Evaluating Electrical Events on the Dairy Farm

What if we had a way to evaluate all the different measurements people make on a dairy farm and we could put this information into a form that the average person could understand?

Chapter C

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Table of Contents

C1. Scope

We can put all the different measurements people make on a dairy farm into a simple graphical format that the average person can understand.

Putting the data on a “graph” may be complicated to some, but understanding the graph should be easier. Section B will discuss the graph in more detail.

There are some basic ground rules for using the graph that must be followed to make the graph practical to use:

1. The electrical event to be plotted on the graph must be an electrical event that the cow can experience. It may be a mouth to foot measurement, a front foot to back foot measurement, a front foot to front foot measurement or a back foot to back foot measurement. The mouth and feet of the cow are the electrically sensitive points on the animal. Electrical contact with the animal on the back or side or other areas protected by hide are much less sensitive.

2. The electrical event may be a transient (short time event) or steady state (long lasting event). Either electrical event will have a maximum voltage magnitude and duration. I’ll explain duration later.

   Something you should know: I will be talking about voltages accessing the cow when everyone knows it is the current through the cow that the cow detects. In order for a cow to have current flow through its body, a voltage must exist across the cow. The amount of current that flows through the cow depends on the internal body resistance of the cow and the strength of the voltage source. A typical cow has an internal body resistance of about 250 to 1100 ohms. The cows I have measured, with very good connections to the cow’s mouth and four feet, showed a body resistance of 300-ohms. In the real world the cow’s mouth and feet do not make perfect connections, so a 500-ohm cow resistance is assumed.

3. The data we collect will be a voltage event with the use of a 500-ohm cow resistor.

Something you should know: We will be collecting information about the voltage across the cow at many different frequencies. As the frequency of the voltage event increases, the body resistance of the cow decreases; but it also takes a higher voltage for the cow to detect the event. By staying with a 500-ohm resistor for all measurements, any error will be in favor of the animal. It is important to note that when I speak of the "frequency" of the event, that does not mean how many times a day the event occurs, it refers to the rate the AC voltage changes from positive to negative polarity per second. Repetitive events will be called multiple cycle events. Some examples of multiple cycle events are steady state voltages or cow contact voltages caused by motor starting.

4. Each voltage event has a peak magnitude or maximum value. We will use the peak voltage level to plot on the graph. The peak voltage recorded, either a positive voltage above zero volts or a negative voltage below zero volts, will be considered an individual electrical event.

Something you should know: Most animal research is performed measuring the actual current through the animal. The peak current is recorded as described above. By using our 500-ohm resistor and measuring the voltage across the resistor, we can accurately determine what the current would be through a cow if the cow was contacting the same points as the two ends of the "cow resistor". This is part of the reason the two points between which we measure voltage are called "cow contact" points.

When I mention positive and negative voltages or currents, I am referring to AC or alternating voltages and currents that change direction of flow many times a second. The AC voltage from the power supplier changes direction 60 times per second. This change in direction may be important to an electrical person, but not to the cows.

5. Only the peak voltage value will be used on the graph.

Something you should know: The value of a voltage can be stated as an rms value, a peak value or a peak-to-peak value. All are correct ways to describe the voltage value, but each method results in a different number value. An AC voltage of 1.0 volts rms is equal to

1.414 volts peak, which is equal to 2.828 volts peak-to-peak. We have to standardize on one unit of measurement. The best unit is peak voltage if you are trying to determine what voltage or current a cow will first detect.

Make sure you write down what units you are using to measure. When using a scope, “peak” or “peak-to-peak” is the simplest values to record.

6. The next thing to determine is the frequency or duration of the electrical event. Frequency means the rate at which the voltage goes from a positive value down through zero volts to a maximum negative value and back up through zero volts. Some voltages start out at zero and just go to a positive peak and back to zero. Some voltages may just go to a negative value. It is the voltage change from zero volts that matters regardless if it is a positive or negative going value.

