AEMC® INSTRUMENTS
CHAUVIN ARNOUX GROUP

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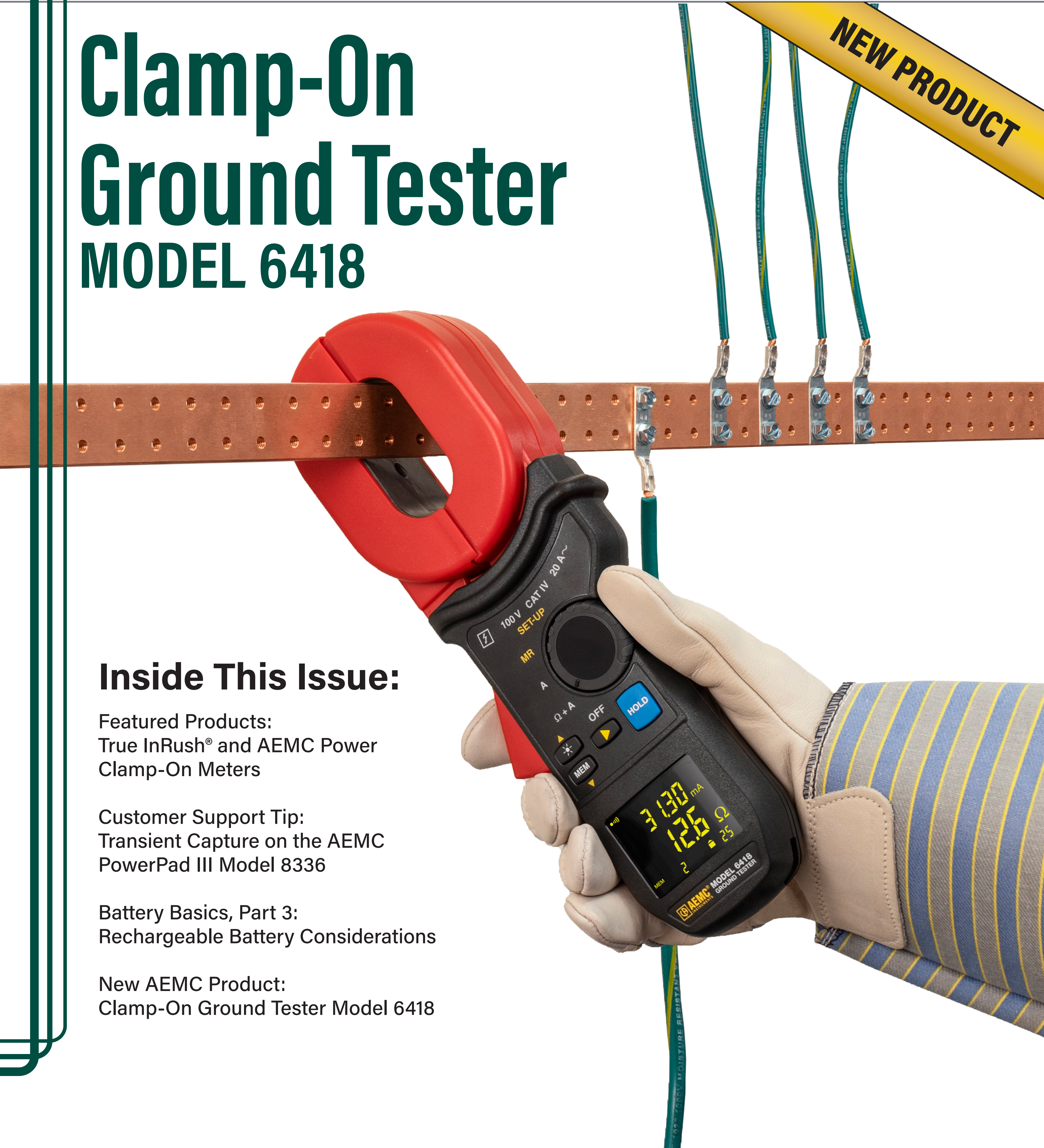
Issue 18 "WATTS CURRENT" TECHNICAL BULLETIN Spring 2019

NEW PRODUCT

Clamp-On Ground Tester
MODEL 6418



Inside This Issue:

Featured Products:

True InRush® and AEMC Power Clamp-On Meters

When an electrical system or device is turned on, voltage and current initially spike before settling down to steady-state operation. For example, when a 3-phase motor powers up, its initial current draw can peak at up to 12x its normal current for a period of 75 to 150 msec. This phenomenon is known as inrush, and it can be an important consideration when monitoring your electrical network for events that could affect the performance of your facility. Inrush is also a critical factor in determining the proper design and sizing of your network.

