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A SIMPLE APPROACH TO UNDERSTANDING A FILTER INDUCTOR APPLICATION.

These inductors are a family of ruggedly manufactured toroidal inductors, designed to filter out noise currents from various electrical and electronic power control circuits.
They find applications in such diverse fields as lighting dimmers, EMI/RFI filters, PWM and PM circuits primarily for motor controls, UPS Systems, and differential mode line filters. These inductors have found many applications in commercial, industrial, medical, consumer or military equipment, and whenever a high quality noise rejection filter system is required. Every inductor is tailored and optimized for each specific application. For example, in lighting dimmer applications, the thyristors are switching to phase control the AC line voltage. This will produce quasi-pulse currents which introduce noise from 120 Hz right into the MHz region. It is necessary to employ special materials and winding techniques to effectively filter the noise generated by the switching thyristors and transmitted to the load. After years of research and development, our engineers at RTIE/Amecon Magnetics have produced inductors utilizing newly developed materials, designs, and processes which have already succeeded in setting new standards for choke performance in the lighting dimmers as well as in the UPS industries.

BASIC DESIGN CRITERIA FOR DIMMER CHOKES

The way a solid state switch controls the current at the load is to chop off parts of the sinusoidal current leaving it with very fast overt shooting pulses every time the thyristors turn on (i.e. once every half cycle). These sudden transitions, occurring from zero to full peak current generate electrical noise over a wide gamut of frequencies, as well as delivering a considerable mechanical shock to the load and thus creating acoustical noise. In the case of a lamp this effect causes the filament to vibrate and more times than not, this will also induce the bulb, socket, and fixture into a coherent oscillatory mode (i.e. resonance) which will manifest itself as a louder noise. These vibrations will shorten the life of the lamp. A simple and widely used practice to remedy this condition is by placing an inductor in series with the load to dampen the current pulses. The manner in which the current rises di/dt is referred to as the slew rate and its magnitude is directly related to the amount Of noise generated at the output. We must keep in mind that when the inductor is designed correctly it will not only help To reduce the audible noise to acceptable levels, it will also filter out the EMI/RFI, and serve as a current limiter which Will save the thyristors from burning up under short circuit conditions. The range of di/dt commonly used by the industry Is from 20 mA/µs to 50 mA/µs.

UNIFORMITY OF THE SLEW RATE

It is important that the current will rise at a smooth and gradual rate for optimum noise attenuation, this will help to accomplish the best performance. Let’s consider an inductor with an l vs. T characteristic as shown in fig. 1.
This inductor clearly supports a voltage for too long after turn on of the thyristor and before full conduction begins, this is Created by high magnetic core losses resulting in a larger than necessary voltage drop, which directly subtracts from the load voltage. This is not a desirable effect, and with its unduly high losses will hinder circuit performance. The noise is determined By the maximum slew rate di/dt, in this instance, as it can be observed from fig. 1. It is quite large.

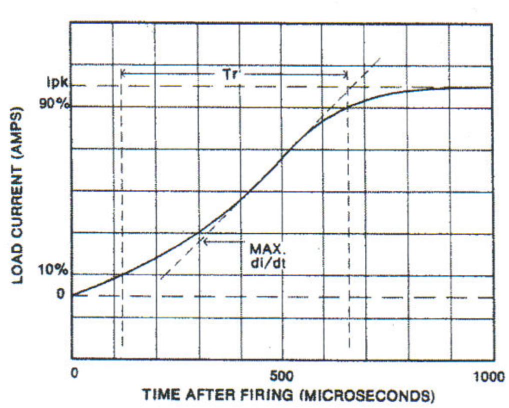

Fig. 1 di/dt at 90° Firing Angle

Fig. 2 shows a Tr (i.e. rise time) curve when an oriented silicon steel core is used as the magnetic material, this type of inductor is typically designed and used in countries other than the U.S. The rise time taken by the current to go from 10% to 90% of its final value, which is the method used to date in determining inductor performance, is large and so is the maximum slew rate which makes this type of inductor ineffective in damping certain critical frequencies, particularly the higher ones, created by the solid state switching devices.

