A NEMA Low Voltage Distribution Equipment Section Document
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Recommendations on AFCI / Home Electrical Product Compatibility

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Foreword

This is a new NEMA white paper. It was developed to provide the designers of home electrical products (HEPs) with information on the operating parameters of arc-fault circuit interrupters (AFCIs), with the purpose of avoiding conditions in which the HEP could cause the unwanted operation of an AFCI.

To ensure that a meaningful publication was being developed, draft copies were sent to a number of groups within NEMA having an interest in this topic. Their resulting comments and suggestions provided vital input prior to final NEMA approval and resulted in a number of substantive changes in this publication. This publication will be periodically reviewed by the Molded Case Circuit Breaker Product Group of the Low Voltage Distribution Equipment Section of NEMA for any revisions necessary to keep it up to date with advancing technology. Proposed or recommended revisions should be submitted to:

Vice President, Technical Services
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This white paper was developed by the Molded Case Circuit Breaker Product Group of the Low Voltage Distribution Equipment Section of NEMA. Approval of this white paper does not necessarily imply that all members of the Product Group voted for its approval or participated in its development. At the time it was approved, the Molded Case Circuit Breaker Product Group had the following members:

ABB Control, Inc.—Wichita Falls, TX
Eaton Corporation—Pittsburgh, PA
General Electric—Plainville, CT
Siemens Industry, Inc.—Norcross, GA
Schneider Electric USA—Palatine, IL

1 Introduction

Modern technology has helped make homes safer and more convenient, but conflicts in performance criteria between interdependent products can result in inconvenience for the homeowner. Designers of home electrical products (HEPs) seek to meet the demands for improved customer convenience and satisfaction as they design new and improved consumer products. Designers of sophisticated electrical circuit protection products, such as arc-fault circuit interrupters (AFCIs), strive to make homes safer by meeting the legal requirements established by local, state, federal, and national electrical codes and standards. While conflicts in the operation of the two product categories are rare, an understanding of some of the operational requirements of AFCIs can help reduce the possibility that unwanted operation of AFCIs could be caused by HEPs. These recommendations will familiarize the HEP designer with the basic operation of AFCIs to help reduce unwanted operations.

HEPs within the scope of these recommendations are those that operate at 120 Vac and are rated 20 A or less. They may include appliances of all types, power tools, electronic products such as computers, printers, office equipment, audio and video equipment, and communications equipment. In other words, any line powered electrical products that may be used in the home.

2 General Design Recommendations to Reduce AFCI/HEP Conflicts

Conflicts do a disservice to our mutual customers. Consumers will inevitably attribute the problems that they encounter to either the AFCI or the HEP manufacturer. It is in the best interest of all concerned, and especially in the interest of the homeowner, the customer, that products are compatible with each other. The recommendations in this paper will help avert these conflicts.

There are three levels at which to analyze the design of HEPs and how they will interact with AFCIs. The information provided below is a composite of the operating characteristics of the four AFCI manufacturers.

2.1 General Design Considerations

Conflicts between HEPs and AFCIs can be avoided in many instances by keeping current requirements within two simple boundaries, defined as a maximum current leakage to ground (ground-fault current) and maximum peak current. These boundaries are fundamental, as exceeding them can cause conflicts with other protective devices as well.

2.1.1 Ground Fault Currents

If the current leakage to ground does not exceed the limits specified in UL 101, the HEP designer can be assured that the product will not cause the unwanted tripping of AFCIs due to excessive ground fault current.

2.1.2 Peak Current Considerations

The second general design recommendation involves the limiting of the peak current drawn by HEPs. When many electrical products are initially energized, it is common for them to draw a high amount of current for a few cycles as the product reaches its normal operating performance level. This start-up or inrush current is typically several times the operating current of the product. If the maximum current during start-up (or for any short period of time during the operation of the HEP) is kept below 100 amperes RMS, unwanted tripping of AFCIs, and standard circuit breakers, should not occur.

2.2 Other Design Considerations

AFCIs evaluate a number of other parameters. The following table lists these parameters.

