Application Brief

Improving Arc Fault Detection with Log Amplifier

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Introduction

Arc fault detection requires distinguishing the signatures of a hazardous arcing condition from the wide range of other noisy load conditions and controlled arc conditions such as that of a brushed motor. Arcing happens in cases of insulation failure or poor wiring connection which results in a gap between conductors close enough to each other to allow electrons to jump across the gap.

The arcing signal starts as an instantaneous step in current as this gap voltage reaches the required level to ionize across the gap. Once the ionized conduction path forms the current path now has a time varying resistance across the ionized arc. This causes broadband frequency variations 40-60dB smaller in amplitude than the load current.

The initial spike as the arc ignites can look like a relay switching or light dimmer. Switch mode power supplies and brushed motors generate noisy load conditions similar to arc signatures. Therefore, it is useful to use higher frequency information where there is less signal overlap to distinguish between a controlled and uncontrolled arc. The arcing signature noise extends beyond 1MHz up to 20MHz, where most of the load noise signature is reduced.

To sample and process this signal digitally requires a sample rate >20MSPS and an MCU with enough processing bandwidth to filter the data in real-time. One other challenge of arc detection systems is that arc currents can range multiple orders of magnitudes. For example, UL1699 requires interruption of 5A-500A.

To solve the challenges above a logarithmic detector is preferred for this application due to its ability to envelope incoming high frequency and output a DC / low frequency signal based on the amplitude of the incoming signal. Besides the ability to down convert high frequency, the 80 to 90dB dynamic range of detection coupled with the low input voltage sensitivity make these log detectors a preferred for this application. The LOG300 with 40MHz of bandwidth and 98dB dynamic range does that and scales the output logarithmically to the amplitude of incoming high frequency arc signal.

Figure 1 shows a brushed motor vacuum which has a small amount of normal arcing as the brushes in the motor spin. The 3d plot shows the magnitude of the current, over 1-30MHz frequencies and time from 0-40ms (two cycles). In normal operation with brushed motor there are small near constant peaks at 15MHz and 5MHz.

Figure 2 shows a vacuum motor with an arc in series. Every 8.3ms (half cycle of 60Hz) there is a noticeable peak from the arc ignition and while the base noise level is only slightly higher, in this case the noise floor is from the probes used to measure the current. The next section shows a clear design of a circuit with a log detector to extract this high peak noise, and low-level base noise for arc detection.

