Standardized Electrofishing Sampling

"Where do I set the dials?"

Purpose & Outline

- We will discuss the development and use of electrical output goal tables for standardization
  - Community of practice website: *electrofishing.net*
  - Waveforms and their fish-catching attributes
  - Development and use of output goal tables

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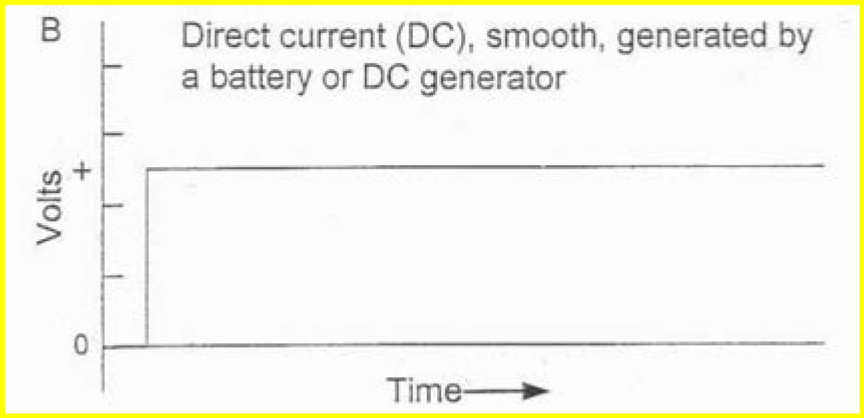
Electrical Waveforms

Description and Fish Catching Attributes

Main Types

- Direct Current (DC)
  - or "Continuous DC" or "Smooth DC"
- Pulsed Direct Current (PDC)
  - many forms
- Alternating Current (AC)
  - many forms

Direct Current (DC)



- Average voltage = Peak voltage
- Average amperage = Peak amperage
- Average power = Peak power (volts x amps)

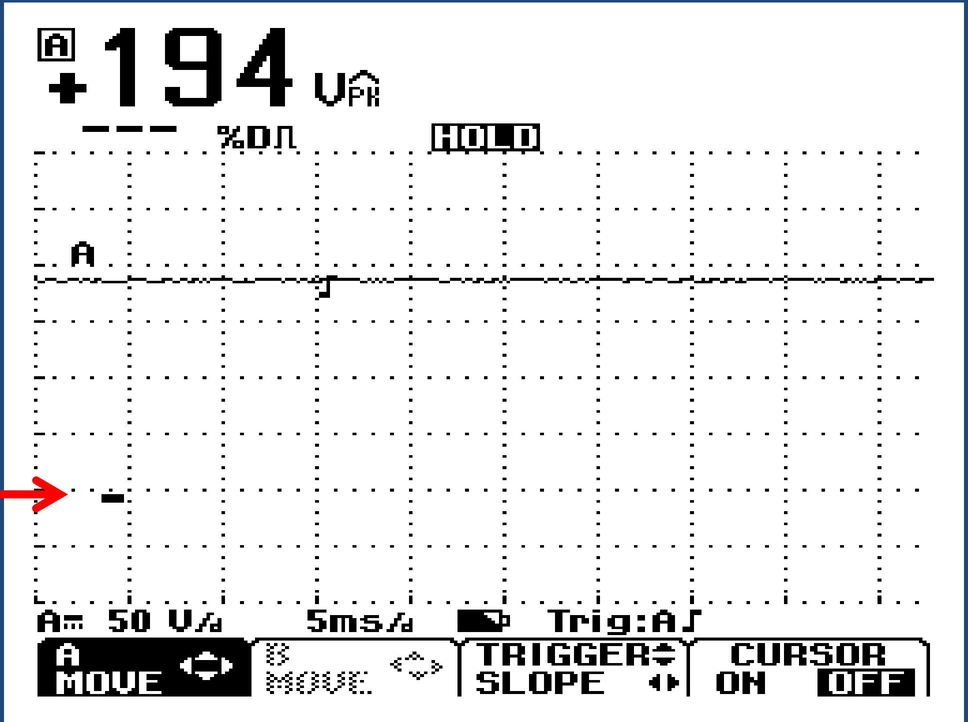
Advantages

- Typically causes attraction of fish to the anode
- Often less injurious, especially with salmonids

