Inductive Load Switching Characteristics of the ChipSwitch®

(ChipSwitch is a trademark of International Rectifier)

by Stan Schneider

Introduction

Due to their unique switching characteristics, solid state relays (SSRs) have firmly established themselves as electronic switches in the world of industrial controls. Many of the loads encountered in this world are inductive, from moderately inductive motors and transformers to extremely inductive solenoids and contactors. When switching such loads, the AC current lags the AC voltage, thus creating a phase angle difference commonly specified as power factor. Power factor is defined as R/Z or the cosine of the phase angle difference between voltage and current and decreases with increasingly inductive loads.

This phase difference has in the past caused switching problems for SSRs, especially those designed to switch at the advantageous zero voltage crossing point of the line, as in the case of International Rectifier's ChipSwitch microelectronic relay. For these reasons most SSRs are rated at a minimum power factor of 0.5, while the ChipSwitch solid state device is rated at a greatly improved minimum of 0.2. Further, the 0.5 power factor rating has been achieved with the use of internal snubbers which, while improving inductive load capability, increase off-state leakage and reduce reliability. The ChipSwitch meets its 0.2 minimum power factor without the use of snubbers. It is the purpose of this application note to indicate the wide safety margin in the unsnubbered 0.2 power factor specification of the ChipSwitch relay and to establish that the performance is maintained over life.

Possible SSR Switching Problems

The inductive effects that could limit performance are those that occur during or following current transitions such as partial turn-on (half-waving) and failure to turn-off (lock-on). In the case of half-waving, the reapplied voltage traverses the zero switching window too fast to trigger the thyristor due to current phase shift in each previous half cycle (Figure 1 — Condition A). Lock-on is where retriggering occurs every half cycle (with no input signal) due to the rapidly rising reapplied voltage (dv/dt), a totally different phenomenon, but also a result of the current phase shift (Figure 1 — Condition B). Increased junction temperature tends to increase the relay's susceptibility to this phenomenon.

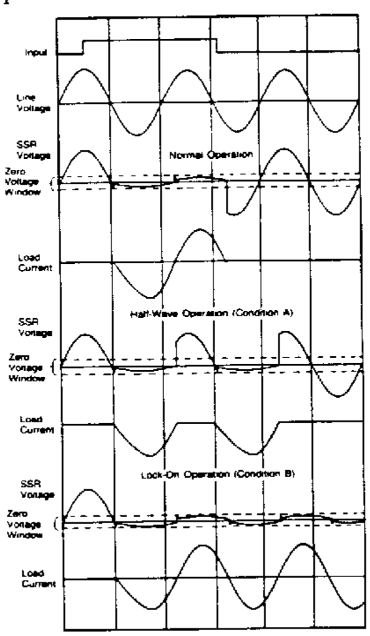

Figure 1. Waveforms Illustrating Half-Wave and Lock-On Phenomena

Power Factor Testing

The initial testing was performed with a load bank of passive inductors (chokes) and resistors that were adjusted to provide the appropriate load and power factor for each test condition. A series of tests were then made on a number of ChipSwitch relays using the test set-up of Figure 2. In order to detect a malfunction, the samples were examined at both turn-on and turn-off, as well as for symmetry of waveform at each test point.

The test samples were selected randomly from past and present production lots and were put through the normal final test procedure.

Samples were tested over a power factor range from 0.5 to 0.1 as measured on an oscilloscope (Figure 3) under the following conditions:

Ambient Temperature:	Room (25°C)
Input Current:	5 mA DC
Output Voltage:	5V, 140V, 280V (RMS)
Load Current:	5 mA,20 mA,300 mA, 650 mA, 1A (RMS) (But not greater than the rated current for each model).

Test Results

All samples operated correctly over the entire range of power factor.

Over Temperature Testing

In order to force a failed condition or a malfunction, five ChipSwitch relays were deliberately heated beyond the maximum specified full load 40°C ambient and the power factor of the load was varied over the same range as in the previous test. In the range of 40 to 50°C above specification and at full rated current, parts began to lock-on, but would recover when cooled. With resistive loads even higher temperatures were attained without lock-on. From this it is clear that, the dv/dt of the reapplied voltage, as is the normal case, is the cause of lock-on. It is also clear that a very large safety margin has been built into the ChipSwitch design.