In addition to motors, transformers are also susceptible to inrush currents. When a transformer is powered up, there is an inrush of approximately 25x its rated current for approximately 10 ms.

Electronically-controlled power supplies are another source of overcurrents, due to their energy-storage capacitors. This also applies to many mass-consumer electronic appliances that incorporate a switching power supply. These devices may cause very strong current surges, which in severe cases can create a spark when they are powered up.

Inrush currents can also be produced by solid-state components such as computers and copiers, as well as heaters and filament lamps.

Inrush Protection

Circuits generally have some form of overcurrent protection, such as fuses and circuit-breakers. These devices trip in the presence of currents that exceed their specified limits, thereby protecting delicate electrical components. The overcurrent protection must be able to react quickly to any overload or short-circuit, but ideally will not trip in the event of a high overcurrent caused by normal use rather than from a fault.

To help prevent this, power supplies often incorporate an internal system known as an Inrush Current Limiter (ICL). This can protect electrical components from overheating due to inrush. Without an ICL in place, inrush is often only limited by factors such as line impedance. ICLs are designed with different specifications and performance characteristics to meet the requirements of a variety of circuits and applications.

When selecting a protection system for a circuit, you must take inrush into consideration to prevent the system from tripping in response to the normal short-lived spikes produced by events such as a motor powering up. In addition to causing needless system downtime, the constant tripping of protection devices by inrush current can significantly shorten their lives – and in extreme cases, can produce pitting and welding in switches, causing them to malfunction and fail to work when actual dangerous currents are present.

Measuring Inrush (and why it's difficult)

An accurate measurement of inrush current is critical for circuit design and maintenance. Instruments used for measuring inrush include clamp meters, digital multimeters, and power quality analyzers. These products use different methods for detecting, measuring, and calculating inrush. They also vary widely in price.

Unfortunately, determining inrush with precision and repeatability can be challenging. **Most instruments can only measure inrush in systems that are initially powered off.** Basically, these instruments measure current and voltage starting with the original powered-down state, through power-up and finally steady-state operation. This usually occurs within the first few seconds after start-up. The instrument then compares the power-up peak to steady-state and, depending on the threshold criteria used, displays the inrush reading.

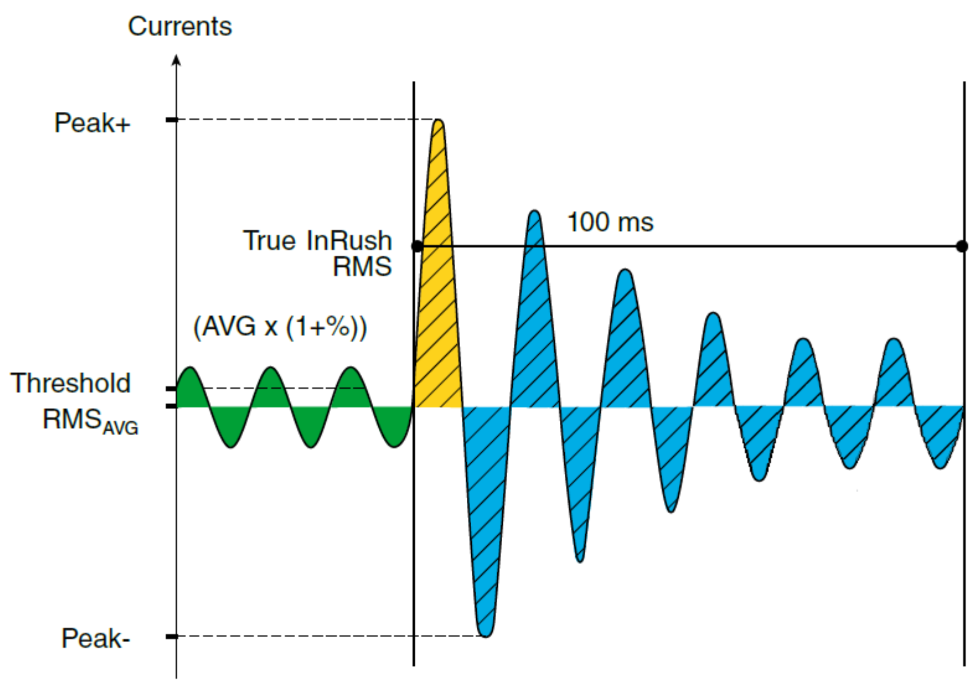
One limitation with this method is that inrush currents frequently occur on circuits that are already powered on. For example, a circuit can have multiple components capable of inducing inrush currents at different times. Powering down the circuit each time you want to measure inrush produced by a single component is inconvenient, and obviously cannot be used for monitoring a system in operation.