Direct Current

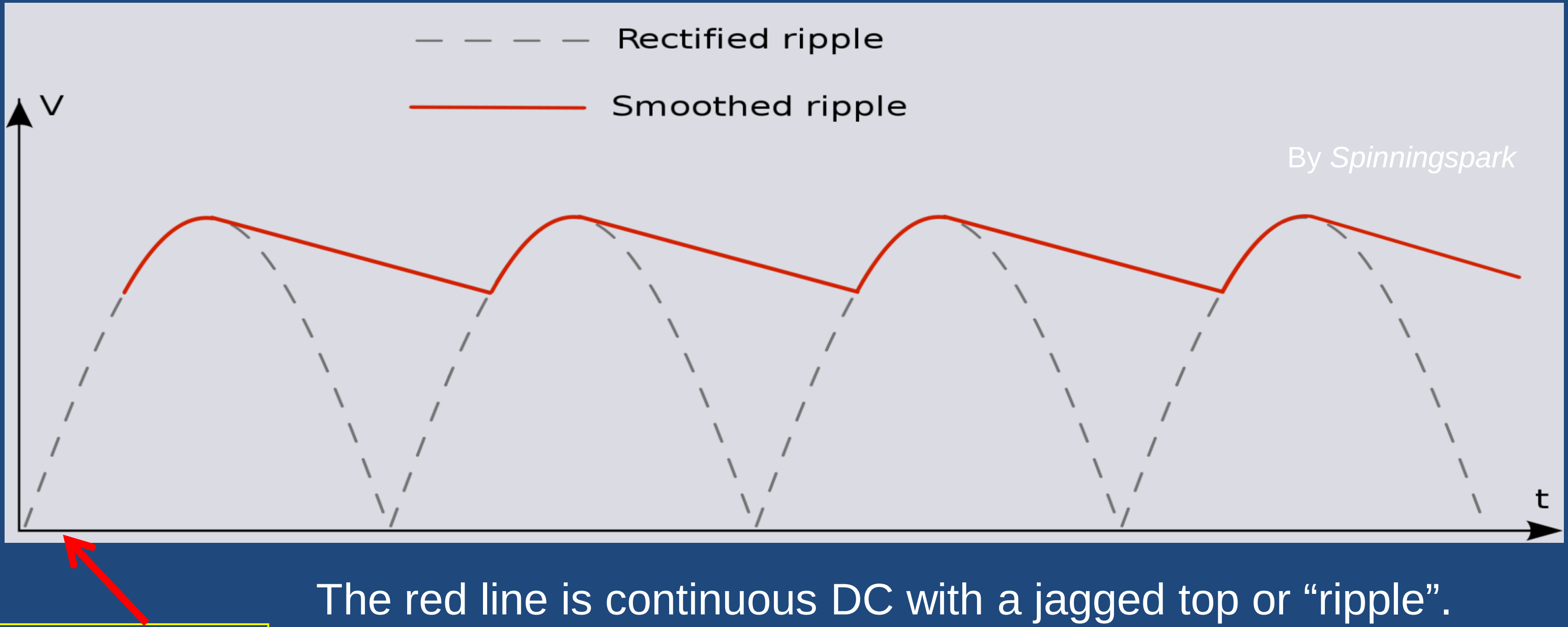
100% Duty Cycle

0 Volts baseline



Scopemeter graphic

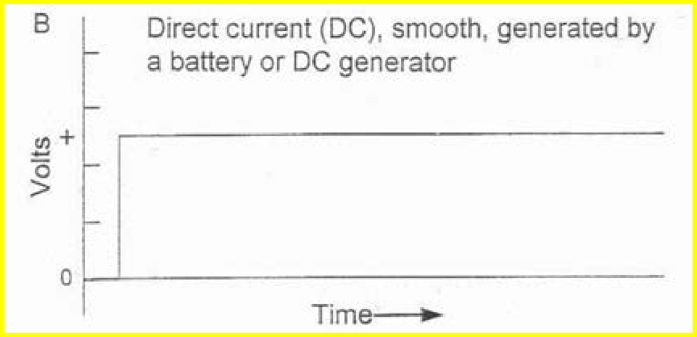
Direct Current with Ripple



0 Volts baseline

The red line is continuous DC with a jagged top or “ripple”. Ripple is a result of smoothing fully rectified AC. This waveform often is used in tow-barges with DC generators. The ripple may enhance catchability and thus is sometimes exaggerated by the manufacturer.

Drawbacks



- May require slightly higher amperage than PDC for successful electrofishing
- Also more energy consumptive, thus the use of DC is restricted to a narrower conductivity range
- Example: for successful fishing of fish assemblages in nearshore Lake Superior, the conductivity range was estimated at 35 – 320 µS/cm using a 2-boom metal hulled boat with an Infinity control box
- Not available in all models

Fish-Catching Considerations

- There are few adjustments possible with continuous DC; duty cycle is always 100% and frequency (pulses per second) does not apply
- The adjustments are DC voltage and amperage, so your strategy is simplified to building and using volt/amp output goal tables for just one waveform

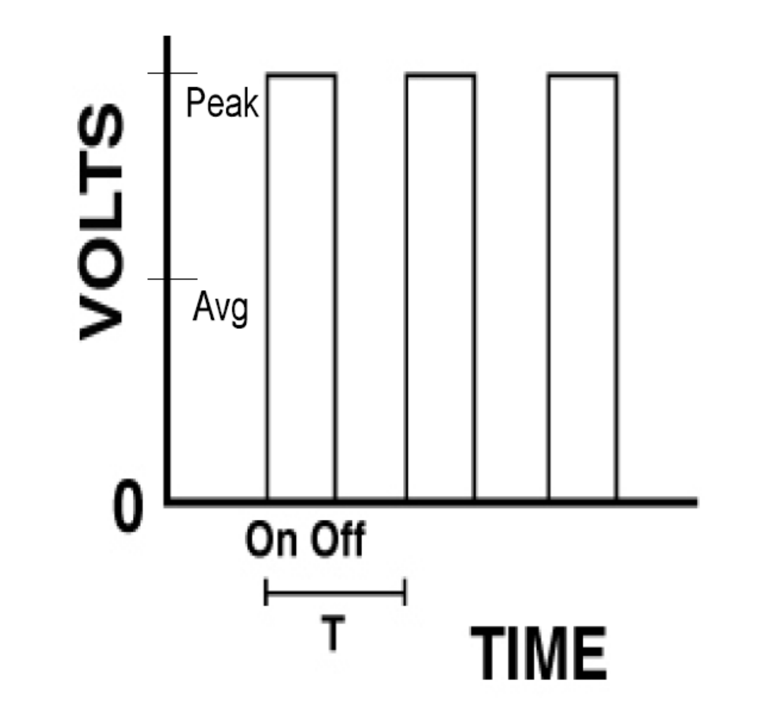
Output Goal Table

Example Backpack Output Goals

Waveform: PDC (fish catching settings, e.g., 60 pps, 25% duty cycle)
Electrodes: Ring anode, rattail cathode
R100: 275 Ohms
Fish Cond.: 115 µS/cm