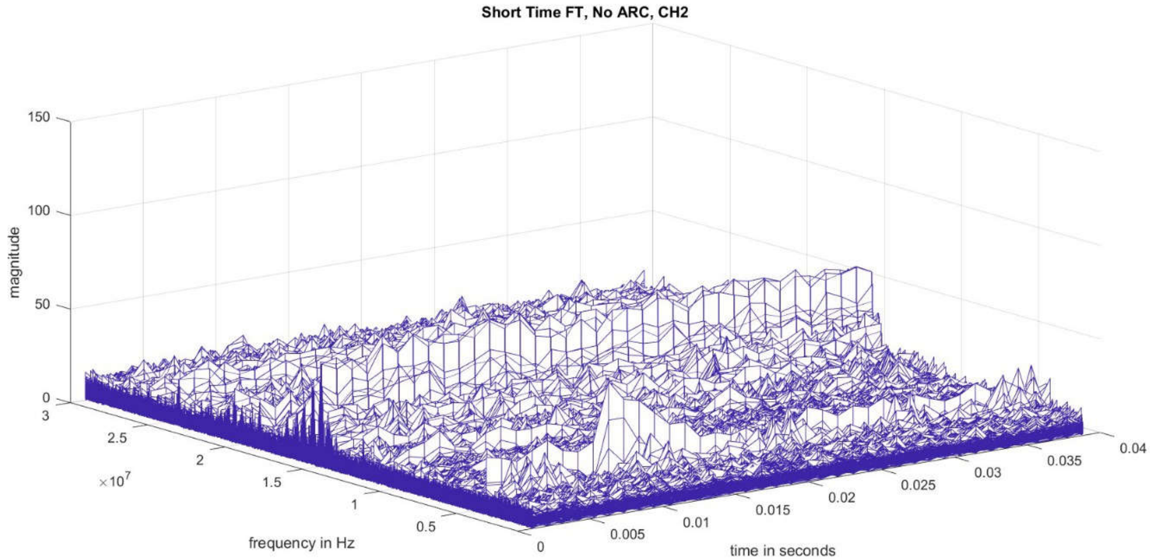

Figure 1. Vacuum Load Normal Operation

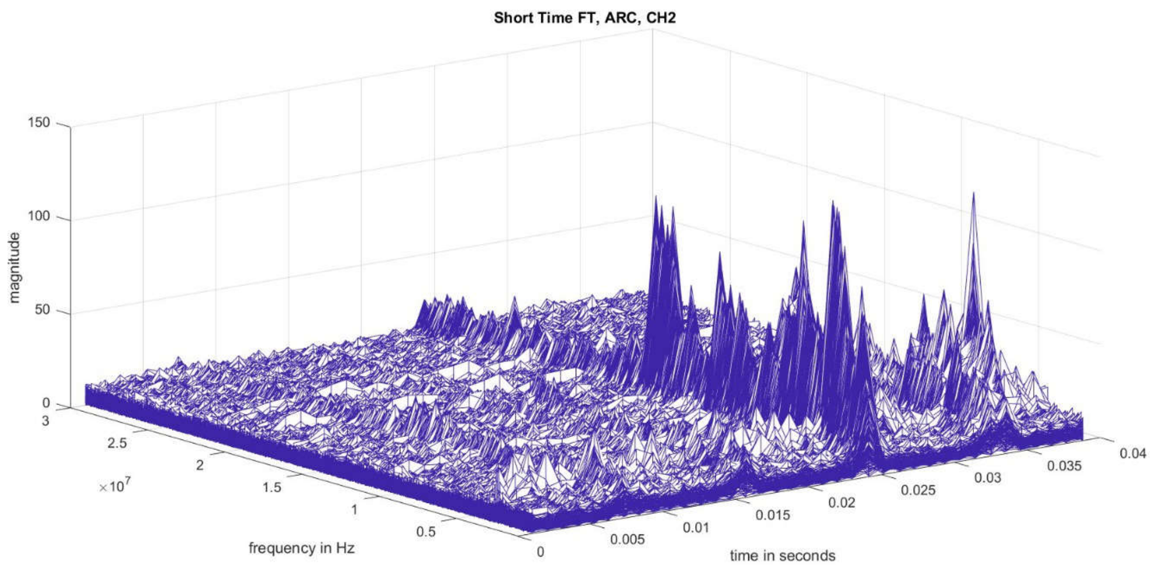

Figure 2. Vacuum Motor with Arcing

Arc Detection Examples With LOG300

Figure 4 shows example arcing data collected using TIDA-010971 analog front end with an arc generator as defined in UL1699. This TI reference design uses precision op-amp TLV387 to integrate a wide bandwidth PCB di/dt current sensor. The reference design also features LOG300 AFE, a device which incorporates a low noise amplifier input stage, and log detector. The output of LOG300 is near constant with typical loads due to the 10MHz passive filter removing most load noise. During an arc event with 10MHz frequency content the LOG300 output responds logarithmically as an envelope of the applied input. The enveloped output is of much lower frequency, therefore this data can be sampled and processed with a much lower requirement on sample rate and MCU bandwidth.

Even for non-sinoisodal loads such as a light dimmer the LOG300 is able provides a clearly separable signal from normal operation. Due to varying circuit and load impedances, a simple linear algorithm may not be sufficient for generalized arc detection. For the most robust arc fault detection, the LOG300 analog output data can be used to train a machine learning algorithm to classify the arcs. (Examples available in EDGE AI Studio)