Common Arc Characteristics (Both Branch Feeder and Combination Types)

Parameter	Magnitude or Trip Threshold	Duration
Current	Greater than 46 peak amps	Longer than 0.4 milliseconds
Number of current pulses	Greater than 2 within ½ second	
Current frequency	Greater than 150 Hz	
Current pulses per half cycle	No more than 1	½ cycle
FCC conductive emissions	Levels exceeding FCC Part 15, Class B conducted emissions	3 cycles or more
High frequency emissions	Greater than 75 KHz	3 cycles or more
Shoulders (see 3.3 below)	Discontinuous current at a zero crossing with respect to the voltage wave	See 3.3 for duration
Missing half cycles (see 3.4 below)	Missing half cycle(s) of current with respect to the voltage wave	½ cycle

3 Additional Recommendations to Reduce AFCI/HEP Conflicts

AFCI designs often evaluate the current waveform of the load in an attempt to identify characteristics that have been found to typify the waveforms generated by arcing faults. In some instances, it has been found that the current waveforms of HEPs also exhibit some of these same characteristics. This makes the task of distinguishing a normally operating HEP from an unwanted arc difficult and has at times led to unwanted tripping and customer dissatisfaction.

The HEP designer should avoid designing a product whose waveform exhibits these characteristics. Some examples are shown below.

3.1 High Frequency Conducted Emissions

One of the key characteristics of arc faults is the presence of high frequency energy when current is flowing through an arcing junction. A significant amount of arc energy spreads throughout a wideband frequency spectrum in a pink-noise pattern that spreads throughout the complete frequency spectrum. AFCI designs take into consideration high frequency content to validate the presence of arcing faults in the line and any source of noise coupled to the line that can potentially affect their performance.

The Federal Communications Commission (FCC) requires certain HEPs connected to the ac power line to not exceed a maximum level of conducted and radiated emissions back into the power line (refer to FCC 47 CFR Part 15 Class B and Part 18 Consumer ISM Equipment). HEP manufacturers must consider following these guidelines as requirements in their designs in order to control the amount of noise emissions in the power line, even if not required to do so by the FCC, to help prevent unwanted action by an AFCI installed on the same circuit.