Water Conductivity (Ambient)	Applied Voltage Goal (Peak)	Applied Amperage Goal (Peak)
50	394	0.71
75	303	0.82
100	257	0.93
125	230	1.04
150	211	1.15
175	198	1.25
200	188	1.36

Pulsed Direct Current (PDC)



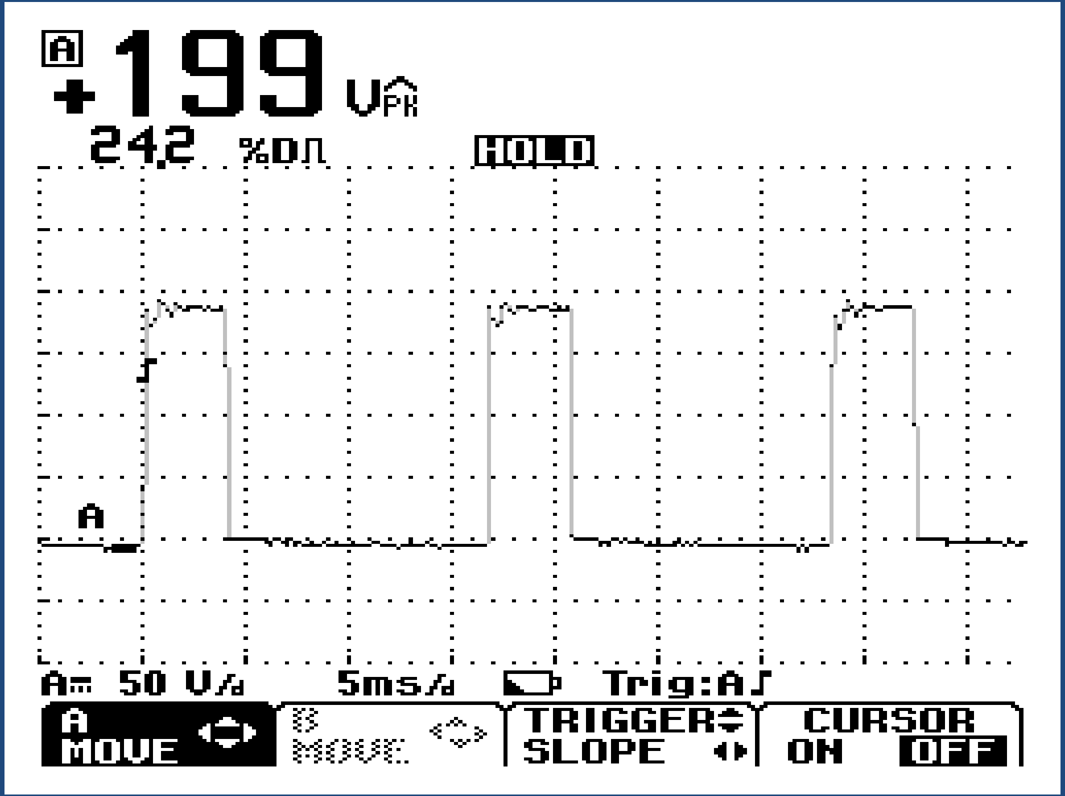
- Pulse: the part of the waveform during which voltage is present
- Pulse width (PW): the time the pulse is on in milliseconds
- Frequency: the number of pulses per second (pulses per second)
- Period (T): the time from the start of one pulse to the start of the next pulse
- Duty cycle: the ratio of "on" time (PW) to period (T), expressed as a percentage.
  - Duty cycle = (PW/T) x 100

Note: Peak Amps = Average Amps ÷ Duty cycle
Confuses many when changing from a GPP to a unit with peak reading meters

Advantages

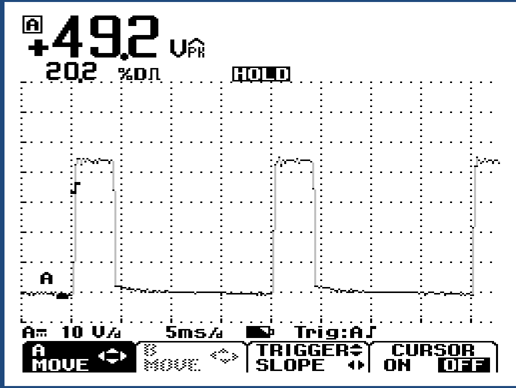
- Many waveform options (combinations of different frequencies and duty cycles)
- May cause attraction of fish to the anode, but not as obvious as with DC
- Much less energy demanding than DC, so can be applied across a broader water conductivity range
- Generally more effective for capturing smaller individuals than DC

