Oscilloscope Applications

MREC Rural Energy Conference 2012

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Introduction

An oscilloscope can help the user get more detailed electrical measurements than can be obtained with a voltmeter alone. Oscilloscopes are not required to complete a stray voltage investigation under any of the investigation protocols energy providers are required to use, however an oscilloscope may be useful during some stray voltage investigations.

These application examples and exercises are designed to introduce you to the functions and operation of an oscilloscope and provide learning experiences which will help you use an oscilloscope to collect accurate, meaningful data in stray voltage investigations. After completing these application exercises you will be able to use an oscilloscope to collect accurate, meaningful data in a stray voltage investigation and evaluate that data. These skills can also be used to apply an oscilloscope to other electrical troubleshooting tasks.

Conventional and Unconventional Stray Voltage

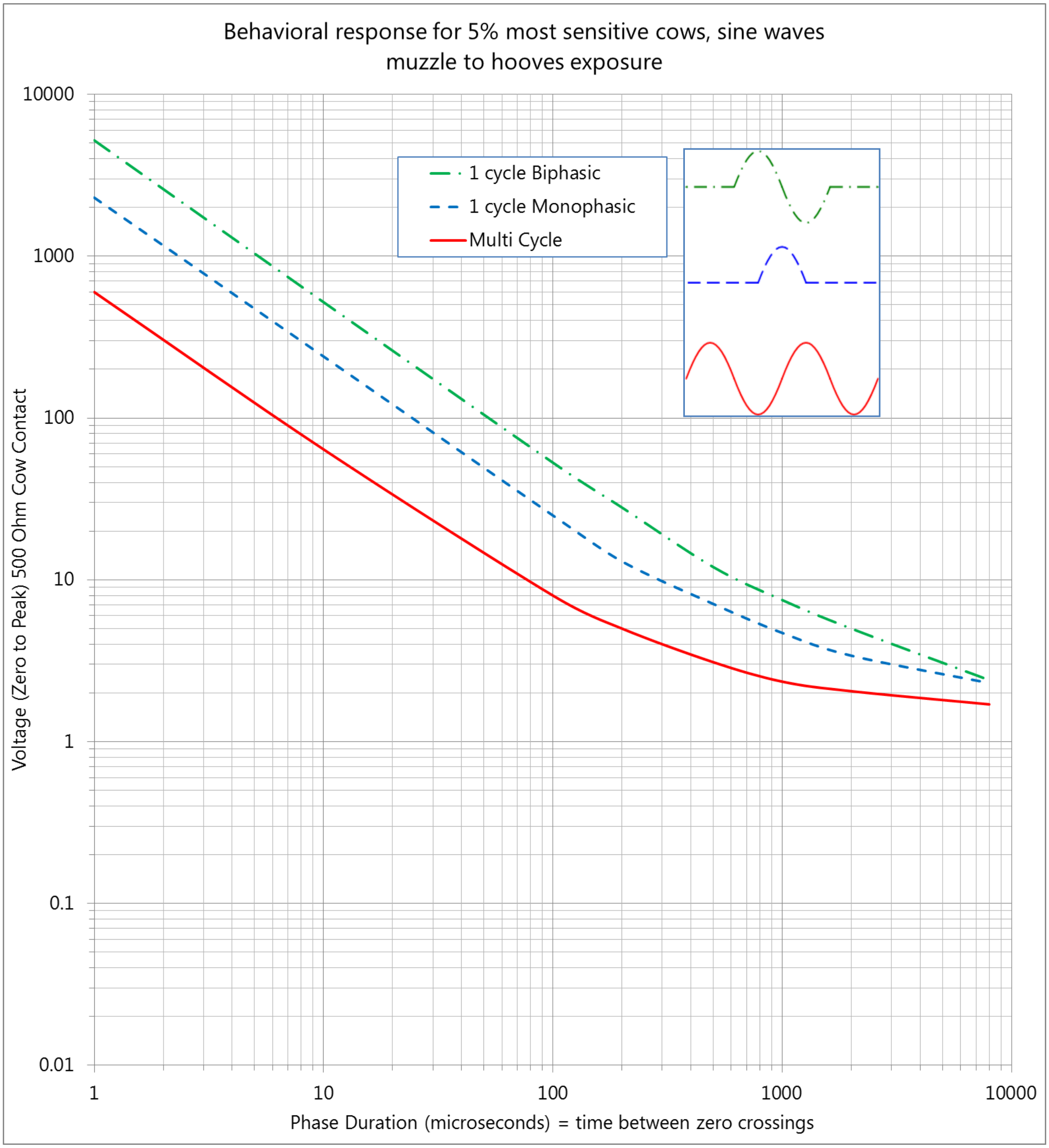
Conventional stray voltage issues generally involve grounding and bonding problems that result in normal load current causing increased neutral-to-earth voltage (NEV) which in turn causes increased steady-state contact voltages. For the purpose of this oscilloscope applications seminar, unconventional stray voltage may or may not involve a grounding and bonding problem. The contact voltage may be intermittent or at significantly higher frequencies than the nominal power system frequency or its common harmonics.