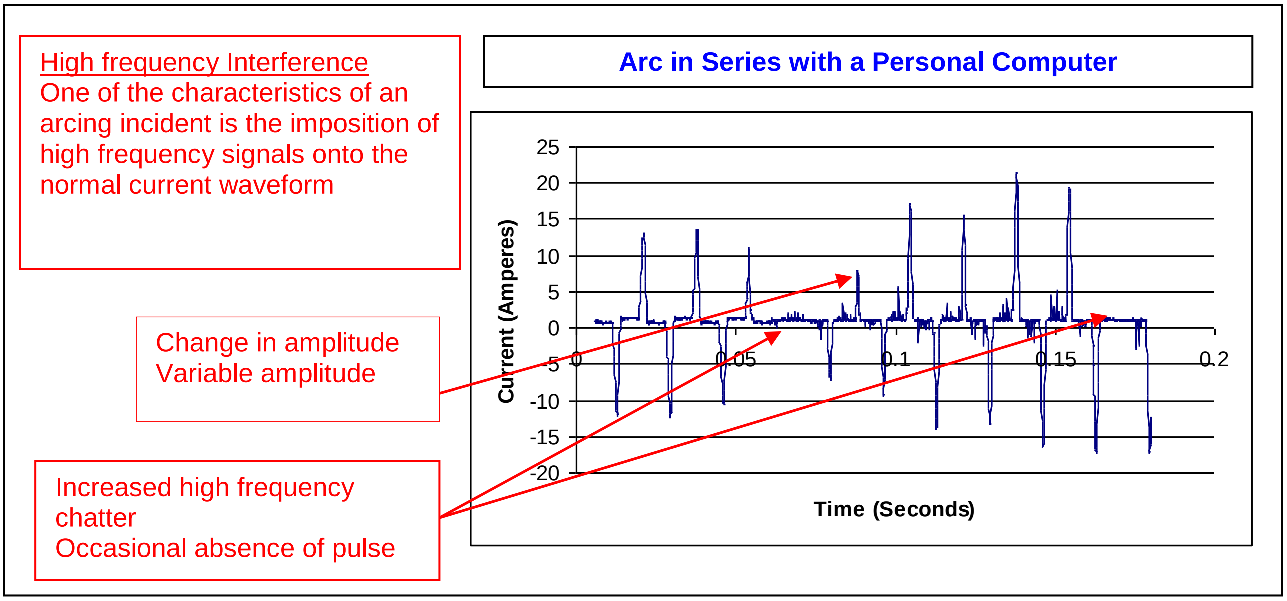

Figure 1
Arc in Series with a Personal Computer

Also, some products, in this case a personal computer (see Figure 1), can exhibit some of the same characteristics as an arcing condition. In the left portion of the graph, the computer is performing in its ordinary manner. It does impress some disturbances on the line, but note that the amplitude of the waveform remains constant from cycle to cycle, and the high frequency noise remains fairly constant. However, when we review the waveform on the right portion of the graph, we note that the high frequency signal becomes much more animated, and that one of the current pulses is missing from the waveform. In this case it is important for the AFCI to recognize the type of signal that the computer emits under ordinary operation, but yet be able to differentiate between the normal signal and the arc signal. UL imposes a lengthy test procedure to ensure that the AFCI can differentiate between these signals and not be masked from responding to the similar (but different) arcing waveform.

3.2 Start-Up Inrush Current with High di/dt

Some electrical products, once turned on, will draw a significant amount of current that will remain high for several cycles until it stabilizes to a steady-state current. This start-up inrush current level will be several times the normal operating current, and decays to the steady state current over several cycles. Certain electronically controlled products may use starting techniques in which the rate of rise in the current (di/dt) may be quite high. This high rate of rise shows as a near vertical leading edge of the waveform, while the trailing edge may assume the partial shape of the ideal sinusoidal waveform. This waveform is typical of products that use thyristor starting controls, and can be interpreted as an arcing fault under some conditions (see Figure 2).