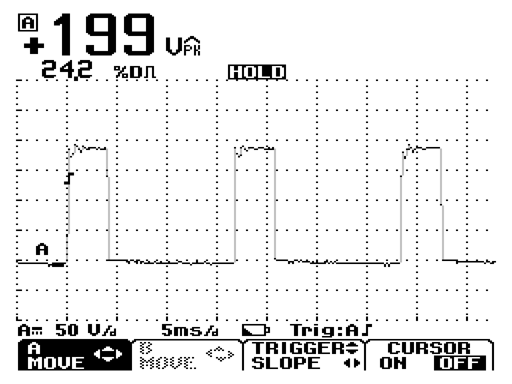
Pulsed Direct Current: Square Wave

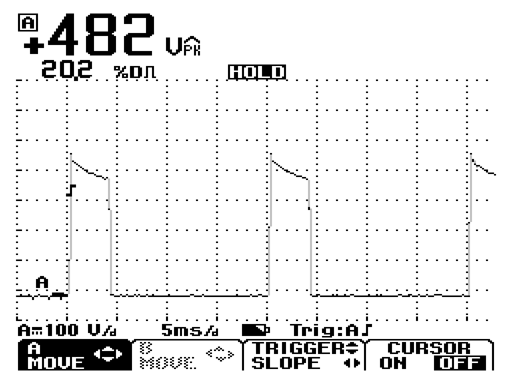


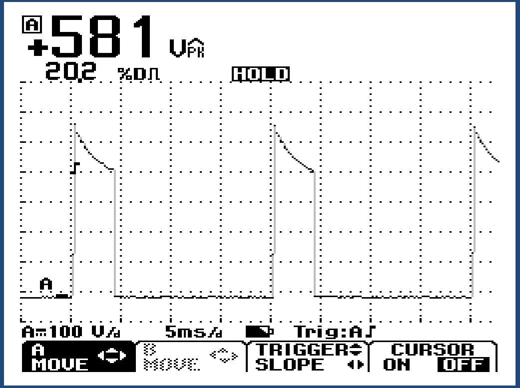
0 Volts baseline

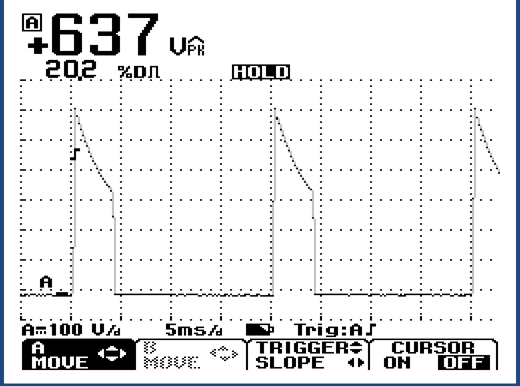
Effect of Voltage on Wave Shape
Smith-Root LR-24 Backpack





