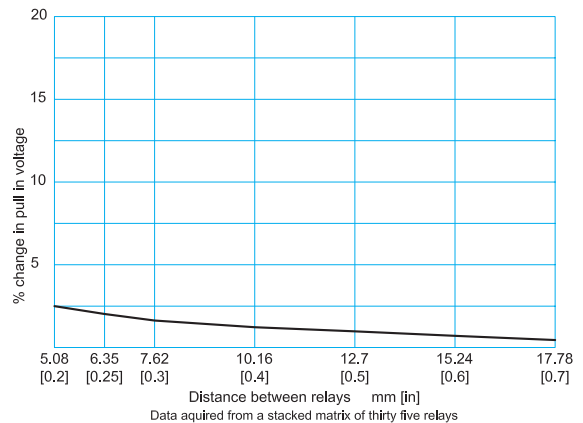


Figure 5. Alternate Pairs Matrix.

2. **Temperature Effects.** If the maximum system operating temperature is 50 0C and the specified relay pull-in voltage is 3.6 V maximum at 25 0C for a 5-V nominal coil voltage, a rise in voltage from 3.6 V to 3.96 V maximum at 50 0C can be expected.
3. **Amount of PC Board Space Required.** A 5 x 10 relay matrix (50 relays) is required. To fit the relays on the board, a crowded arrangement must be employed (only 7.75 in.2 of board space is available).

4. **Distance Between Adjacent Relays.** The relays must be placed on 0.20" centers, five rows of 10 relays each.
5. **Energizing the Matrix.** In this application, a maximum of three relays is energized simultaneously. Figure 3a presents the interaction data required for this application. Here the worst case occurs for the nonmagnetically shielded 0.20" separation and is 7.5 %. By using equation 2, the interaction effects are calculated as a worst-case pull-in voltage increase of 0.38 V.
6. **Magnetic Shielding.** It is decided not to use magnetic shielding.
7. **Life Characteristics.** In general, when switching intermediate to high- level loads, the coil voltage overdrive should be about or equal to 100% (about or equal to two times the actual pull-in voltage) for best-life characteristics. Here the relay coil overdrive is small; however, only low-level switching is expected. Therefore, the life characteristics should not be affected.
8. **Design Analysis.** If the results found in item 5 were added to the results in item 2, the maximum pull-in voltage will rise to 4.34 V under interactive conditions. This exceeds the minimum voltage of 4.3 V. Probably the two simplest approaches at this

point are increasing the power supply voltage or lowering the initial maximum pull-in voltage rating from 3.6 V to at least 3.2 V maximum. This would leave sufficient added overdrive under worst-case conditions.

## Summary

Magnetic interaction effects on Reed Relays can represent a significant problem if ignored. Many solutions are possible.

The foundation for determining worst- case scenarios on the basic matrix types is presented in this article. A systematic approach to designing a relay matrix can be achieved by referring to the checklist provided.

It is strongly suggested that the user consult with the relay manufacturer early in the design process. Following this methodology will greatly diminish the potential for unpredictable relay matrix performance.

## References

1. Stickley, B.C., "Magnetic Characteristics of Miniature Reed Relays," 14th Annual NARM Conference (1966).
2. MEDER Specification Sheets SIL-Series
3. Evaluation Engineering, May 1989.