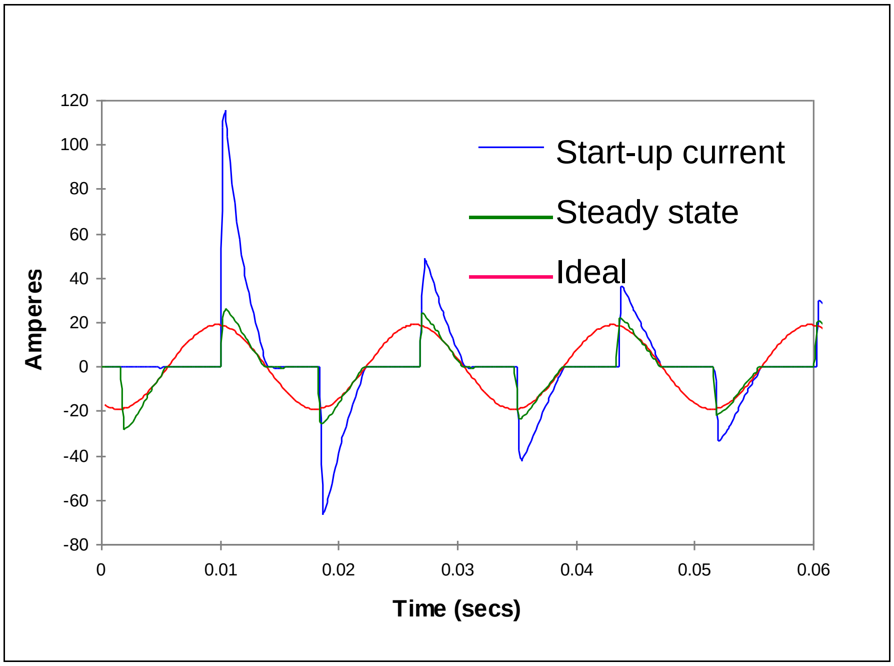

Figure 2
Start-Up Inrush Current with High di/dt

3.3 Shoulders

Another characteristic of arc faults that could be duplicated by a HEP is the appearance of periods of no current for ± 1 millisecond or less at the zero crossing of the ideal waveform. An arc fault can extinguish briefly when there is enough of a drop in source voltage and the conditions are not capable of sustaining the arc. This phenomenon is referred to as “shoulders.” Typically, the arc reignites when the source voltage is available in the next ac half cycle. The current waveform for this occurrence is shown in Figure 3, with the ideal current shown in red, and the arcing current, exhibiting shoulders, shown in blue.

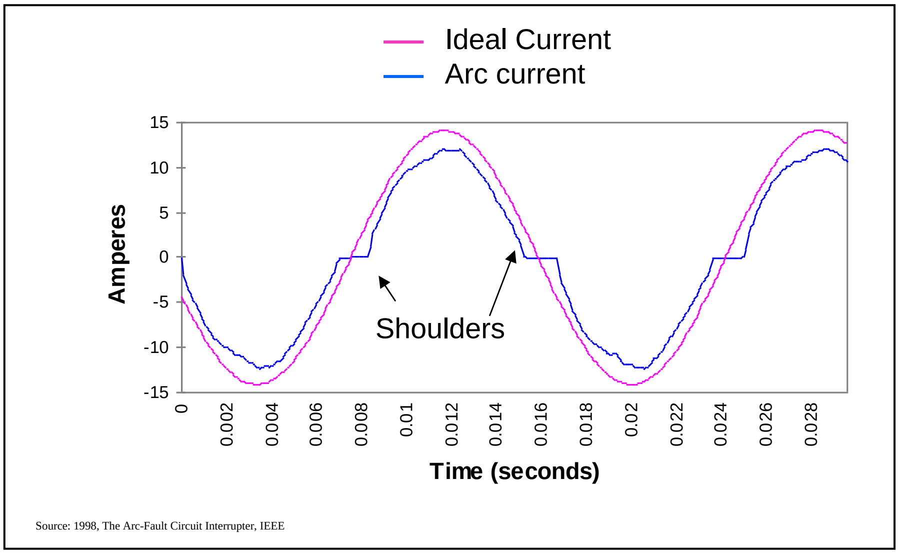

Figure 3
Shoulders

The relationship between the voltage and the current during an arcing event is shown in Figure 4. Note the shoulders at the zero crossings.