True InRush®

AEMC's True Inrush® function provides the unique ability to measure power-up events from devices on a network that is already energized. In addition to the initial power-up event, True InRush can also detect subsequent power-up inrush events that meet user-defined threshold criteria. True InRush captures these overcurrents, making it simpler and easier to size complex installations correctly. The basic steps in the True InRush process are as follows:

1. When turned on, the instrument acquires the steady-state current for the installation.
2. The instrument processes the signal to filter out normal operational variations.
3. When the base RMS current has been calculated, the instrument performs half-period monitoring on the circut.
4. If the instrument measures a half-period with an RMS current that exceeds the user-defined overcurrent threshold (indicating an inrush event has occured), it triggers a 100ms session during which the instrument takes a measurement every 1ms.
5. At the end of the 100ms period (which encompasses 6 cycles on a 60Hz network and 5 cycles on a 50Hz network), the instrument digitally filters and processes the samples to calculate the actual inrush RMS current for the period. This value is then displayed along with the peak instantaneous maximum and minimum.

   This process is shown below for a 60Hz network:



AEMC provides power clamp-on meters that provide True InRush capability. These instruments feature high-speed, digital signal processing to filter out electrical noise and capture inrush current to a high level of precision and repeatability. They include the 400 Series and 600 Series families of clamp-on meters. AEMC also offers other 3 phase analyzers, including the Model 8333 and Model 8336, that provide True InRush detection and storage.

Measuring True InRush with the AEMC Model 607

To demonstrate, we'll explain how to set up the AEMC Power Clamp-On Meter Model 607 for True InRush detection and measurement. The Model 607 is a 10,000-count professional electrical measuring instrument that combines the following functions:

- Current and voltage measurement
- Frequency measurement
- Harmonic distortion (THD) measurement
- Continuity testing (with audible alarm buzzer)
- Resistance measurement
- Power (W, VA, var, and PF) and Energy measurements
- Crest Factor (CF), Displacement Power Factor (DPF), and RIPPLE measurement

Measurements can be recorded and stored in the Model 607 memory. The instrument then can be connected via Bluetooth to a computer running DataView software, for data download and report generation.

In addition to these features, the Model 607 can perform True InRush detection and measurement.

Step 1: Setting the Inrush Threshold

To get started, we'll set the inrush threshold percentage. This is the percentage by which the half-cycle RMC current must exceed the steady-state current in order to trigger an inrush event.

1. With the Model 607's rotary selection switch in the OFF position, press and hold down the button. (Note this button is also labeled "Inrush.") While holding this button down, turn the switch to the setting. After a few moments the instrument beeps, and the symbol **Inrh** appears on the LCD. The inrush threshold also appears on the display, blinking to indicate it is in edit mode. By default, this is set to 10%, representing 110% of the measured steady-state current. Possible values are 5%, 10%, 20%, 50%, 70%, 100%, 150%, and 200%.

2. To change the threshold, press the instrument's yellow button. Each press displays a different value.We suggest initially setting the threshold at or near the default 10%, and conducting a recording session. If the threshold results in a high number of inrush events being recorded, you can reset this to a higher value. Conversely, if few if any events are recorded, you can change this setting to 5% to capture smaller overcurrents.

3. When the desired threshold is displayed, turn the switch to another setting. The chosen threshold is stored and a double beep is emitted.

Step 2: Recording True InRush Current

With the threshold percentage set, we are ready to conduct an inrush recording session.