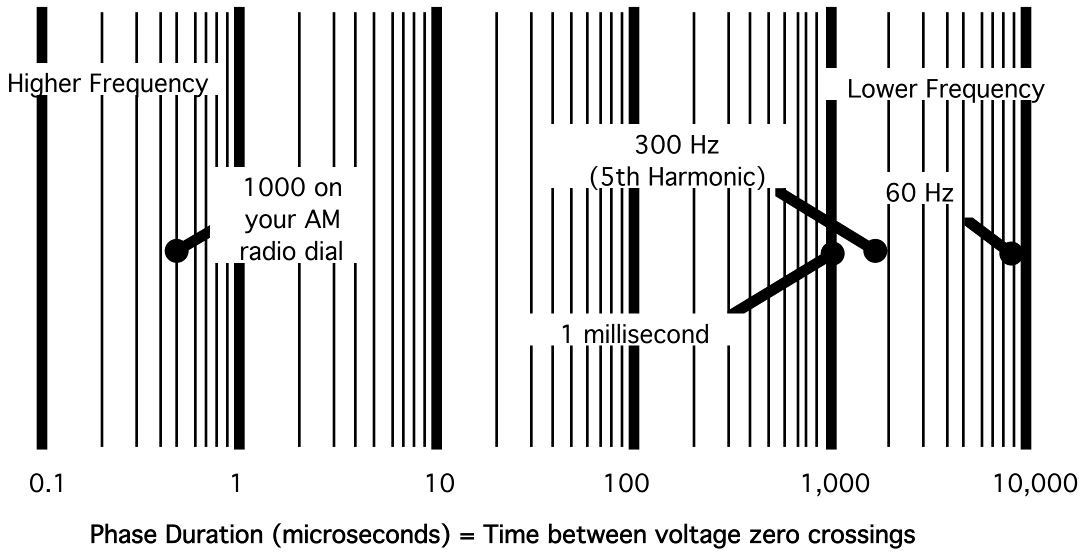
Something you should know: When measuring 60 Hertz (cycle) AC voltages, the frequency is 60 Hertz. That means the voltage goes from zero to a peak positive value, back through zero to a peak negative value and back to zero in 16.666 milliseconds or 60 times a second. The duration of this single cycle is 8.333 milliseconds for the positive portion and 8.333 milliseconds for the negative portion of the cycle.

C2. Plotting data points on the graph

Assume we have measured an electrical event and know the peak magnitude and the duration. How should we plot the data point?

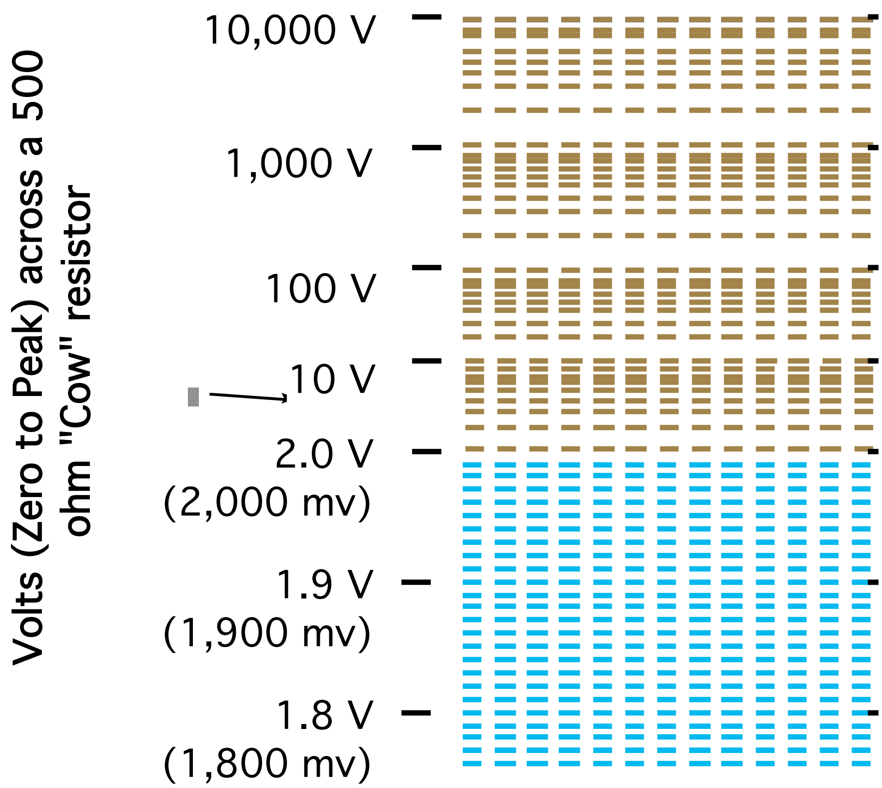
A graph has a horizontal axis and a vertical axis. We will use the horizontal axis for frequency or “duration” to be plotted. The vertical axis will plot peak magnitude.