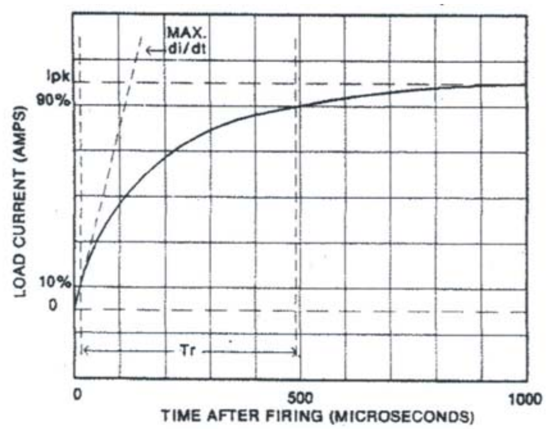

Fig. 2 di/dt at 90° Firing Angle

THE INDUCTOR'S CORRECT AND NEW DESIGN CRITERIA

It should by now be clear to the reader that many of the traditional design concepts, materials and techniques don't work quite right in this application. After analyzing the results of a thorough study from past designs and technology it became evident to us that a new approach was needed. It is obvious that in order to get the minimum slew rate would be to have a current-rise which will closely approximate that which we consider the ideal curve, shown in Fig. 3a. In this instance the rise time "Tr" is inversely proportional to the slew-rate di/dt and it is representative of a choke's noise level (i.e. lower di/dt means lower noise).

The slew-rate is then approximately given by $\frac{di}{dt} = 0.8 \times \frac{lpk}{Tr}$ the answer will be in mA/µs. Fig. 3b shows how close to the ideal one can easily get with proper materials and design criteria.

Example: A choke which will give a 400 µs Tr at a 20A load based on the approximation formula will give $\frac{di}{dt}$ of 40 mA/µs.

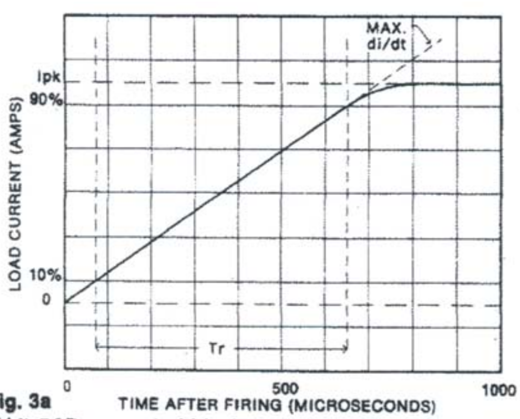

Fig. 3a
di/dt CAD generated ideal curve simulating a 90° turn on point.

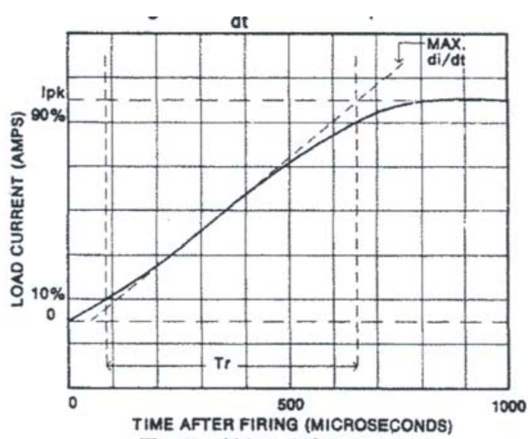

Fig. 3b di/dt at 90° Firing Angle

THE LOAD DEPENDENCE ON MAXIMUM SLEW RATE

When the slew rate changes with load, then a change in acoustics level will result, a condition easily detectable when extra lamps are switched on or off. This is a very undesirable condition, since varying acoustics levels are by far more noticeable and disturbing than those which are a monotone and of the same magnitude. It is therefore, very important that the slew-rate remain nearly constant not only with time, but also over a wide range of loads. After years of experimenting and research working with many materials and hundreds of choke designs, we at RTIE/Amecon Magnetics have succeeded in producing inductors with slew rate very nearly constant from approximately 25% to 125% of their rated loads, these same inductors are also excellent for attenuating both odd and even harmonics in a lighting dimmer system.

THE TEMPERATURE DEPENDENCE

All materials should be stress relieved or environmentally cycled to improve thermal stability and thus reduce deviations, over the normal operating temperature range, from published specifications, all inductors should comply with this requirement. RTIE/Amecon Magnetic's do.

Note: Should you like a complete 8 page design manual compiled by RTIE/Amecon Magnetic's engineering staff. Please request it on your company's letterhead stating your area of responsibility.