1. Before making the actual inrush measurement, we need to "zero" the DC component. First, ensure the instrument is not clamped around a conductor. Turn the rotary switch to and observe the instrument's mode indication, which appears blinking in the upper right corner of the LCD. If this does not indicate **DC**, press the yellow button until **DC** is displayed.
2. Press the button until the instrument emits a double beep and displays a value at or near zero. The correction value is stored until the clamp is powered OFF.
3. Clamp the Model 607's jaws around the conductor to be measured. Then press the button for two seconds, until a beep sounds and the symbol **Inrh** appears on the LCD. The backlight blinks, indicating the instrument is acquiring the steady-state RMS current. When complete, the triggering threshold appears on the screen.

   The Model 607 then begins monitoring the circuit for an inrush event. During this process the mode indicator **A** blinks and a series of dashes appears in the measurement area of the screen.
4. When the instrument measures a half-cycle with an RMS current exceeding the triggering threshold, it initiates a 100 ms session during which it makes a series of 1 ms measurements. When complete, the LCD calculates and displays the True InRush current.
5. Press the button to display the minimum and maximum peak instantaneous current values measured during the 100 ms session. (Note that this step can only be performed if an inrush event has been detected; otherwise pressing has no effect.)
6. Press and hold down the button (or turn the rotary switch to a different setting) to exit True InRush mode.

True InRush: An Important Tool for Circuit Design

As we've seen, determining the magnitude of a circuit's inrush events is critical to its design, particularly when choosing protection devices such as circuit breakers, fuses, switches, and Inrush Current Limiters. Correctly selecting and sizing these systems can help prevent them from interrupting circuit operation in response to normal inrush currents – while still preventing dangerous overcurrents from damaging sensitive components.

True InRush gives designers an important tool for accomplishing this goal, by providing a method for measuring inrush during normal operation, **without powering down the network**. And once the circuit is designed and put into operation, True InRush offers an easy way to monitor the network, identifying potential problem areas. It also enables you to determine the effects of adding or removing system devices, and making modifications as appropriate.

For more information on AEMC Power Clamp-On Meters with True InRush capabilities, including the Models 400 and 600 Series of instruments, please visit the AEMC web site.

Customer Support Tip:

Transient Capture on the AEMC PowerPad III Model 8336

Transients are short-term current and voltage phenomena that occur in the system under measurement. The process the AEMC PowerPad III Model 8336 uses for recording transients is as follows:

- The instrument sampling rate is a constant 256 samples per cycle.
- When a transient search is started on the instrument, each sample is compared to the corresponding sample from the preceding cycle.
- The transient threshold is the user-defined amount of volts or amps for any datapoint to differ from the corresponding datapoint exactly 1 cycle earlier. The preceding cycle defines the mid-point of the trigger envelope and is used as reference.
- As soon as a sample is outside the envelope, the triggering event occurs; the transient data is then captured by the instrument.
- The cycle preceding the event and the three following cycles are saved to memory.

The following explains how to configure, schedule, and view a transient recording session on the Model 8336. These instructions assume you are using the Model 8336 as a standalone instrument.

Note that you can also perform these tasks by connecting the instrument to a computer running AEMC's DataView software. For more information, see the PowerPad III Model 8336 User Guide.

Transient Recording Configuration

1. With the instrument turned ON, press the button to display the Waveform Capture screen.
2. Ensure Transient is highlighted, then press .
   - If there are no transient detection sessions stored in the instrument, the Detection Schedule screen appears.
   - If there are recordings in the instrument, the Detection List screen is displayed. In this case, press to display the Detection Schedule screen.

3. Press the function button under the icon to display the Voltage Thresholds screen. At the top of the screen is the Threshold Set-up field. Options are:

   - **4V:** The same voltage difference threshold applies to all phases and the neutral in the elecrtical hook-up
   - **3V+VN:** One threshold applies to the phases and one applies to neutral
   - **V1+V2+V3+V4:** Each phase and neutral has its own assigned threshold

   Depending on the electrical hook-up currently under measurement, not all these options may be available.

4. The setting in this field determines which of the four fields below it (1, 2, 3, and N) are editable:

   - **4V:** a single field is active for 1, 2, 3, and N.
   - **3V+VN:** one field is active for 1, 2, and 3; and another is active for N.
   - **V1+V2+V3+N:** each field is active.

   To edit a voltage threshold field, highlight it using the up and down arrow buttons, then confirm the selection by pressing . Use the left and right arrows to select a digit, and the up and down arrows to change it. You can also use these buttons to select units (V or kV). Press to confirm the edited field.