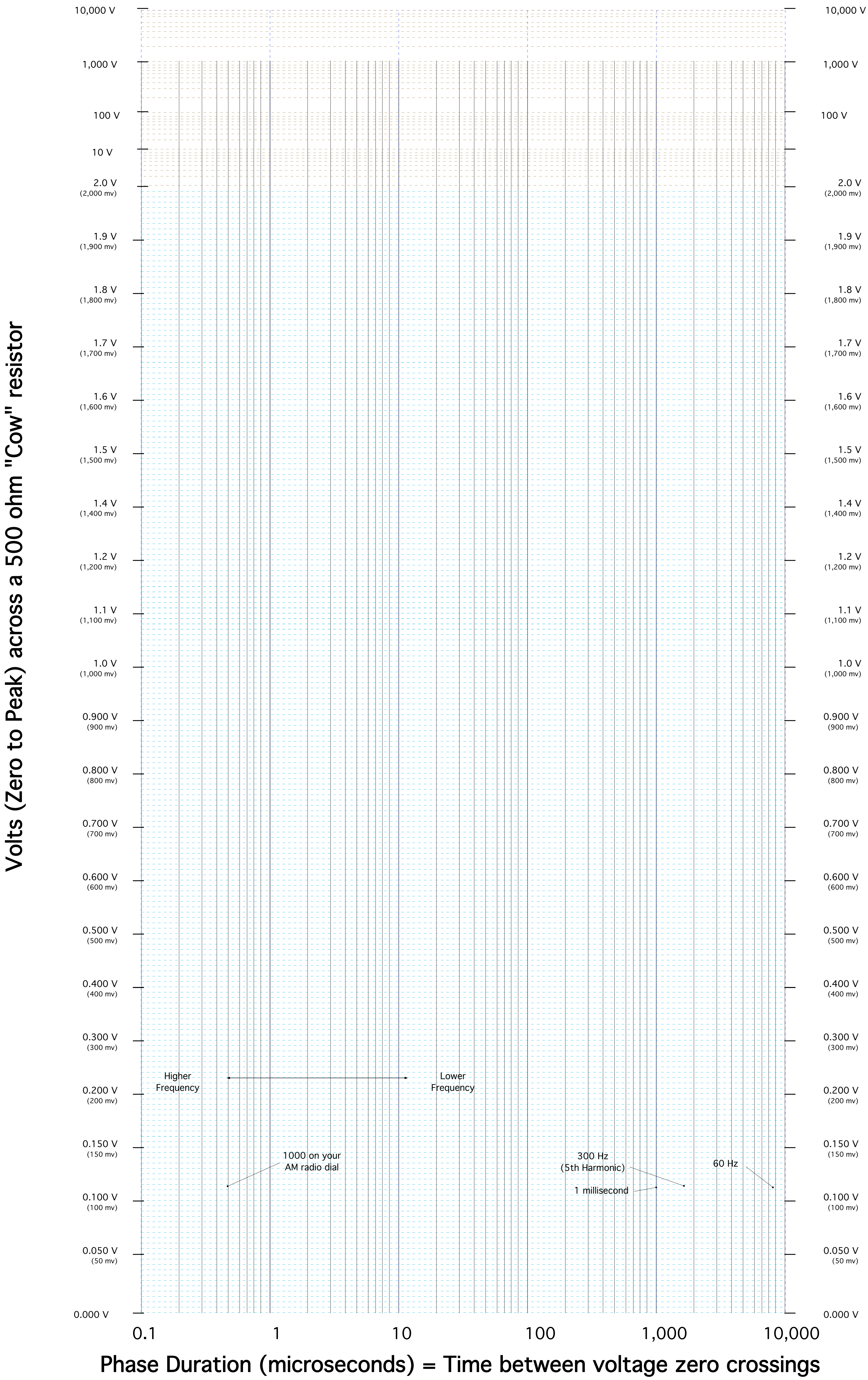
The horizontal axis will be a logarithmic axis. This allows a much greater range of frequencies or “durations” to be plotted on the graph. Please note that moving left or right on the graph axis results in non-linear changes in frequency or “duration” values.



