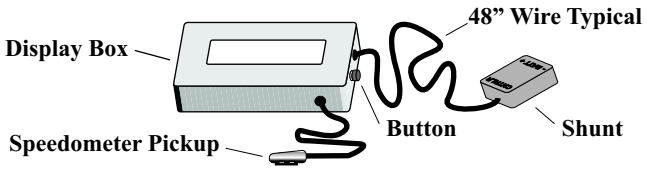
1. Introduction

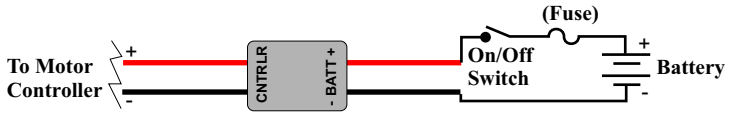
Thank you for the purchase of a DrainBrain, the first digital dashboard and battery monitor designed to the specific requirements of electric bicycles, scooters, and other PEVs. We hope that you find it a useful accessory that optimizes the experience of your electric vehicle.

2. Installation

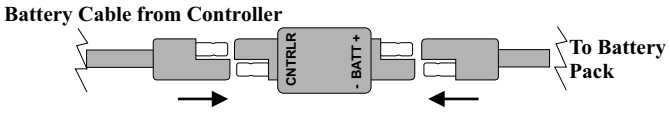
The DrainBrain consists of a handlebar mounted display box, a remote current sensing shunt, and a speedometer pickup cable.



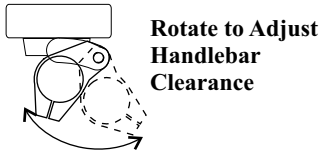
For operation, the shunt must be connected directly in series with the positive and negative leads of your vehicle's battery pack. It is recommended that the shunt is placed after any series switch or fuse so that the meter powers down when the pack is shut off. The correct polarity and orientation are embossed in the molding. In the event that the polarity is accidentally reversed, the meter will not power up. An internal diode protects against damage from reverse voltages.

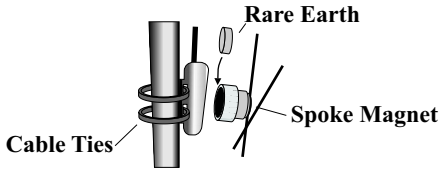


For the model using molded 2-prong trailer connectors, the shunt simply plugs directly between the battery cable and controller cable. No wiring is required. The polarity is correct for Crystalyte, Wilderness Energy, and BionX kits. The Currie USPD uses the opposite polarity standard and is not plug and play compatible. For Currie setups, either use the bare wire model or visit *www.ebikes.ca/drainbrain* for instructions on how to modify the polarity with the molded plugs.



The back of the display box has a mounting bracket for direct attachment to a bicycle handlebar. This bracket has pivoting arm which allows the box to be raised high above the tube for clearance from other devices if necessary. The inside radius of the clip is 1", and so an included rubber shim is necessary for 7/8" handlebar tubes.

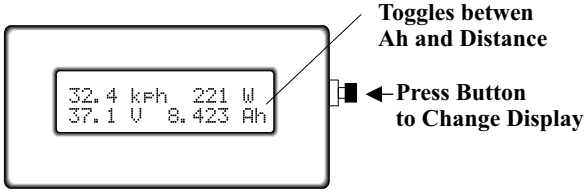




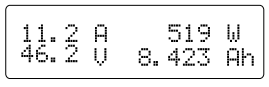
On the speedometer model, there is also a speed pickup cable and spoke magnet to detect the wheel rotation. The pickup attaches to the fork with two cable ties, and must be mounted to pass within 1mm of the magnet for the speed readings to function. The optional rare earth magnet is included that can be attached to the weaker ferrite magnet to allow for much greater clearance.

3. Operation

The DrainBrain turns on automatically whenever more than 14 Volts appears across the shunt. The default display screen shows five units that are most relevant to the rider. This includes three instantaneous quantities: the voltage of the battery pack, the power output in watts, and the speed of the vehicle, as well as two accumulated quantities since the last reset: trip distance and net amp-hours from the battery.



A quick press of the button will toggle to show other display screens of interest. The 2nd display shows just the electrical statistics from the battery pack, including the current in amps. This is the default screen for the non-speedometer model.



2nd Display Screen

4. Display Information

A total of 5 additional display screens can be selected to show a variety of statistical information relating to the energy use of your vehicle.

Display Screen #3 - Power Information

***Watt-hrs*:** This is a measure of the total energy that has been pulled out of the battery pack. One watt-hour is 1/1000th of a KWh and slightly less than one Calorie. To a first approximation, the watt-hours available from a battery should be equal to the voltage of the pack times its amp-hours, but it will typically be less than this because of voltage droop caused by large current draws. Notice that only the positive watt-hours pulled from the pack are recorded. During regenative braking when the watts is negative, the watt-hours value does not decrease.