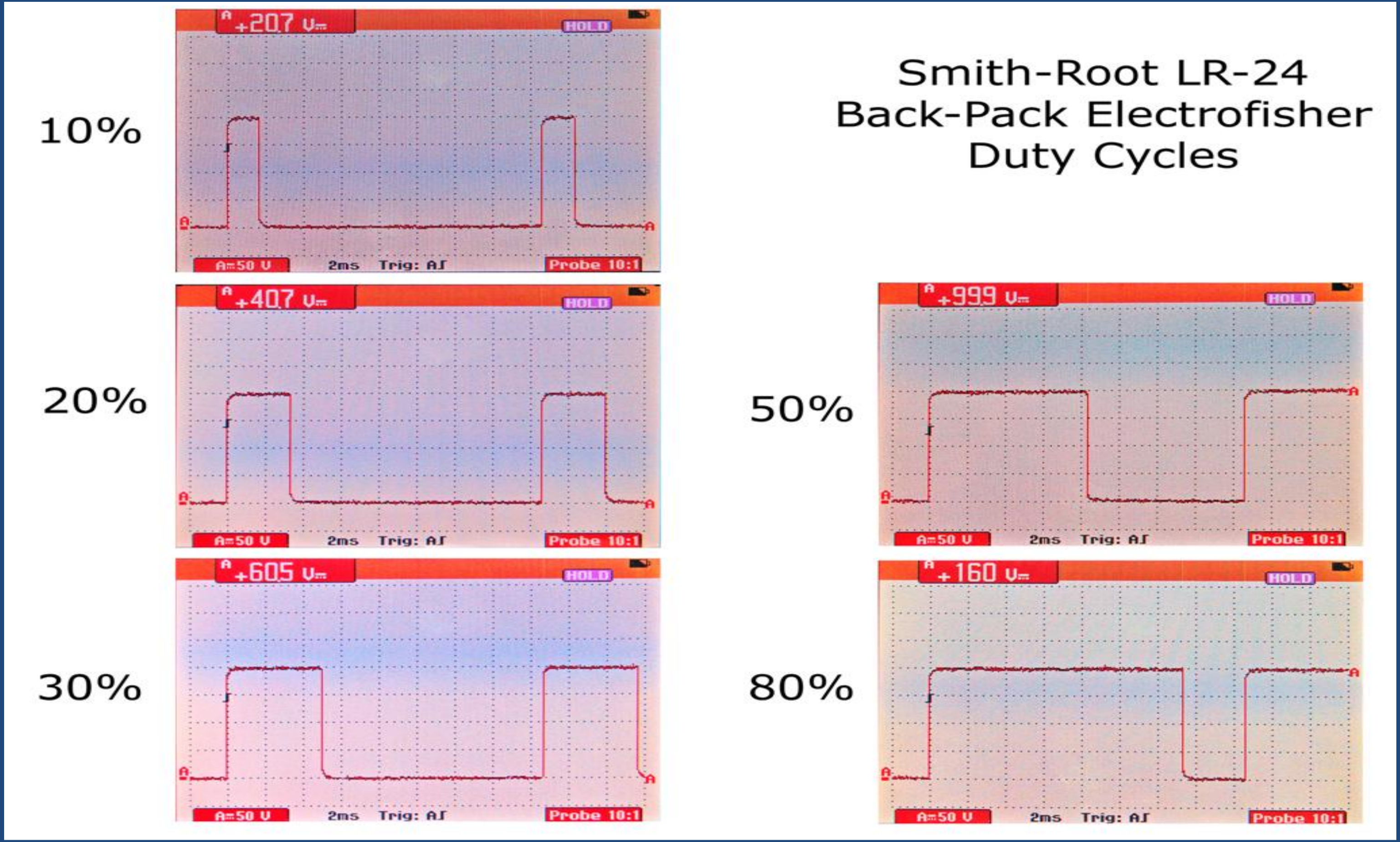






High loading can cause spiked pulses

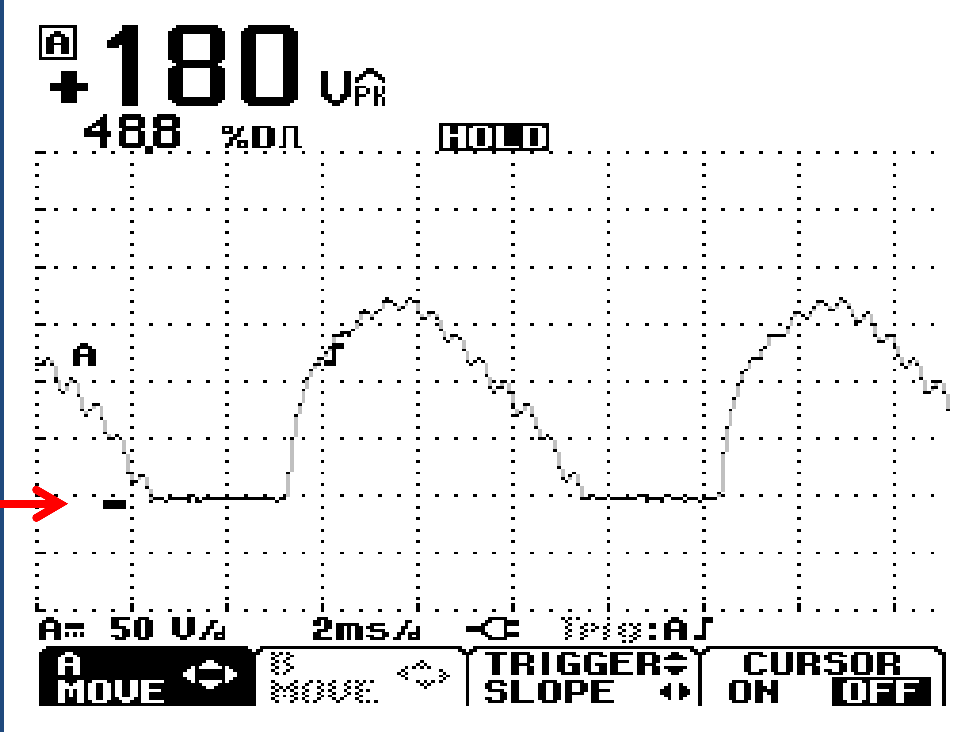
Scopemeter Tracings (Graphs)



Pulsed DC: Rounded Wave

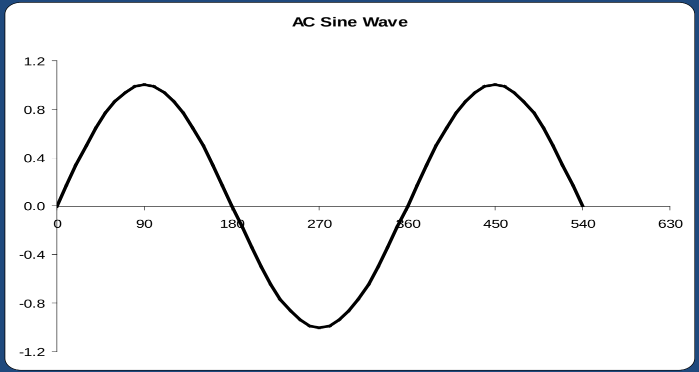
Mostly limited to GPPs and Type IV Models