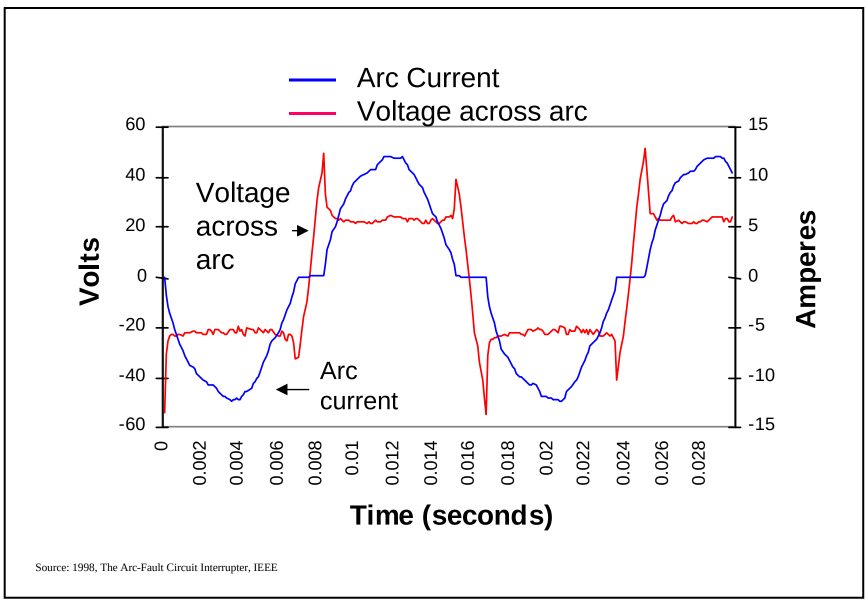

Figure 4
Arc Current and Voltage

An extension of that behavior is seen with loads with a crest factor. A typical sinusoidal current will have a crest factor of 1.414. As the crest factor increases, the shoulders are more pronounced. Figure 5 shows a typical load with those characteristics. A vacuum cleaner is one example of how the current waveform of a HEP can mimic the characteristics of an arc, much like those observed during UL 1699 testing.

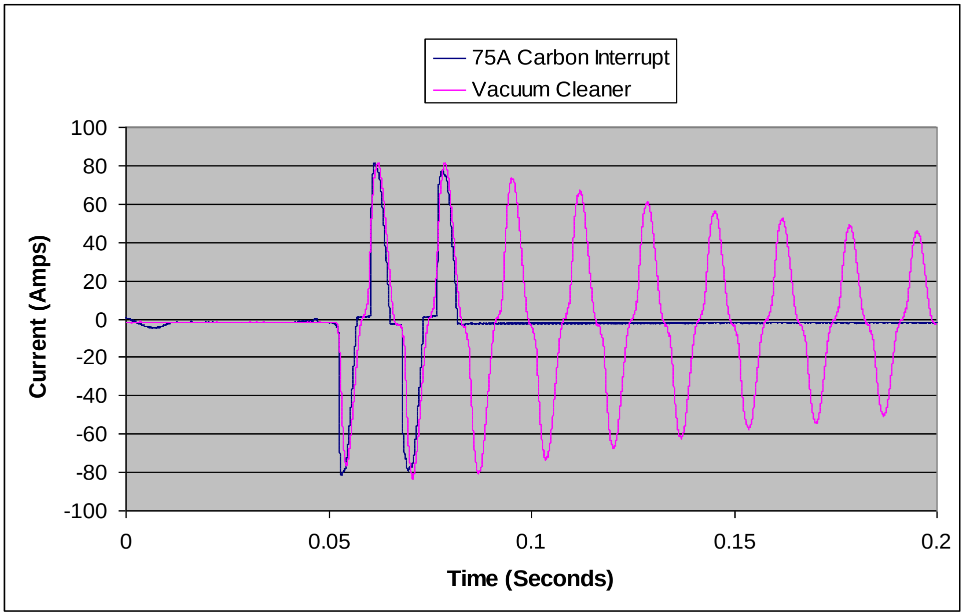

Figure 5
Typical Arc Current vs. that of a Vacuum Cleaner

3.4 Missing Half Cycles

In Figure 6, this laser printer had missing half cycles and high current peaks when warming up. Both of these are arc characteristics.