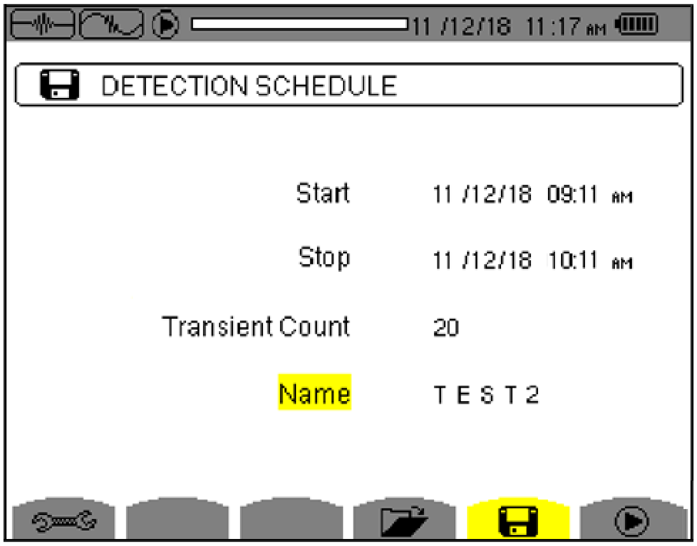
   Press the A button to display the Current Thresholds screen. This is similar to the Voltage Threshold screen. You can select which thresholds apply to which phases, and specify the value of the threshold (1mA through 9999kA). As with the voltage thresholds, not all these options may apply to all electrical hook-up types.

Note that current transients typically occur frequently. We recommend performing a current transient search only when looking for a specific type of transient. At other times, such as when you are primarily interested in voltage transients, you can effectively disable current transient searching by setting the threshold to its maximum value.

Scheduling Transient Detection

1. Press the button to display the Waveform Capture screen.
2. Ensure Transient is highlighted, then press .

   - If there are no transient detection sessions stored in the instrument, the Detection Schedule screen appears.
   - If there are recordings in the instrument, the Detection List screen is displayed. In this case, press the button to display the Detection Schedule screen.



3. This screen displays four input fields:
   - **Start** defines the time and date when the recording starts. This must be later than the current date and time.
   - **Stop** specifies when the recording ends. This must be later than the start date and time.
   - **Transient Count** defines the maximum number of transients that you want to capture before stopping the session.
   - **Name** allows you to name the test. This can be 8 characters long.
4. Use the arrow and buttons to highlight, select, and edit these fields.
5. Press the button to write the settings to the instrument and start the session.
6. If not enough memory is available, an error message appears informing you of this. Otherwise, the transient detection session will begin at the scheduled start time and date.

   If a session is scheduled but not yet started, the message DETECTION ON STANDBY appears on the screen until the start time is reached, at which point the message changes to DETECTION IN PROGRESS.

   When the session is active, the icon blinks at the top of the screen, along with a status bar showing the progress of the session. In addition, the (stop) button appears in place of .

   During the session, the Transient Count number is reduced by 1 every time a transient is recorded. If this number counts down rapidly and appears as though it will reach zero well before stop time is reached, we recommend stopping the session and setting the threshold to a higher, less sensitive value.

   The session will continue until:
   - you press
   - the Transient Count limit is reached (see Step 3)
   - the stop time/date is reached
7. When the transient detection session is finished, it appears in the Detection List screen. You can now open the session and view its contents, as explained below.