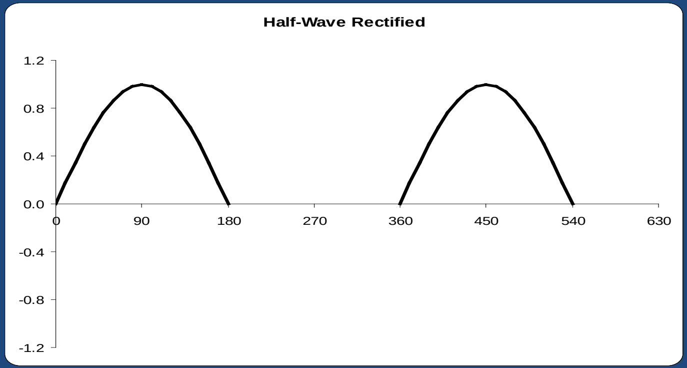
0 Volts baseline



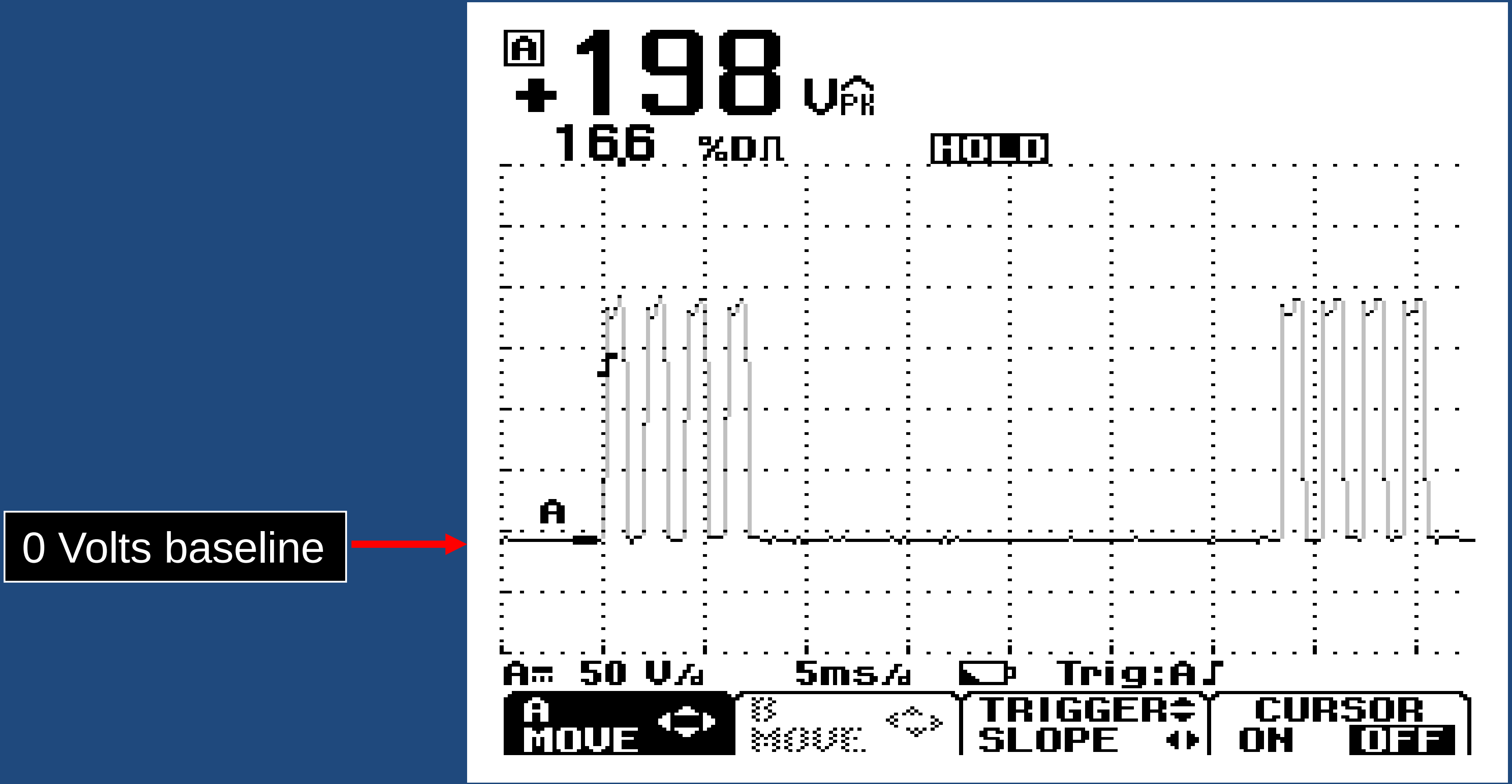
Half-Wave Rectified

Alternating Current + Diode = Half-Wave Rectified DC





Pulsed DC: Gated Burst



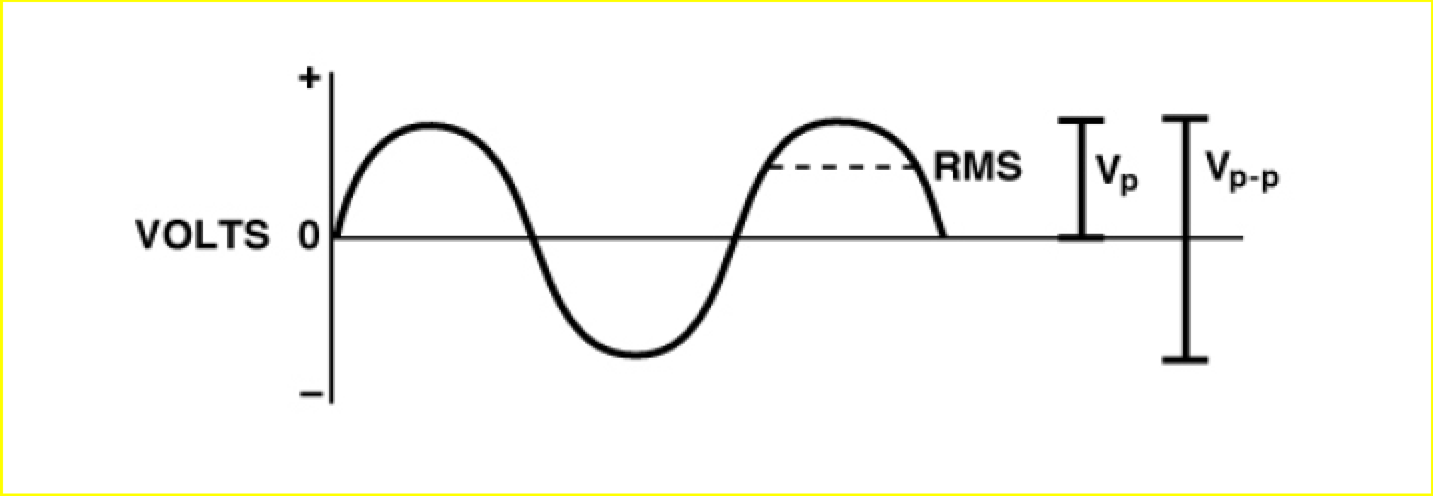
PDC Drawbacks

- Often does not cause attraction response
- Almost an infinite number of waveform options to choose from, can lead to use of sub-optimal frequency and duty cycle combinations
- May cause high rate of trauma, especially in salmonids (for trout, use $\leq$ 30 pps)
- Not as effective as alternating current in very low and very high water conductivity