***Wh/km* or *Wh/mi*:** The watt-hours used per unit of distance travelled is a measure of the average energy efficiency of your vehicle. With this figure, you can readily quantify how different riding styles impact your range and predict with high accuracy the expected travel distance with any particular battery pack.

The Wh/km or Wh/mi figure is calculated taking into account currents that may have flowed back into the battery pack from regenerative braking. The actual formula used is:

$$\frac{Wh}{Dist} = Wh\left(\frac{FwdAh - RegenAh}{FwdAh}\right)\frac{1}{Dist}$$

In order to reduce computational round-off errors, the figure only displays after a total distance of 0.5 km or mi has been travelled.

Display Screen #4 - Regenerative Braking

The next screen shows information that pertains to negative currents which flowed into the pack.

***% Regen*:** The percent regen indicates by how much your range was extended as a result of energy returned to the battery from regenerative currents. Most direct drive vehicles that do not have explicit regen braking can still produce negative currents when they are being ridden fast enough. As well, vehicles with a freewheel in the drive will often regenerate for brief periods from the energy stored in the motor's inertia. The formula used for computing this percentage is:

$$\%Regen = \frac{RegenAh}{FwdAh - RegenAh} \times 100$$

***Fwd Ah* and *Regen Ah* :** The actual forward amp hours and regen (negative) amps hours to the nearest 0.0001 Ah alternate on the right side of the screen. The net amp-hours shown on the main display is the difference between these two.

Display Screen #5 - Peak Statistics

The peak electrical statistics yield information that is useful to understanding the electrical limits that the battery is subject to.

***Amin*:** Is the peak negative or regen current that was captured by the meter.

***Amax*:** Is the maximum amperage that was drawn from the battery.

***Vmin*:** The voltage of a battery pack will sag, sometimes considerably, when large currents are drawn from it. Vmin is a local minima measurement that shows by how much your packs voltage droops. Typically Vmin and Amax occur at the same point, and the maximum power that was drawn can be computed from Vmin*Amax.

Notice that the correct Vmin is sometimes lost when the DrainBrain is powered down and back up again. For measurements where Vmin is important, a Peak Stats Reset (see Section 6) is recommended beforehand to record a correct value.

Display Screen #6 - Speeds and Time

Smax and ***Savg*:** The maximum and average speed of the vehicle in the programmed units of km/hr or mi/hr.

***0h00m00s*:** This is the trip time in hours, minutes, and seconds. It counts only the time that the vehicle's speed is greater than 0.

Display Screen #7 - Lifecycle Statistics

The final display screen provides the lifetime information of the battery pack. These figures are especially useful in figuring out the lifecycle costs of the vehicle and comparing the economics of different battery chemistries.

***Cycl*:** The cycles value increments when the meter is reset. Provided that the meter is reset each time the battery is charged then this will indicate the number of charge and discharge cycles on the pack. In order to prevent false cycle counts from cases where frequent resetting is performed, the value is only incremented if more than 1.6 amp-hours was drawn at the time of the reset.

***TotAh*:** The total battery amp-hours is a running sum of Ahrs that have been pulled from the pack over its life to the nearest 1Ah.

***TotMi* or *TotKm*:** This is the odometer function, showing the total distance that has been travelled on the battery pack.

5. Saving

The DrainBrain will automatically save all the statistics when power from the battery pack is cut out. This allows you to turn off the ebike at a destination or stopover point, and then have the meter resume where it left off once the main power switch is turned back on.

6. Resetting

After the battery pack is recharged, you will typically want to reset the accumulated amp-hour and trip distance information. These statistics can be reset at any point by holding down the button for one second, until the message "RESET" shows on top of the display. This clears everything except the lifecycle data from memory. If more than 1.6 amp-hours were drawn from the battery pack, then the total battery cycles will be incremented as well.

Peak Reset

In some instances for diagnostics and performance testing, it is desirable to clear only the peak statistics (Amax, Amin, Vmin, and Smax) without resetting anything else. This can be accomplished by holding the reset button when the display is showing Amin, Amax, and Vmin. The message "PEAK STATS RESET" will appear on the screen and only the previously mentioned values will be cleared.

Full Reset

When it is time to switch battery packs, then the battery cycle count, lifetime amp-hours, and total distance, can be zeroed by performing a full reset on the system. This is accomplished by continuing to hold the button for 6 seconds after "RESET" is displayed. The message "FULL RESET" will appear to indicate that all stored data has been cleared from memory.

7. Setting Wheel Size and Units

The DrainBrain is shipped with a default wheel circumference of 2075mm, corresponding to a typical 26" tire. In order to program your exact wheel size, hold the button down while the meter is being powered on. You will then be presented with the wheel circumference in millimetres. Toggle the value of the flashing digit by pressing the button, and hold the button to save it and move to the next digit.