Higher Frequency
Lower Frequency
1000 on
your AM
radio dial
300 Hz
(5th Harmonic)
60 Hz
1 millisecond
0.1
1
10
100
1,000
10,000
Phase Duration (microseconds) = Time between voltage zero crossings

The vertical axis will be linear from 0 to 2 volts peak and logarithmic above 2 volts. This allows more precision in the range of normal cow contact voltages and still lets us plot the voltages from fencers and cow trainers. Note that for the logarithmic section of the graph, the value increases 10 times more than an equal distance on the linear section.





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C3. Plotting some examples

Assuming we have measured an electrical event and know both the peak magnitude and duration, let's plot the data point on the graph.

The first measurements you might obtain are from digital voltmeters, chart recorders, logging instruments and the like.

Assume you have a digital voltmeter and you are observing a reading of 0.1 volts AC. I am going to assume that the voltage is mostly 60 Hertz with some harmonics included. I am also assuming the voltage was measured as rms. To get a peak value for the 0.1 volt rms reading, multiply the 0.1 by 1.414 and you have a peak voltage value of 0.141 volts.

Next we need to know the duration. If the voltage waveform is close to a 60-Hertz sine wave, the frequency is 60 Hertz and the duration is 8.333 milliseconds. But wait, the graph has the horizontal axis calibrated in MICROseconds not MILLIseconds. To get microseconds from milliseconds multiply 8.333 milliseconds by 1000 to get 8333 microseconds.

Now we have a point to plot. The point will be at 8333 microseconds along the horizontal axis and 0.141 volt (1414 millivolts) up on the vertical axis. Plot this point as #1.

> *Something you should know*: Some digital meters can record peak events or "spikes". The peak event should be a peak rms event. "Spike" or "glitch" captures may be peak or peak-to-peak events. It is important to know what your meter does and how it responds to short duration electrical events. For this example we assume that you are monitoring a steady state voltage. Sometimes short duration electrical events can fool a meter and it is anyone's guess what the meter will display.

I mentioned an example using a digital voltmeter because that is typical of the most common metering devices used for stray voltage measurements. I am including a list of common devices in use and my comments on how each can be fooled when used outside of the specifications of the unit.

Remember when you connect to a cow contact point, you can expect to measure electrical events that cover a large range of frequencies. Some meters and recorders can be fooled when a high frequency event is presented to the meter.

> Fluke 87 digital voltmeter – Can measure accurately from DC to 5,000 Hertz or as short of a duration as 100 microseconds. Value reported should be in rms.
>
> Fluke 189 digital voltmeter - Can measure accurately from DC to 100,000 Hertz or as short of a duration as 5 microseconds. Value reported should be in rms.
>
> Metrosonics SRV-4 – Rated to capture events with durations as short as 130 microseconds, but may capture events as short as 10 microseconds. Value reported should be in rms.
>
> Waverider – Can capture events as short as 100 microseconds. Value reported as a peak voltage is the most accurate. The unit calculates rms equivalent assuming electrical event was a sinusoidal waveform.
>
> Fluke 199C in scope record mode – Will capture electrical events with durations less than 2 microseconds.

So which meter is best? Should I use the meter that can capture the shortest duration event? They are all good if you know what the duration of the electrical event was… well that's the problem. All of the above meters can measure the peak magnitude of the event fairly accurately, but none of them can accurately tell you the duration of the event.

To know the magnitude of the electrical event and not know the duration means you only have 1/2 of the information required to plot a point or know if the event was significant.

For most testing, the steady state cow contact voltage is the item of concern and the type of meters listed above do a fine job.

If they are fooled into reporting the higher magnitude of a short duration transient or impulse as an rms voltage, you may suspect a stray voltage concern when none exists. If you are doing a stray voltage survey the error will be in favor of the animal. If you are selling a solution, the error is not acceptable.