Life Cycle Testing

While the previous tests confirm performance with passive inductive loads of varying power factors, it was felt that a practical test with a highly inductive, high inrush load would be in order. A NEMA No. 2 motor starter was chosen with the following coil characteristics:

	VA	Watts	Power Factor	Amps
Inrush	360	—	—	3.3
Sealed	41	10	0.24	0.37

With 5 mA of control current five ChipSwitch microelectronic relays were operated 100,000 times with a 50% duty cycle and a 10 second period.

Test Results

No malfunction occurred during the entire test duration and the ChipSwitch relays when retested showed no deterioration in specification. These results have been re-confirmed by additional testing as reported in Application Note AN-100.

Analysis of ChipSwitch Performance

The problems that might have afflicted conventional SSRs when subjected to the same series of tests were described in earlier paragraphs. Some of the reasons why the ChipSwitch was successful in these cases, even without a snubber, are as follows:

The two independently fired photo coupled switches, IC_1 and IC_2 shown in Figure 4, do not have the recovery time problems that might occur with a single SCR in a full-wave bridge circuit or with a triac which is used in many discrete SSRs. With the input energized the very fast turn-on properties of these SCRs allow the device to have sufficient time to turn-on when subjected to the step function reapplied line voltage at zero current. This insures that half-waving cannot occur.

The novel zero voltage detection and clamping circuit formed by C1, distributed gate capacitor C2, and FET Q1 effectively protects the SCR from turning on under the conditions of high reapplied dv/dt occurring when the ChipSwitch relay is turned off. Therefore, lock-on cannot occur under specified conditions.

Conclusions

In this application note we have shown the excellent inductive load switching capabilities of the ChipSwitch solid state relay and its inherent immunity to the ill effects of phase shift that so often plague more conventional SSRs.

Although no lower limit for power factor was found, the ChipSwitch can clearly operate loads with power factor magnitudes down to 0.1, thus assuring its successful use in what must be its greatest area of application. For example, the majority of motor starters and contactors have power factors between 0.15 and 0.4.

The unwillingness of the ChipSwitch microelectronic relay to half-wave, even well beyond its specification is tremendously important with inductive loads such as transformers that are prone to saturation. The DC component produced by a half-waving SSR can bring about saturating currents that result in its own destruction. The ChipSwitch will not self destruct in this manner and will provide dependable performance in an area that has long been questionable for SSRs.

Finally, the absence of a snubber and the ChipSwitch relay's inherently low leakage permit the switching of small, highly inductive loads at low voltage (e.g., 5 mA at 20 VAC and 0.1 pF). These characteristics together with a small zero switching window make International Rectifier's ChipSwitch microelectronic relay unique among AC SSRs.□

References

1. International Rectifier Application Note AN-100. "The Switching Life of ChipSwitch Microelectronic Relays."

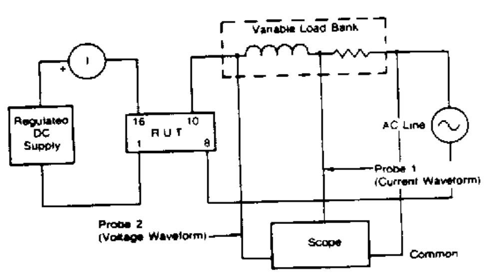

Figure 2. Test Set-Up

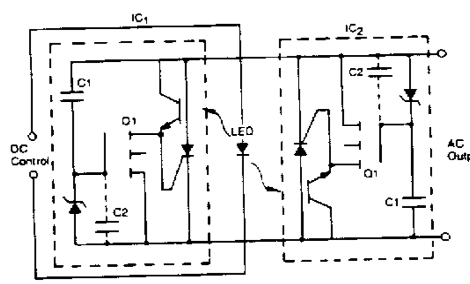

Figure 4. ChipSwitch Equivalent Circuit

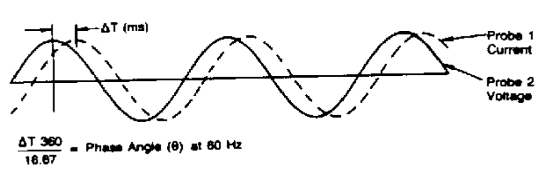

Figure 3. Power Factor Measurements