Note:

These exercises were designed using a Fluke 199-series oscilloscope, however other oscilloscopes will have similar functions/options. Where specific control sequences are described, these are the steps for a Fluke 199-series oscilloscope.

Evaluating steady-state and transient cow-contact voltages:

Cows (and humans) are less sensitive to short duration and higher frequency electrical exposures than they are to longer duration and lower frequency electrical exposures. The strength/duration graph below can be used to determine if a particular steady-state or transient voltage is likely to elicit a response from a sensitive cow.



Adapted from "What do we know about Stray Voltage?" Douglas J. Reinemann, Ph.D., University of Wisconsin-Madison, 2009

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Module 1: Oscilloscopes and cow behavioral response

Purpose: Gain experience plotting and analyzing waveforms captured at cow-contact locations.

Learning outcomes: You will learn to recognize different types of waveforms and use their phase duration and peak amplitude to plot them on a behavioral response graph.

1. Plot one point for each of the waveforms described below on the behavioral response graph on the next page. Assume each was measured across a 500-ohm shunt resistor.

   a. A continuous sine-wave with a peak amplitude of 5V and a frequency of 20kHz.

   b. The transient shown below:

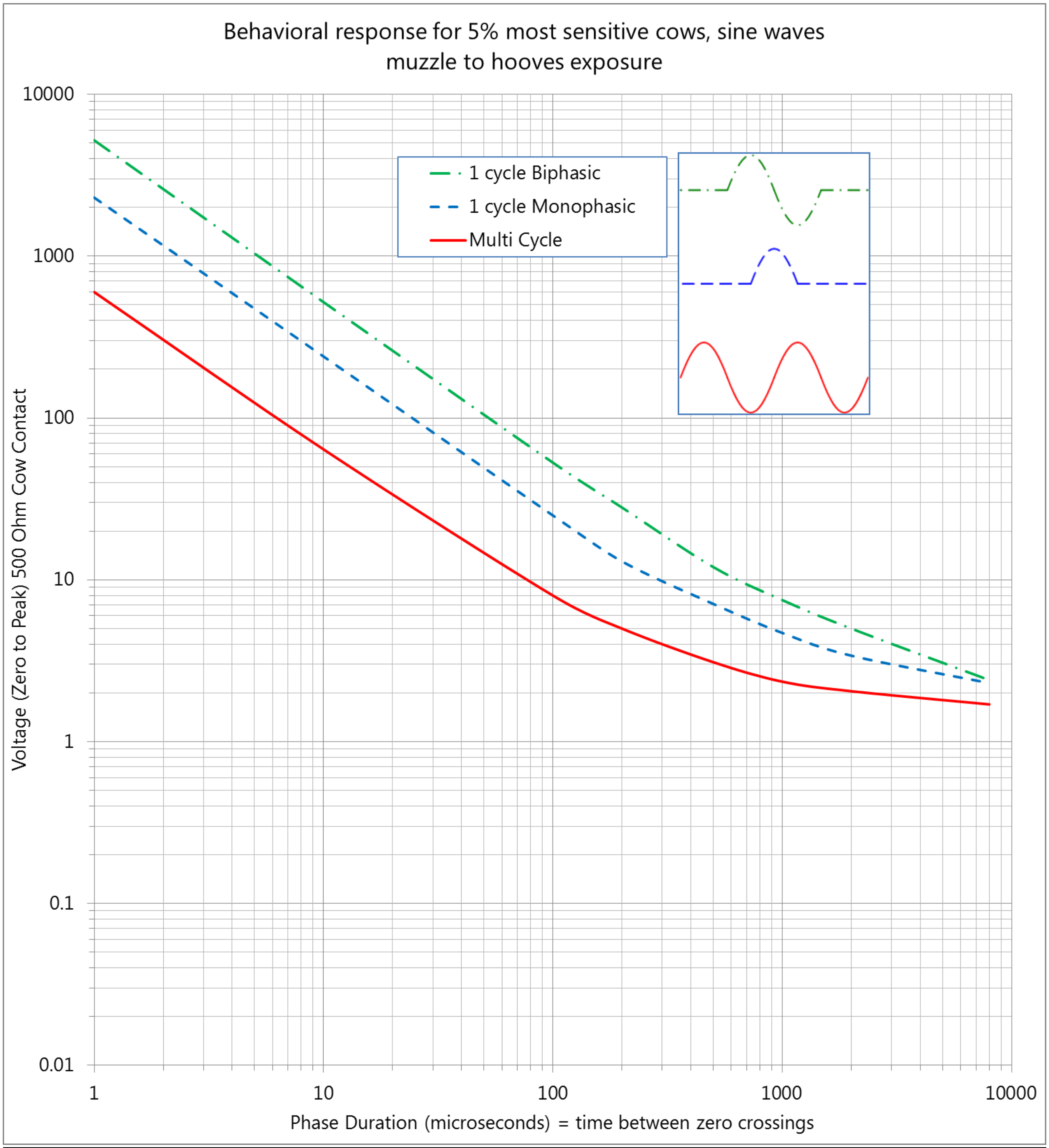
Horizontal 50 μs/ div.
Vertical 10 V / div.