Once the last digit has been saved, then the option of switching between kilometers or miles appears. Again press to toggle between units, and hold the button until "OK" appears to save it. The meter will then resume normal operation with the updated parameters.

Note that the existing odometer value will not be updated numerically if there is a change in units.

8. Operation in Wet and Cold Conditions

The DrainBrain enclosure contains a clear sealed window to protect the circuitboard and LCD from water exposure. There is no problem using the meter in light rain. However, in cases of prolonged exposure to wet conditions, it is possible for moisture to enter the box though the back cover which is not sealed. This can cause the window to fog up in cold conditions and render the display difficult to read. Should this occure, then simply remove the back cover and let the unit dry thoroughly indoors so the moisture can escape. When it is reassembled, you may consider using a sealant around the lip and screw holes to render the box fully waterproof.

The LCD screen is specified by the manufacturer to operate between -10°C to 50°C. At the colder end of the temperature range, the response time of the LCD segments is slow, and so rapidly changing digits and screen changes will appear as a blur. The underlying operation of the circuitry inside is unaffected.

9. Advanced

Display Specifications

The electrical and speed ranges of the DrainBrain are compatible with the majority of PEVs. If any of the accumulated quantities exceed the maximums below, the meter will clamp the result to the maximum. Notice that in this case, calculated values such as wh/dist and %Regen that are based on clamped quantities will be incorrect.

Reading	Minimum	Maximum	Resolution
Amps	-40*,-60**	40*,60**	0.1 A
Volts	14	99.9	0.1 V
Watts	-4000	4000	1 W
Fwd Amp Hours	0	199.9	0.0001 Ah
Regen Amp Hours	0	199.9	0.0001 Ah
Watt Hours	0	1999	0.1 Wh
Speed	0	99.9	0.01 km/h or mi/h
Distance	0	199.9	0.001 km or mi
Time	0:00:00	18:12:16	1 second
Cycles	0	9999	1 cycle
Total Amp-Hours	0	99 999	1 Ah
Total Distance	0	99 999	1 km or mi

Electrical Specifications

Voltage Range	-100V to 100V
Quiescent Current	7mA
Shunt Resistance	0.005*, 0.003**
Max Continuous Current	20 A*, 30 A**
Sampling Frequency	50 Hz
Maximum RPM	700

*** 20A model with molded trailer connectors**
**** 30A model with inline wires**

Accuracy

The DrainBrain is designed as an ebike accessory and not a piece of precision electronics instrumentation. Each unit is factory calibrated and tested at 10 amps for 1% accuracy before being shipped. Over the entire span of temperature and current ranges it can be expected to stay within 3% accuracy and ± 1 digit of precision, comparable to the DC amps specification of most digital multimeters.

Calibration

The electronics are stable with time and the unit should stay calibrated over its life. However, in the event that a new shunt is installed, or the wires between the shunt and the display have been extended, then it may be necessary to readjust the gains and/or offsets.

Calibration mode is entered by following the steps to set the wheel circumference. Keep holding the button down once the units (km or mi) have been re-selected. The message "OK" will appear as usual, followed by "CALIBRATE" after approximately 6 seconds.

This allows you to reprogram the scaling factor for the voltage, positive current, and negative currents, (respectively kV, kP, and kN). If for instance it is desired to increase the positive amps reading by 5% and the number 08947 appears for kP, then this value should be changed to 09394 by toggling and saving each digit in succession.

After kV, kP, and kN have been saved, then the message "OFFSET" will appear. Pressing the button once more will cause the meter to measure the amps that are seen and subtract this value from all future readings. Once the new offset is recorded, then the DrainBrain will exit calibration mode and resume normal operation.

Trickle Currents

One thing that the DrainBrain will not do is accumulate trickle currents that may be drained out of the battery if the vehicle is left on but not running. While the internal quantization is approximately 30mA, the software deliberately blanks out any currents that are below ± 100mA so as not to mislead the user that it is recording these quantities accurately.

Most motor controllers will consume between 20-40 mA when powered up, which can deplete a pack by up to 1 amp-hour per day. It is always advisable to have a master switch on the battery that can be turned off to guarantee zero amps when the vehicle is not in use.

Version History

V1.0 is the first speedometer release. Both the option of selecting between miles or kilometres, and a user accessible calibration routine were added since the beta model.

V1.0.1 This version corrects a small glitch in V1.0 which occasionally resulted in the Splash Screen staying on indefinitely after power-on until the button was pressed. As well, the Vmin saving function was improved to more consistently maintain the actual minimum pack voltage even after power down and power up.

V1.0.2 This update adds a time delay on start-up before the EEPROM is accessed. There had been the odd instance reported of a bogus value like 199 Ah or km showing up on the screen after it was powered up by plugging in a noisy connector rather than using a switch. While this has not been successfully reproduced in the lab, it is thought that the time delay will resolve it.