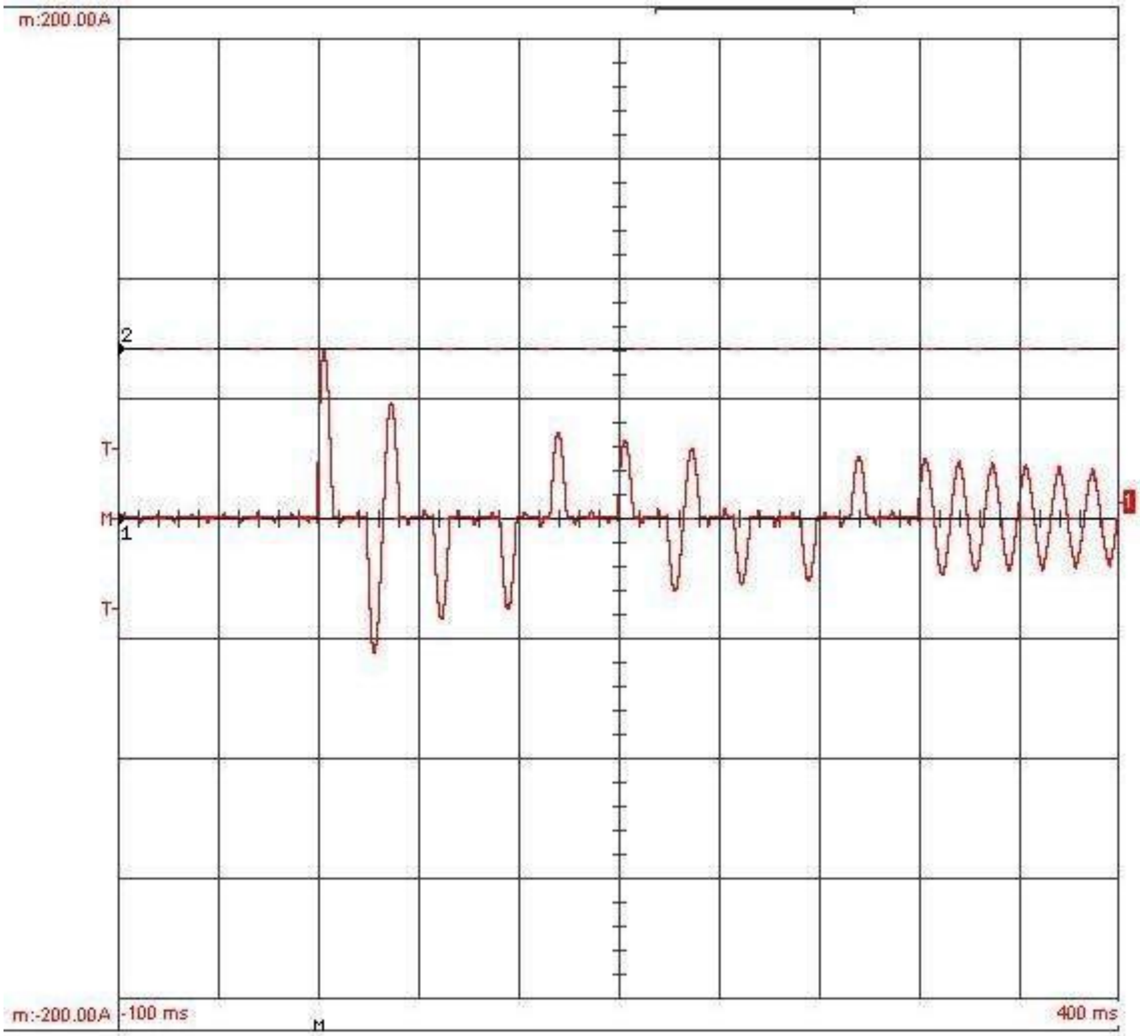

Figure 6
Laser Printer

In Figure 7, this vacuum cleaner, with an electronic control, also had missing half cycles and inconsistent starting current decay when starting up.