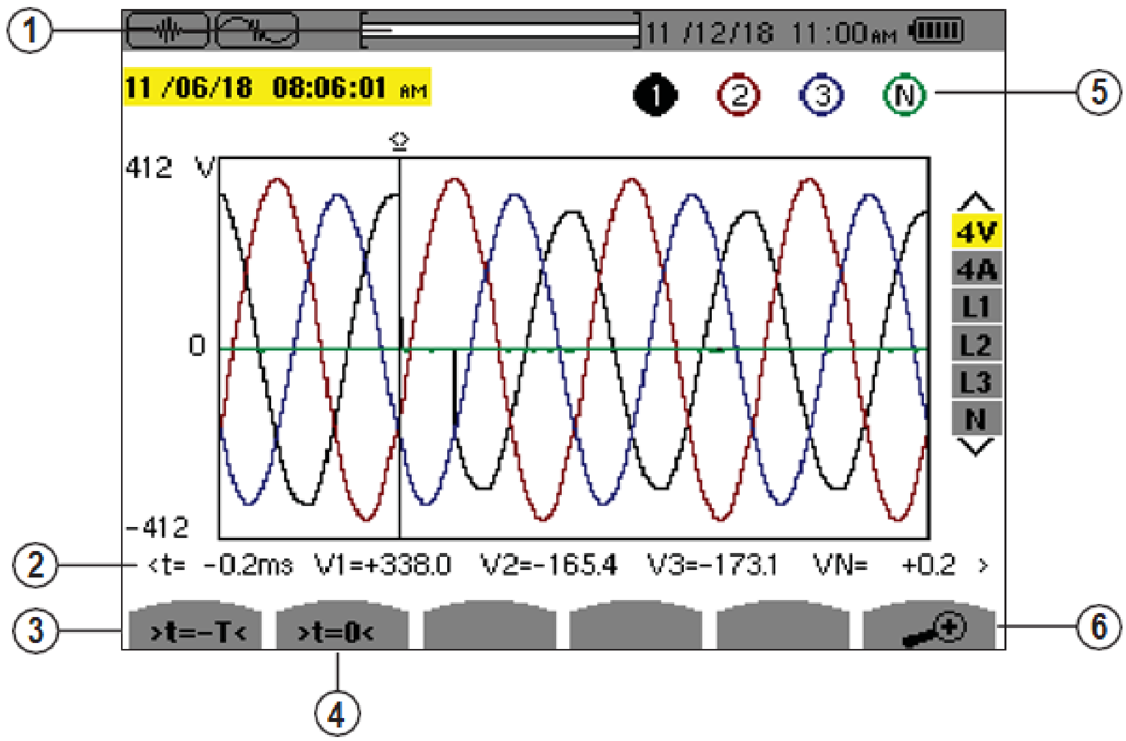
Viewing a Transient Detection Session

1. **At the detection schedule screen**, press the button.

   For all other displayed screens, press the button, and then select Transient.

   Either action displays the Detection List screen.

2. If more than one transient recording is stored, use the arrows to select the desired recording, then press to open it.



In the preceding illustration:

1. Location in the record of the zone displayed.
2. Instantaneous value of the signals according to the position of the cursor on the scale. Use ◄ and ► to move cursor.
3. Move cursor to one period of the signal before transient triggering time.
4. Move cursor to transient triggering time.
5. Number assigned to displayed graph (e.g. 1 is highlighted indicating channel V1 triggered capture of the transient)
6. Zoom In/Out

Battery Basics, Part 3:

Rechargeable Batteries Considerations

In Part 1 of our review on battery basics, we presented a brief explanation of how a battery works, the difference between disposable and rechargeable batteries, and the various designs used for each.

In Part 2, we looked at how to interpret battery specifications (such as capacity, performance, and life) and how to match them to your specific application to help ensure you select the most appropriate battery for your requirements.

In the conclusion of our article series, we turn our attention to the operation, maintenance, and storage of rechargeable batteries. To prepare, let's define some key terms:

- **Depth of Discharge**, or DoD, is the percentage of maximum battery capacity that has been discharged. A discharge to 80% DoD or more is referred to as a deep discharge. The inverse of Depth of Discharge is State of Charge, or SoC. This is roughly equivalent to a fuel gage, and represents how much charge remains in the battery. SoC is normally used for measuring the current state of a battery in use, while DoD typically is referenced when discussing the lifetime of the battery after repeated use.
- **Self-discharge** is the tendency for batteries of all types to lose power when not in use. Rechargeable batteries tend to have much higher self-discharge rates than disposable. For example, nickel-metal hydride units can self-discharge as much as 20% to 30% of their power per month. Self-discharge is affected by temperature, with the rating increasing as temperature rises.
- **Internal Resistance** within the battery is usually different for charging and discharging. As internal resistance increases, the battery efficiency decreases as more charging energy is converted into heat.
- **Cut-off voltage** defines the "empty" state of the battery.
- **Cycle Life** is the number of discharge-charge cycles the battery can experience before it fails to meet specific performance criteria. The battery's operating life is affected by the rate and depth of cycles, as well as environmental factors such as temperature and humidity.