   c. A voltage corresponding to the inrush current of a motor starting. Frequency is 60Hz. The motor takes 10 cycles to accelerate. At the end of the 10-cycle acceleration time the voltage drops to 0.2V RMS at 60Hz.

2. Did any of these events exceed their corresponding behavioral response threshold? If so, which one(s)?____

3. What is the zero-to-peak voltage threshold for a monophasic pulse with a phase duration of 40us?___
____

Notes:
Phase duration in microseconds = 1,000,000/(2 x frequency in hertz)



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Module 2: Preliminary Setup

Purpose:

Check/correct scope parameters to start with a "clean" scope.

Learning outcomes:

In this module you will have the opportunity to see and practice the following skills:

4. Set your scope to the factory default settings and clear the oscilloscope's memory: User > Options > Factory Default
5. Set the correct date and time in your oscilloscope: User > Options >Date Adjust…
6. Set channel A to voltage, with a 1:1 probe and DC coupling. Does your scope screen indicate AC or DC coupling for channel A, and if so, how?
7. Set channel B to current, with a 100mV/A probe and AC coupling:
8. Reset the scope to factory defaults again. Did it retain the date and time settings? Did it retain the probe and coupling settings?

Conclusions:

Was your scope set to the correct date and time to begin with?______________________
What was the default probe attenuation?____

AC/DC coupling tradeoffs: In stray voltage investigations we can easily introduce DC voltages into our measurement through the use of different metals in moist environments. However, using AC coupling to eliminate any DC also changes the shape and polarity of the waveform.

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Module 3: Getting Signals to Scopes

Objective: Ensure that the signal gets to your scope with minimal distortion and without picking up excessive noise along the way.

Learning outcomes:
In this module you will have the opportunity to learn how different types of leads affect the integrity of your signal:

1. Connect two separate leads to one channel of your oscilloscope and to a 500 Ohm resistor approximately 5-10 feet away. Allow the two leads to form a loose, open loop. Observe the waveform on your scope: ____
____
____

2. Twist the two conductors from step 1 around each other, turning them into a twisted pair and observe the waveform on your scope. Is the signal amplitude larger or smaller than in step 1? ______
____
____

3. Replace the twisted pair with a shielded twisted pair and repeat your observation of the signal. Which signal cable produced the "cleanest" signal at the scope? ___________________________
____
____

Notes:
The voltage leads between a measurement point and your scope, meter, or recorder will probably pass through different electric and magnetic fields which can induce "noise" in the leads. It is important to take steps to minimize this effect. A good first step is to make the leads as short as practical. Using twisted pair leads or shielded twisted pairs helps ensure that the loop area in your voltage leads is very small, and that both leads are exposed to nearly identical electric and magnetic fields. This minimizes the voltage difference that appears between the leads at your instrument due to these external fields. Even if the shield "floats", it can improve the performance of your signal cable by helping to distribute any electric field evenly around the pair.

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Module 4: Capture a continuous waveform, then measure it automatically

Objective: Display a continuous waveform of a

Learning outcomes:

In this module you will have the opportunity to see and practice the following skills:

1. Check the probe multiplier for channel A and adjust it if necessary to match the probes/leads you'll be using.

2. Connect a low-voltage AC source to channel A. Neutral-to-ground voltage at a power outlet or the signal from a function generator is suitable. Does the scope automatically display a stable waveform? If not, move the trigger point up or down to a consistent, repetitive point on the waveform. What did you have to do to get a stable waveform?

3. Once a stable waveform is displayed, experiment with time-scale, and voltage-scale adjustments. Your waveform should have at least three full cycles on the screen and should not extend beyond the top or bottom of the screen. Describe the displayed waveform. Is it "noisy"? Are there occasional higher frequency transients displayed?

4. Let the scope measure the peak and phase duration for you. (Fluke)*Scope > Reading1 > (on A) > Peak…> PeakMax.* Repeat for Reading 2 and select pulse width or frequency (Hz). What is the peak voltage and phase duration of the waveform you captured?