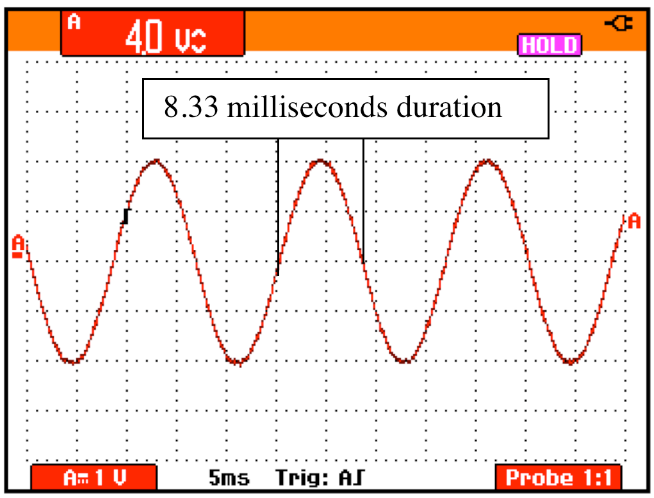
If you use the above meters and the voltages measured are below the steady state level of concern, you do not have a stray voltage concern for that measurement.

C4. Measuring and plotting high frequency electrical events accurately

If you want to measure short duration (high frequency) events accurately, you must use an oscilloscope. The display on an oscilloscope is similar to a graph. The horizontal axis shows time. The vertical axis shows voltage magnitude.

An oscilloscope sweeps the display screen from left to right showing a plot of how the voltage measured changes in magnitude with respect to time.

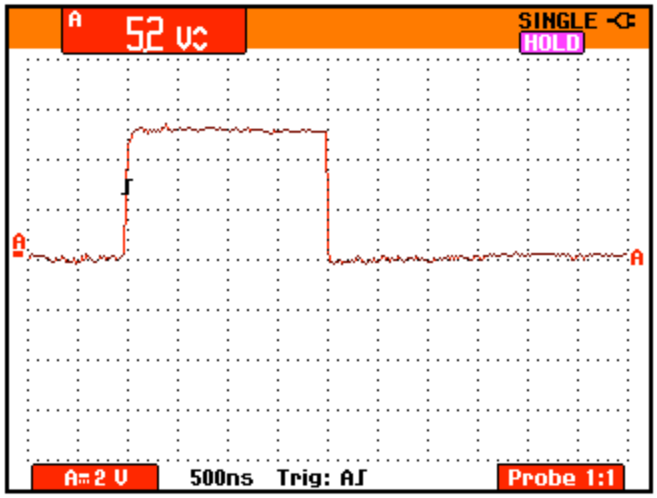
Below is a sinusoidal waveform typical of the waveform of electricity that is provided by the electric utility to your home or farm.



Note that the 60-Hertz peak-to-peak voltage shown is about 4 volts. The peak value is 1/2 of the peak-to-peak because the voltage is the same above and below the horizontal axis. The duration is the same for the positive and negative going voltages and equals 8.333 milliseconds or 8,333 microseconds.

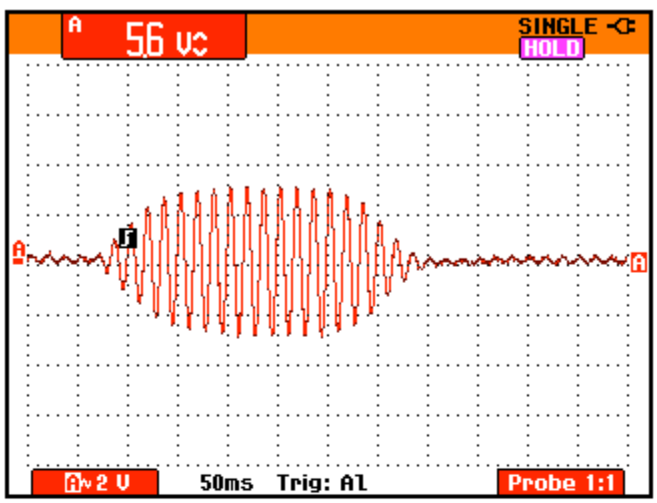
We will plot this point as #2.

This is an easy one!



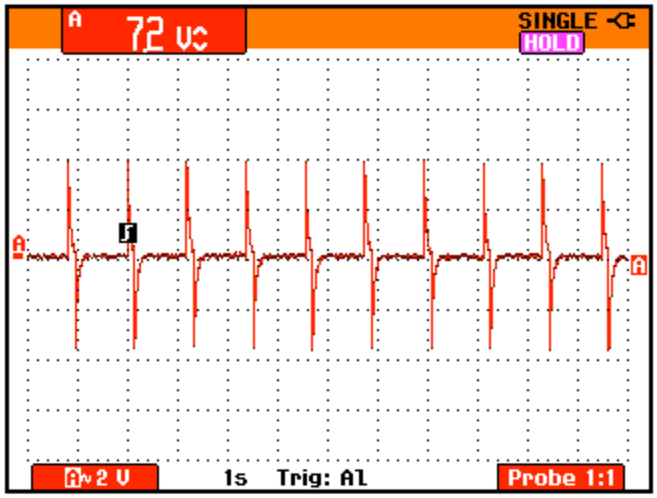
The magnitude is 5.2 volts and duration is 2 microseconds. Plot this as Point #3.