The recharging process

Typically, recharging involves connecting the battery to a device that applies electricity to the battery. The device usually runs on AC power, although some chargers operate on 12 volt DC. Internally, positive active material within the battery is oxidized, producing electrons. Simultaneously, the battery's negative material is reduced, consuming electrons. This restores the battery to an operational state.

The time required to recharge a battery varies. So-called "dumb" chargers, which lack the ability to sense voltage or temperature, generally are the slowest and may take 14 hours or more to achieve a full charge. More sophisticated chargers require as little as 15 minutes, although 2 to 5 hours is more typical. These incorporate features to prevent overcharging and overheating. Some chargers can only recharge one type of battery, while others can accommodate several chemistries.

Different battery chemistries require different recharging schemes. For example, some types can be safely recharged from a constant voltage source. Other must be recharged with a regulated current source that tapers as the battery reaches full voltage. Lead-acid batteries should be recharged before they are fully discharged, while nickel-metal hydride units should be fully discharged.

Incorrect recharging can damage a battery. This is particularly true for lithium-ion units, which if overcharged can overheat, catch fire, or explode.

When preparing to recharge a battery, start by selecting recharge voltage and current. Recharge voltage is based on the battery's size and chemistry. Note that manufacturer specifications often list recharging voltage in terms of voltage per cell, or VPC. In this case, you can determine recharging voltage by multiplying VPC by the number of cells contained in the battery.

For instance, recharge voltage for lithium ion batteries is typically 4.2 volts per cell. As a rule of thumb, batteries are charged at 10% to 30% of its amp-hour rating. So to recharge a 2000 milliamp-hour battery, set the recharge current to between 200 to 600 milliamps.

When recharging is in progress, monitor the battery temperature, voltage, and current. Recharge only at ambient temperatures in a well-ventilated room.

A lead-acid or lithium ion battery is fully charged when either of the following conditions is met:

- The recharging current falls to 3% of the amp-hour rating.
- The current bottoms out and falls no lower after 16 to 24 hours.

One note about lead-acid batteries: When discharged for an extended period of time, they are subject to a process called sulfation. This occurs when the lead sulphate within the battery crystalizes. This causes the battery to lose its ability to accept a charge. Sulfation can also occur when these batteries are insufficiently recharged during normal operation.

Some sources claim that sulfation can be reversed through measures such as charging above the recommended voltage and lowering the charging current. Others state that there is no known, independently verified way to reverse sulfation. So to avoid sulfation, be sure to promptly and properly recharge lead-acid batteries as required.

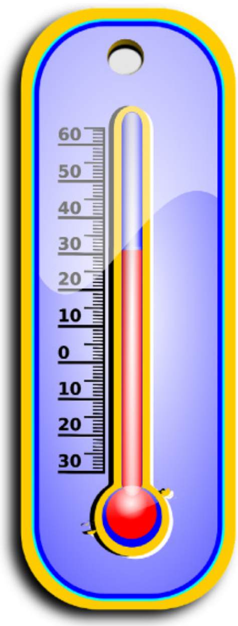
Recharging NiMH

Nickel-metal hydride batteries can present a special challenge when recharging. These batteries generally require a higher recharging current compared to other battery chemistries. A fully discharged 2000 milliamp-hour battery requires a recharge current of 750 to 1000 milliamps applied for around 3 hours.

Another issue is self-discharge, which for NiMH batteries can be as high as 30% per month. When fully discharged for several months, voltage in these batteries may be so low that some chargers cannot accurately measure it. As a result, the charger only produces a so-called "trickle" or maintenance charge, which is insufficient to fully recharge the battery.

In these situations, you may be able to recharge the battery if its voltage is above 1 volt. To do this, apply DC voltage approximately 2 volts higher than the normal battery voltage, with a current of 500 milliamps or lower. After a few minutes, battery voltage should be sufficient for the regular recharging process to function normally.

If the battery voltage falls below 1 volt, it likely cannot be recharged and must be replaced.



Batteries and Temperature

As we are reminded whenever we try to start an automobile on a winter morning, temperature can have a significant effect on batteries. Most are designed to operate optimally at room temperature. Lower temperatures increase the battery's internal resistance and lower its capacity.