5. Save the captured waveform screen with its readings to your scope's memory, and then recall it from the memory.

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Module 5: Using cursors to measure waveforms

Objective: Learn to use cursors on a scope for accurate measurements of waveforms.

Learning outcomes:
In this module you will have the opportunity to see and practice the following skills:

1. Check your scope's setup (probe attenuation, AC/DC coupling, etc) and adjust as necessary.

2. Connect a signal to channel A of your scope and adjust the trigger point to slightly above any steady-state signal that is present. Set your scope for "single shot" or "trigger and hold". Capture a waveform as you did in Module 4. You may need to adjust your time and voltage scales in order to get a good picture of a transient. Once you have captured a transient, select the horizontal cursors and move them to measure the zero-to-peak voltage of your waveform:

3. Select the vertical cursors and move them to measure the phase duration of your signal. (Hint, measure the time between a positive and a negative peak if your waveform appears symmetrical):

4. Compare your measurements to those taken by the others in your group. What was the highest zero-to-peak voltage captured? What was the shortest phase duration captured?

Capturing transients is often a process of trial and error. The time and voltage scales and triggering point are gradually adjusted to obtain a picture of a waveform that can be measured. Don't be worried about missing a transient. Most equipment starts and stops repeatedly, causing the transients you'll capture.

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Module 6: Time of arrival to find transient sources

Objective: Learn how to use a transient's travel time to help locate its source.

For this module you'll need a square-wave generator or something similar that can produce a pulse with a very steep leading edge.

Learning outcomes:

In this module you will have the opportunity to see and practice the following skills:

1. Connect a single transient source (square wave generator) to BOTH channels of your oscilloscope, using a short coaxial cable on channel A and a long coaxial cable on another channel. A difference in length of 50-feet or more is ideal. What is the approximate difference in the length of the two signal leads? ____

   ____

2. Adjust your scope so that you capture and display the leading edge of the transient pulse on both channels with a time scale of about 50ns/div. Do the two waveforms line up vertically, or is one shifted in time compared to the other? ____

   ____

   ____

3. What is the time difference between the arrival of the transient at channel A and the arrival of the transient at channel B, in nanoseconds? ____

   ____

   ____

   ____

The time-of-arrival method is a powerful tool for locating transient sources. Transient signals will travel away from the source at nearly the speed of light, but a fast oscilloscope can measure the time it takes the transient to travel between two points. Using leads of equal length and measurement points that are approximately 20-feet or more apart, you can use a scope to determine which point is closer to the source of the transient.

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Module 7: Recording with an Oscilloscope

Objective: Explore your scope's recording capabilities, and possible drawbacks.

Learning outcomes:
In this module you will have the opportunity to see and practice the following skills:

1. Connect your scope to a continuous signal, such as neutral-to-ground voltage at a receptacle. Set the scope to display the zero-to-peak voltage. What is this voltage? ____________________

   ____

2. Start your scopes recording function to record the reading (not the actual waveforms) over time. In Fluke scopes we'll be using "trend plot". Start the recording and let it run for a few minutes. What is the timescale displayed during the recording? ____________________

   ____

   ____

3. After the recording has run for about two or three minutes, stop the recording and select "view all" to view the entire recording. What is the peak voltage recorded? ____________________

   ____

   ____

4. Is there enough data for you to determine phase duration for the peak voltage during the recording, even at the maximum available time resolution? ____________________

   ____

   ____

Both Fluke and Tektronix scopes are designed to capture very fast transients in a voltage signal, regardless of the displayed timescale. On the Fluke 199, there are 25 screen pixels from one division to the next, so each pixel represents 1/25th of the total time per division. For the Fluke 199 series, the scope will capture and plot the maximum (and minimum) voltage for transients as short at 50ns (nanoseconds) when displaying or recording waveforms. If a transient is displayed one pixel wide and the timescale is set to 1 minute, this can make a 50ns transient appear to be 2.4 seconds in duration. This is 48,000,000 times longer than the transient actually lasted! In short, trend plots and scope recordings can provide some information regarding the maximum voltage measured, but do not provide adequate duration information for analysis.

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Module 8: Using a computer with a scope

Objective:

Learning outcomes:

In this module you will have the opportunity to see and practice the following skills:

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Module 9: Electrical fingerprints

Objective:

Learning outcomes:

In this module you will have the opportunity to see and practice the following skills:

<May just demonstrate this – the glitch/peak detect issue needs to be explained.>

1. Waveform smoothing. Your scope may have bandwidth settings, averaging settings, and "glitch detect" or "peak detect" (usually in the waveform options settings). Turn off glitch or peak detect, set the bandwidth to 10kHz or the closest available setting, and set the scope to average two cycles. How did these changes affect the displayed waveform? ____