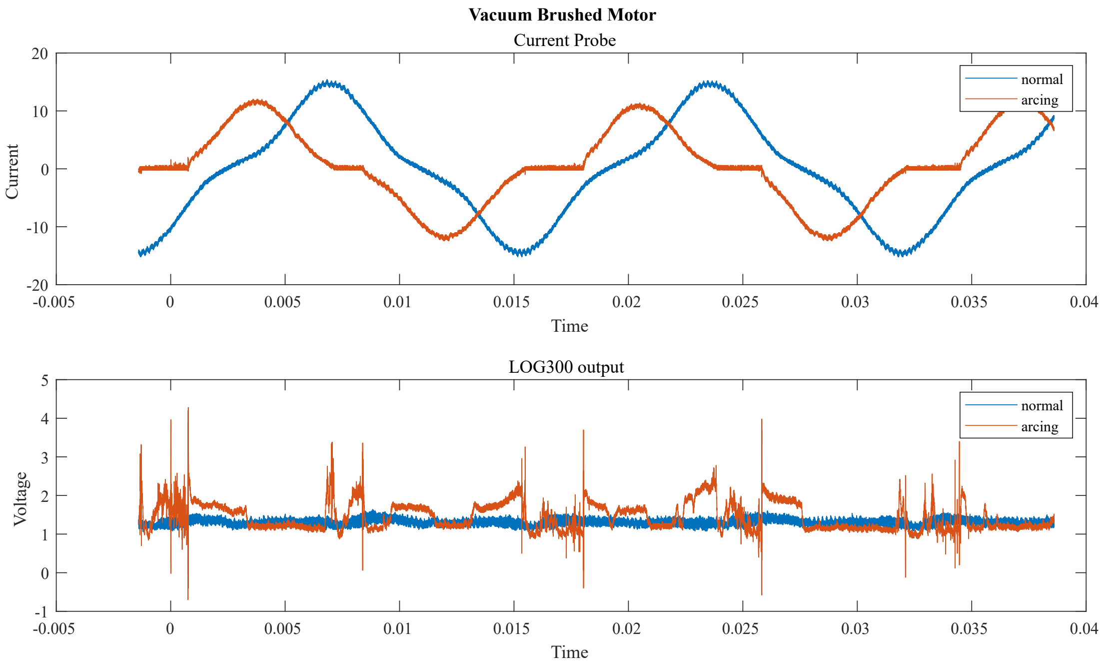

Figure 3. Vacuum Motor Normal vs Arcing

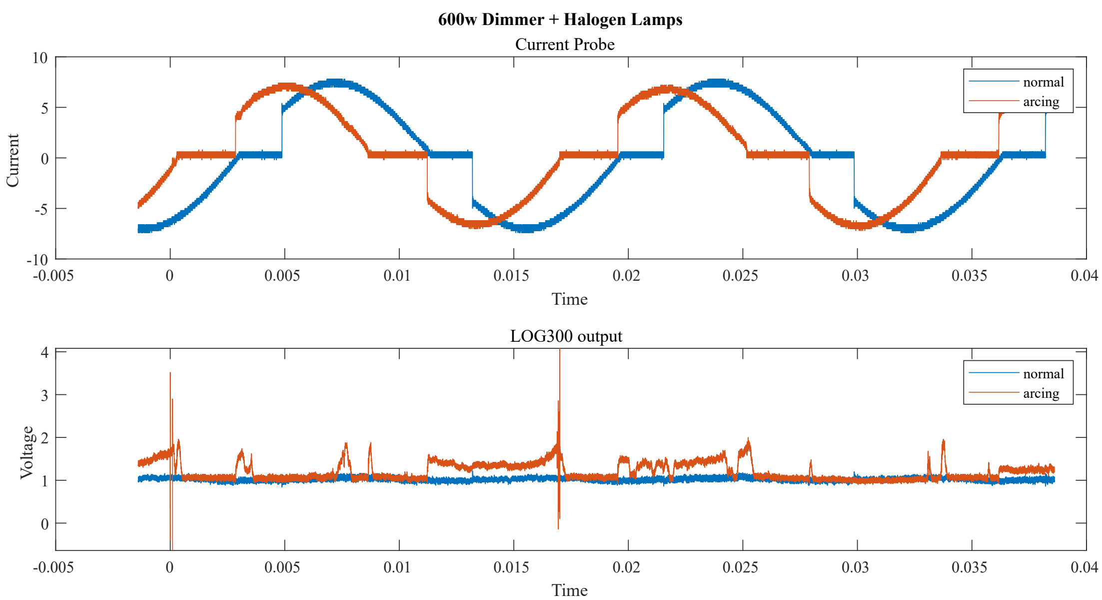

Figure 4. Dimmer Normal vs Arcing

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