What happens when a motor starts and causes a multiple cycle event as shown below?



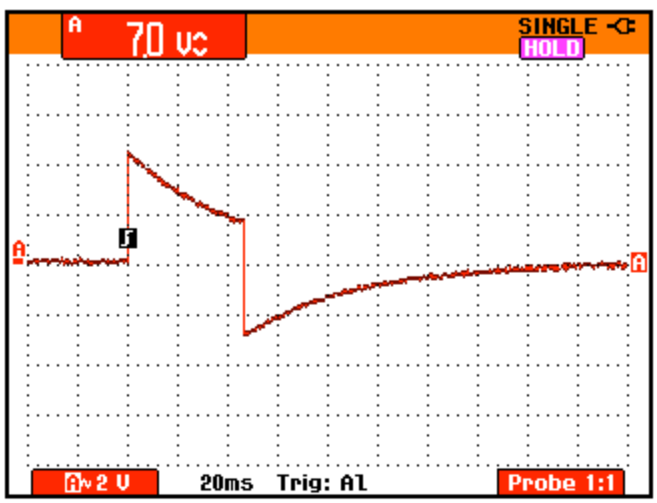
The magnitude is 5.6 volts and duration is 8333 microseconds. Plot this as Point #4.

A fencer could produce a voltage similar to that shown below.



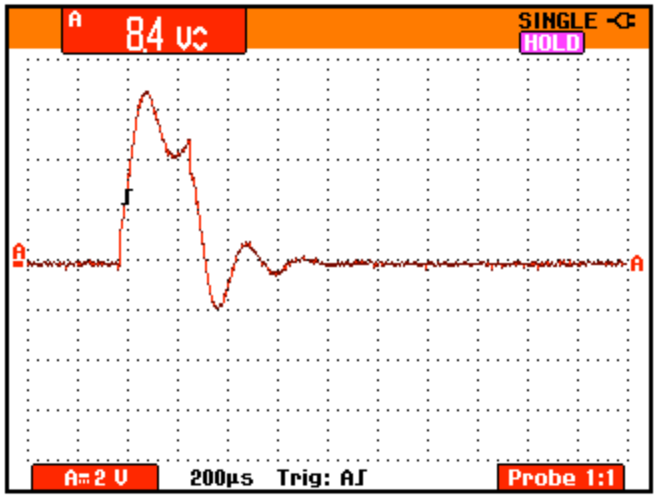
The repetitive impulses about 1 second apart are a giveaway on this one. The impulses are about 1 second apart and have a magnitude of about 7.2 volts peak-to-peak. Since there is a considerable zero time between the impulses, each impulse must be considered as a separate event. This is really not a multiple cycle event.

Looking at the impulse in detail we see the following:



The positive going pulse has the largest magnitude of 4.4 volts and the duration is about 45,000 microseconds. Plot this point as #5. This is not a real fencer. A typical fencer would have a pulse that lasts about 100 microseconds made up of many individual impulses of much smaller duration.

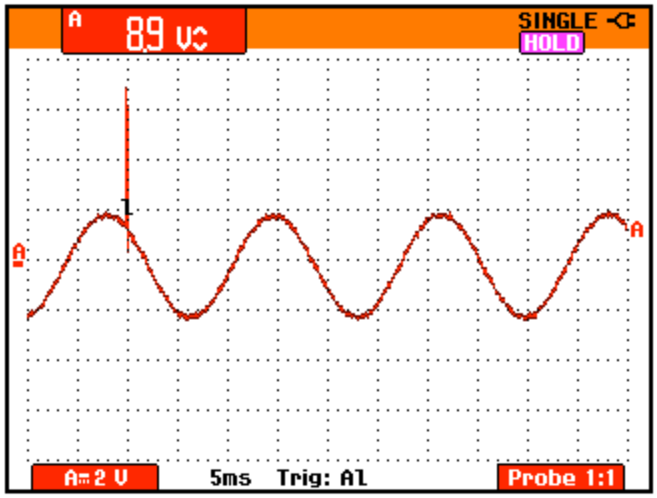
The next waveform is interesting.