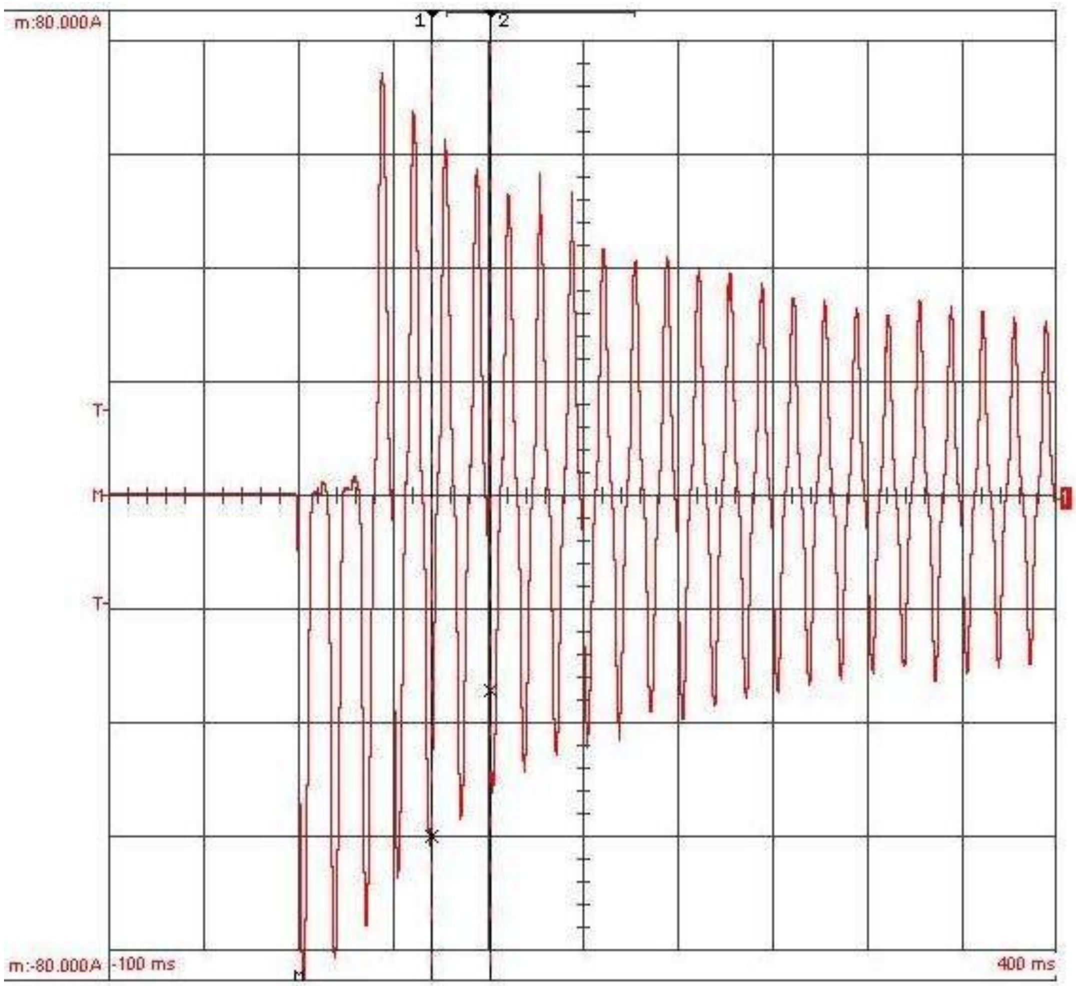

Figure 7
Vacuum Cleaner with an Electronic Control

4 Conclusions

The need for better, safer homes and increasingly efficient and convenient operation of HEPs can result in the rare conflict between the home electrical product and the operation of AFCIs. It is vitally important that the operation of the AFCI be understood in order to avoid operational conflicts, and that designers of both products work together to resolve these operational conflicts. By recognizing the operational characteristics outlined above, it is anticipated that even these rare instances of unwanted tripping of the AFCI can be eliminated.

The above discussions on the design and operation of AFCIs are intended to familiarize the HEP designer with the operation of AFCIs, and to help reduce the potential that the normal operation of a HEP will cause unwanted tripping of the AFCI. While designing with these parameters in mind should greatly reduce the probability that a newly designed HEP will cause unwanted tripping of an AFCI, further testing with the available brands of AFCIs will help identify any compatibility issues with existing AFCI technology. In the event that unwanted tripping does occur, it is recommended that the HEP designer contact the AFCI manufacturer to analyze the compatibility issue.

5 Additional Information

5.1 About AFCIs

Additional information about AFCIs may be found at www.afcisafety.org.

5.2 AFCI Manufacturers

AFCI circuit breakers are manufactured by the following companies:

Eaton Corporation
1000 Cherrington Parkway
Moon Township, PA 15108

GE Industrial Solutions
41 Woodford Avenue
Plainville, CT 06062

Schneider Electric
1415 S. Roselle Rd.
Palatine, IL 60067

Siemens Industry, Inc.
5400 Triangle Parkway
Norcross, GA 30092

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