Fish-Catching Considerations

- Often, 60 pps or 120 pps optimal for general catch efficiency; higher frequencies for capturing smaller fishes or if using a GPP unit so that a “robust” duty cycle is output
- Lower frequencies (30 pps or less) used on salmonids to reduce injury rates;
- Low frequency (15 pps) for blue and flathead catfishes in moderate conductivity; in very high conductivity (as near an estuary), “pulsed AC” has been found to be effective
- In colder water, higher frequencies may be more effective on blues and flatheads
- Duty cycle range for general catch efficiency is 20 – 40% (can go down to 15% without much loss) ; 25 – 30% is the sweet spot
- Build volt and amp output tables as guidance for settings given water conductivity
- Square waves typically need less power applied then rounded waves
- Gated bursts (or CPS, Quadrapulse, pulse trains) were developed for reducing injury in salmonids while keeping catch efficiency high; more power is needed typically vs. square wave PDC

Alternating Current (AC)



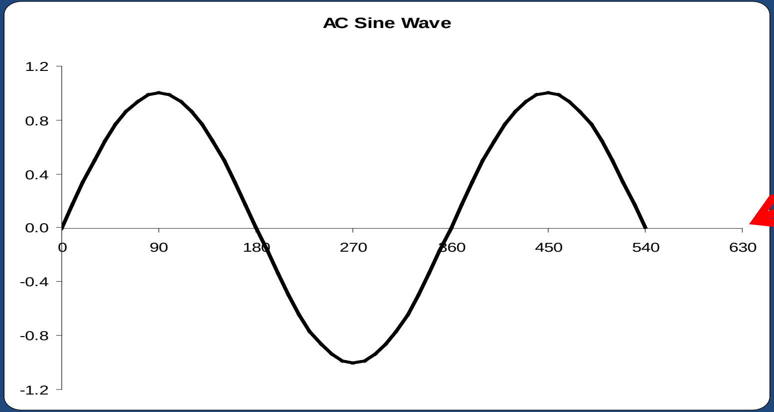
- AC Voltage (= RMS Voltage) is about 70% of peak in a sine wave (but electrofishing equipment rarely outputs a sine wave)
- Same for RMS Current and RMS Power
- No constant anode and cathode (switching occurs at the frequency of the generator (60 times per second in the U.S.)

Advantages

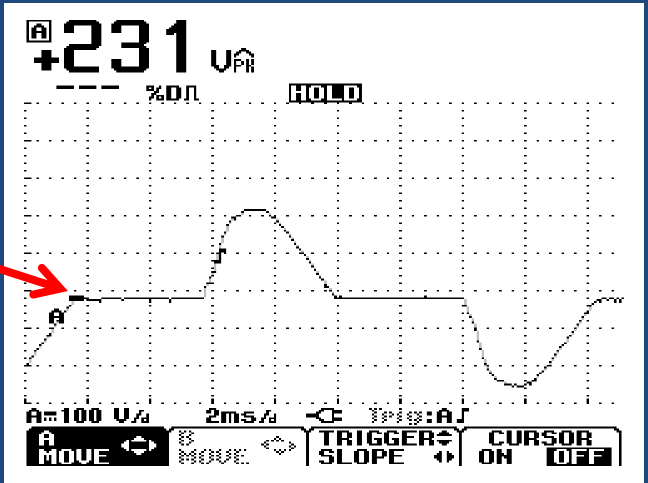
- Can be effective across a broad conductivity range; more effective than PDC in very low or high conductivity
  - This is because AC has higher voltage ($V_{peak} – V_{peak}$) for low conductivity water and higher current ($Amp_{peak} – Amp_{peak}$) for high conductivity water

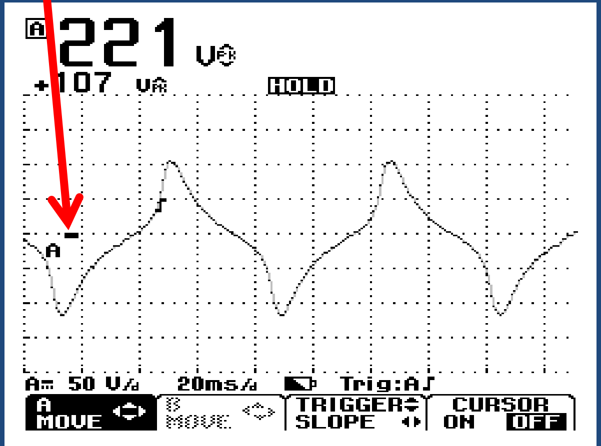
Alternating Current

Full Sine Wave



0 Volts baseline





Electrofishing gear output many different forms of AC. The full sine wave is uncommon, but one model example is the MLES Infinity control box.

AC Drawbacks

- Does not cause attraction response
- There are many AC waveforms (Triac, “AC Nerve”, Full Sine, and deviations from full sine via changing duty cycle)
- Many forms are specific to particular models; this can hinder fleet standardization unless all boats or backpacks have the same model control box
- Most volt and ammeters display RMS voltage or amperage; this is OK if using a full sine wave because there is a relationship between RMS and peak (Peak voltage = RMS x 1.41); usually a full sine is not being output and thus you can’t use this relationship and thereby have to monitor peak outputs with external metering
- Not available in all models (particularly backpacks)
- May cause high rate of trauma and injury

Fish-Catching Considerations

- Some units have one form of AC, others have the capability to change the shape of the waveform (through changes in duty cycle), thus consider building volt/amp output goal tables based on a particular form of AC; this is the same case for pulsed DC as well.
  - Most likely, you will need external metering (as a scopemeter) to monitor volts or amps.