The positive going pulse has a magnitude of 7 volts and a duration of about 300 microseconds. Plot this point as #6.

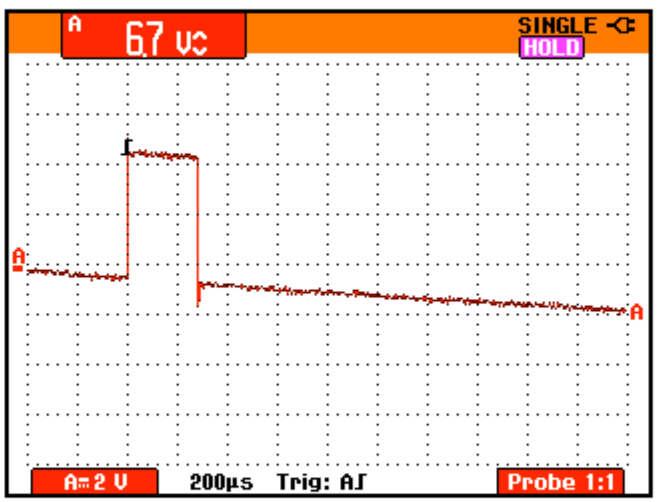
The negative going pulse has a magnitude of 2 volts and a duration of about 180 microseconds. Plot this point as #7.

The following waveform is typical of many you will find on the farm. Hopefully the 60-Hertz background voltage at cow contact is not really 4 volts peak-to-peak.



There are two items to consider for this waveform. The background 60-Hertz voltage has a magnitude of 2 volts peak and a duration of 8.333 milliseconds. Plot this point as #8.

In order to plot the short duration impulse, we need to capture the higher frequency impulse as shown below.



The magnitude of the short impulse is about 5 volts peak and the duration is about 300 microseconds. Plot this point as #9.

C5. What does the plotted data mean? Do I have a stray voltage concern?

The graph we are using allows you to plot electrical events that range in frequency from 60 Hertz to 5,000,000 Hertz. This frequency range covers power line frequencies, harmonics of power line frequencies, frequencies covered in "electrical pollution" discussions, cow ID systems, the AM broadcast band and a good share of the short wave radio band.

The graph does not cover citizen band radio, FM radio, VHF TV, UHF TV or cell phone frequencies. One of the reasons is the oscilloscope is not accurate above the FM bands and the concern for these high frequencies changes from conducted current to radiated energy. Other types of instruments are required for higher frequency measurement. Another good feature is that it is hard for a transmitter of these higher frequencies to exist without someone being aware of its close proximity.

The University of Wisconsin has prepared a graph showing the level at which the 5% most sensitive cows will detect or respond to electrical events. The UW research includes a review of over 500 animals at the UW and a worldwide search for information from other people studying dairy animals. Over 60 studies performed by over 22 different research groups in 6 different countries support the information shown on this graph.

The graph considers short duration events that may either go above or below zero, events that may go both above and below zero and multiple cycle events such as steady state.

If you measure an event and plot it on the following graph, look to see if the plotted point is above any of the three sensitivity curves shown. If it is, eliminate or reduce the source of the electrical event you detected.

The graph shows three (3) curves. The lowest curve is for multiple cycle events such as steady state or voltage increases from motor starting that create a voltage increase for several successive cycles.

The next curve is for 1 cycle monophasic events where there is a single pulse that rises from zero volts to either a positive or negative value and back to zero.

The last curve is the curve showing the animal has the least sensitivity to a single biphasic pulse that goes both positive and negative from zero. A typical waveform would be a decaying ring pulse.

C6. The rest of the story

I made a large assumption that you the reader would know how to use an oscilloscope to record the electrical events. This is not always easy to do. On my webpage, www.phasorlabs.com, I have information on how to use an oscilloscope to capture transient or impulse events.

I hope to have more information soon. If you have an instrument that I have not discussed, please let me know and I will try to include that unit in my work.

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Behavioral response for 5% of the most sensitive cows using sine waves from muzzle to hooves exposure