Film Capacitors – AC Capacitors

Application note

Drive Circuit for Induction Motor Control, using EPCOS LCap Series and STMicroelectronics Triac or ACS

Series/Type: B32350 LCap
Date: 2012-12-04
Drive circuit for induction motor control, using EPCOS LCap series and STMicroelectronics Triac or ACS (AC switches)

Summary

This document describes a highly cost-effective solution for electronic motor control in domestic appliances for bidirectional motors such as washing machines, dryers, gate / door openers, awning drives and blinds. This solution reduces the need for mechanical switches and relays, thereby improving the efficiency and reliability of these appliances.

Application

The standard bidirectional asynchronous induction motors used in appliances such as washing machines have two windings: main and auxiliary. A run capacitor is needed to start the motor into the required direction by phase shift. Electromechanical switches are used to control it (on-off, direction of rotation).

An electronic motor control can be used to reduce power consumption and relay noise, increase efficiency and reliability as well as eliminate mechanical switch constraints.

An effective way to enhance performance while remaining cost effective is to control the motor with a microcontroller unit (MCU) that drives two AC switches.

Compared to a circuit using electromechanical switches, this approach offers:

- Higher efficiency: No power is consumed by continuous current flowing through the relay coil. The AC switches are operated by a single pulse.
- Increased reliability: Longer operating life of AC switches
- Spark-free operation reduces electromagnetic interference (EMI)
- Noise reduction through elimination of mechanical relays

The AC switches of the latest generation are ideal for this application. They offer fast switching, spark-free and noiseless operation and a longer operating life, as they are driven by gate currents as low as 5 mA. The $I_{TSM}$ (surge current) capability can sustain very high levels. Thus one 16 A AC switch can sustain a surge current of 160 A and a repetitive $dI/dt$ of 100 A/µs. The phase angle can be easily controlled, whereas this would be hard to achieve for mechanical relays.
Purpose of the induction coil in series with the capacitor

If one AC switch is in the “on state” and the second one also goes to this state due to a perturbation (for example, EMI could force both switches to the “on state”), both switches will discharge the capacitor without any current limitation. This electrical overstress may damage the switches. To prevent this, an inductor is inserted in series with the capacitor to limit the current supplied by the capacitor during the period of electrical overstress.

Example

A typical AC switch current of 1000 A (see Figure 1) for the first peak lasting 25 µs is possible when both AC switches are forced to the “on state” simultaneously. This value is typical for a bidirectional asynchronous induction motor of 230 V, 50 Hz with a rated power of 150 W driven by a circuit with two AC switches using a phase shift capacitor of 10 µF. This high current exceeds the maximum value allowed for the AC switches.

Figure 1: Peak current of -1073 A for 25 µs (without inductor in series with capacitor)
Drive circuit for induction motor control, using EPCOS LCap series and STMicroelectronics Triac or ACS

Figure 2: Peak current of -232 A for 110 µs (with inductor in series with capacitor)
Solution

A series inductor limits the current peak. The \( \frac{dl}{dt} \) rate will be shifted to values that AC switches can handle without sustaining any damage. In the above example, an inductance of 80 \( \mu \)H reduces the first peak current to below 250 A (See Figure 2) with a duration of 110 \( \mu \)s.

Tests at the STMicroelectronics laboratories have shown best results when using an LCap from EPCOS, an integrated capacitor and inductor device combining the phase shift capacitor with the current limitation inductor in one case. This is seen as the best solution for assembly in production lines thanks to improved FMEA (failure modes and effect analysis) results due to fewer operations and a lower component count.

Figure 3: Schematic diagram for electronic motor control

In Figure 3, C is the motor run capacitor producing the phase shift for the auxiliary winding. The series impedance L is needed to protect the AC switches in case of false triggering causing both AC switches to be in the “on state”. The parasitic resistor R represents the total impedance of the branch (C+L).

Circuit design

The capacitor and inductor ratings depend on the motor characteristics (power, operating voltage, frequency). STMicroelectronics offers free selector guide software to help calculate and select the required characteristics of the Triacs or ACSs (AC switches). It is available upon request from the sales departments of STMicroelectronics.
Modes of application in washing machines

During washing mode, the drum is rotated in both directions by turning-on each AC switch alternately. One of the two windings of the induction motor is supplied directly by the mains voltage. The other is supplied through the capacitor C providing a phase shift and a high voltage across the capacitor, which can reach a peak value of 650 V.

During spin mode, only one AC switch will be turned on, since the drum will be spinning at maximum speed.

Advantage of EPCOS LCap compared to discrete capacitor / inductor combinations

- Low-rated parasitic resistor
- Long-term stability of narrow tolerances
- Highly rugged, maintenance-free
- Compact size
- Two connections instead of four
- Reduced assembly time

This technology is successfully used by global market leaders. It produces cost-effective, easy-to-mount solutions. The combination of an inductor coil and a capacitor in a single package allows narrow tolerances to be specified for both components.
Typical combinations for LCap, AC switches (Triac and ACS™)

<table>
<thead>
<tr>
<th>Motor power</th>
<th>B32350 LCap (EPCOS)</th>
<th>Triac and ACS™ (STMicroelectronics)</th>
</tr>
</thead>
<tbody>
<tr>
<td>190 W/ 230 V 50 Hz (washing machine)</td>
<td>10 µF 80 µH</td>
<td>ACST1235* ACST1035* BTA12-800CW* High Tj Triacs*</td>
</tr>
<tr>
<td>250 W/ 230 V 50 Hz (washing machine)</td>
<td>50 µF 100 µH</td>
<td>ACST1635-8FP* BTA16-800CWRG* High Tj Triacs*</td>
</tr>
<tr>
<td>120 W/ 230 V 50 Hz (fridge compressor)</td>
<td>4 µF 5 µH</td>
<td>ACST610-8* BTA06-800TWRG* BTB12-600TWRG* High Tj Triacs*</td>
</tr>
</tbody>
</table>

* Several packages are available, please check the respective datasheets

Table 1: Typical combinations of LCap and AC switches - actual values defined in each case

Products and pictures

<table>
<thead>
<tr>
<th>EPCOS</th>
<th>STMicroelectronics</th>
</tr>
</thead>
<tbody>
<tr>
<td>B32350 LCap series (integrated capacitor / inductor device)</td>
<td>AC switches: Triac series BTBA, high TJ (TxxxxH) and ACST</td>
</tr>
</tbody>
</table>

Table 2: EPCOS and STMicroelectronics products for this application
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Authors

- Mischa Baur, Manager Product Marketing AC Film Capacitors, EPCOS, mischa.baur@epcos.com, +49-89 636 26353
- Jean-Michel Simonnet, Application & System Engineer, STMicroelectronics, jean-michel.simonnet@st.com, +33-2 47 42 40 00
- Odilon Deroldo, Technical Product Marketing, STMicroelectronics, odilon.deroldo@st.com, +33-2 47 42 42 70

Terms

Triac: Triode for alternate current

ACS: ST AC switch designed to sustain overvoltage without the need for a varistor

High TJ: Triac with a junction temperature capability of 150 °C
The following applies to all products named in this publication:

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