Standardization Using Output Goal Tables

Example 2-boom Boat Output Goal Table

Waveform: PDC (fish catching settings, e.g., 60 pps, 25% duty cycle)
Anode: Two booms Wisconsin rings 4 – 6 droppers (amperage goals can be used for two spheres fully immersed)
Cathode: Boat hull (16 – 18' length)
R100: 35 Ohms
Fish Cond.: 115 µS/cm

Water Conductivity (Ambient)	Applied Voltage Goal (Peak)	Applied Amperage Goal (Peak)
50	502	7.17
75	385	8.26
100	327	9.35
125	292	10.43
150	269	11.52
175	252	12.61
200	239	13.70
225	230	14.78
250	222	15.87

Standardization Concepts

- The purpose of standardization is to reduce variability in fish catchability (q); a more constant q helps CPUE data track population trends more accurately
- Components to standardize include gear type, electrode design, waveform, crew number, crew experience, dipnet mesh size, sampling design (as day or night , reach length), environmental conditions (e.g., temperature and discharge), and electrical output

Output Goal Tables

- The standardization aspect we are going to cover is electrical output goal tables
  - Peak Volts, Peak Amps, and/or Peak Power
- These tables are used for guidance for selecting voltage and current based on ambient water conductivity; they can be strictly followed or used as a starting point (make trial runs near a sample site to fine tune settings)

Output Goal Tables

- Output goal tables are specific to gear type, electrode design, waveform, target species or assemblages, water body type (large reservoir, shallow lake, large river, mid-sized stream).
- Output goal tables are based on the power transfer model of electrofishing and require input of "threshold data" (minimum voltage, current, or power needed to successfully sample a water body type) and an estimate of fish conductivity

Inputs

- We often use a fish conductivity of 115 µS/cm
- Biologists should obtain threshold data and develop their own tables using the Excel file EF Goal Power or the Electrofishing App.
- Protocols for gathering threshold data are at the end of this presentation.

Inputs

- If you do not have your own threshold data and want to build tables, here are some suggestions. All outputs are at 115 µS/cm:

Backpack with ring anode and rattail cathode: 1 amp, 240 V

Barge with one ring anode: 2.5 amps, 330 V

Barge with two ring anodes: 5.0 amps, 390 V

Boat with 2-boom Wisconsin-type anodes: 10 amps, 300 V

- Also see Table 2 in the blog "Final Electrofishing Field Blog in the Series" in electrofishing.net by Jan Dean

Important Notes

- These tables may not be accurate enough for your particular equipment or sample sites. Try them and adjust as needed. We'd appreciate feedback on your experiences using these tables or your output goal tables.
- Amperage is the best output to use for standardization (see recent blogs by Jan Dean). Using current as the output goal allows broader application to different electrode types. However, in low conductivity water, or when using low power units as backpacks, voltage may be a better choice to use instead of current

Let’s Make Some Tables

- Use EF Goal Power

Protocol to Use Tables in Sampling

1. measure ambient water conductivity (or specific conductivity and water temperature and convert to ambient [see blogs on water conductivity and meters]);
2. deploy electrodes in "fishing" fashion within typical habitat conditions; for backpacks, we suggest deploying electrodes as you would while sampling in about 1 - 1.5' depth;
3. consult the goal table;
4. standardize by volts or amps;

Protocol to Use Tables in Sampling

5. if you are using amperage, then adjust voltage until the current goal is reached as indicated on your gear's peak ammeter;
6. if you are using voltage, adjust voltage until the voltage goal is reached as indicated on your gear's peak volt meter;
7. if you have time to run a trial test, go outside but near your sample area and assess subjectively your electrofishing success; if unsatisfactory, adjust settings
8. record ambient conductivity, threshold voltage or amperage used (preferably both outputs)
9. optionally, record the major reaction of fishes (escape, inhibited swimming, attraction, immobilization)
10. optionally, record your assessment of the quality of the sampling, such as "successful" or "unsuccessful"

Protocol to Collect Threshold Data

1. Choose a waveform (AC, DC, PDC [frequency, duty cycle]) and gear type/electrode configuration
2. Take ambient water conductivity
3. Start at a low voltage setting
4. Begin electrofishing in a representative section of stream or lake
5. Note fish reactions, characterize the sampling as “successful” or “unsuccessful”; describe fish reactions as “escape”, “inhibited swimming”, or “immobilization”

Protocol to Collect Threshold Data

6. If unsuccessful, increase voltage (e.g., by 25 or 50 V) and follow steps #4 and #5 until the lowest voltage or current levels are found that result in successful electrofishing (threshold)
7. Once you have determined candidate threshold settings, increase voltage (e.g., by 25 or 50 V) and note if sampling is the same; if improved, then your initial threshold estimate was too low; if effectiveness appears the same or even declines, then use your original threshold estimate; you may change your threshold values depending upon fish recovery times (i.e., fish welfare)
8. (If successful on the first attempt, go in reverse-
reduce voltage (power) and sample again; follow this procedure until successful electrofishing results)
9. If you cannot get to successful electrofishing, change waveform type or PDC attributes(frequency or duty cycle) and start over with low voltage settings

Protocol to Collect Threshold Data

10. Once you obtain successful electrofishing, record:
    - -Ambient water conductivity (µS/cm)
    - -Gear type (e.g., backpack, model, and electrode type and dimensions)
    - -Voltage setting
    - -Voltage output on meter (if available)
    - -Current output on meter (if available)
    - -Waveform type and attributes if PDC
    - -Fish capture-prone response (escape, inhibited swimming, immobilization)
    - -Water body type and size (e.g., for a stream, at least mean width, mean depth if possible)