For instance, a battery that provides 100% capacity at 80 °F will usually deliver only half this power at 0 °F. In extreme cold, the electrolyte in lead-acid batteries can freeze and crack its enclosure. Some lithium ion batteries can operate in temperatures as low as –40 °F but only at a reduced discharge rate. Note that the battery cannot be recharged at this low temperature.

Raising battery temperature can temporarily improve performance, although doing so for prolonged periods will reduce the battery's life. A battery designed for optimum service at 68 °F will have its life reduced by 20% when operating at 86 °F, and up to 40% at 104 °F.

Low temperatures can also cause multi-cell batteries to experience a condition known as cell-reversal. This happens when a negative voltage potential occurs across the weakest cell in the battery. This stresses the weak cell to the point it develops a permanent short circuit. The more cells in the battery, the greater the risk of cell-reversal. This is a major cause of failure in cordless power tools operating at low temperatures.

Leakage

Alkaline batteries (and to a lesser extent, other chemistries as well) are subject to leaking. As the battery discharges, hydrogen gas is generated. As more and more gas is generated, pressure increases within the battery. This eventually ruptures the battery.

Leakage can also result when the battery is subjected to physical damage, such as rust and high temperatures. It can also occur when you attempt to recharge dead alkaline batteries in a charger designed for other chemistries, mix different chemistries in the same device, or store batteries in environmental conditions outside the recommended range. This can result in damage to the battery compartment or other areas of a device.

To clean terminals after an alkaline battery leak, use either one tablespoon of boric acid in one gallon of water or a mixture of equal amounts of diluted vinegar or lemon juice with water. To clean a leak from a lead-acid battery, use baking soda and wipe with a damp cloth.

Storing batteries

Temperature is also a consideration for battery storage. Most manufacturers recommend storing batteries at 59 °F, with an extreme range between –40° and 122 °F for most chemistries.

Another factor for battery storage is State of Discharge. Lead-acid batteries must be stored at full charge, while nickel- and lithium-based chemistries should optimally be stored at around 40% SoC. This helps ensure the battery remains operational by allowing for some self-discharge. If necessary, nickel hydride can be stored while fully discharged. However, lithium-ion batteries will be damaged if stored with a voltage lower than 2 volts per cell for any length of time.

Disposal

All batteries will eventually fail to provide a usable charge and must be discarded. The regulations governing disposal of batteries differ from one jurisdiction to another. In some locations, alkaline batteries can be disposed as regular domestic trash. Other jurisdictions, such as California, mandate that batteries be treated as hazardous waste.

In the European Union, most stores that sell batteries are required by law to take back old batteries for recycling. In the U.S., large retail outlets that sell batteries may also accept old batteries for recycling.

Review

We've covered a fair amount of ground in this article series, so let's take a minute to review a few major points:

- Batteries come in a wide range of shapes, sizes, and capabilities. Some are used in thousands of different applications and devices, while others are designed for more specific uses.
- Most batteries are disposed when they can no longer provide sufficient power, while an increasing number can be re-charged and used multiple times.
- Batteries employ several different chemistries. Alkaline is the most common type for disposables, with lithium used for button batteries. Lead-acid, nickel-metal hydride, and lithium-ion among others are popular chemistries for rechargeable products. Each has its strengths and weaknesses. For instance, disposable alkaline batteries are suited for applications such as alarms, where the device is inactive for extended periods then requires a high level of available energy. Nickel-metal hydride and lithium ion rechargeable batteries are used for high-energy mobile devices, while lead-acid is the choice for applications where small weight and size are not critical.
- In addition to voltage and current, measures such as amp-hours, watt-hours, and C-rating are critical for comparing battery capacity and performance.
- The battery recharging process is affected by a number of factors, including environmental conditions and battery chemistry.
- Temperature has an important effect on battery operation, storage, and transport.
- Other battery-related considerations include safety, leakage, and disposal.

This concludes our review of battery basics. Hopefully, we have provided some good background to help you make the right choice as you decide which battery is suited for your application's requirements. Please visit our YouTube channel for instructional videos on other topics in electronics, including the many products offered by AEMC.

New Product:

Clamp-On Ground Tester Model 6418

AEMC® Instruments is pleased to announce the Model 6418, the latest addition to AEMC's family of clamp-on ground testers. The simple-to-use Model 6418 makes ground impedance measurements in a parallel earth network, such as power distribution poles and overhead ground conductors. These measurements are simpler to perform than traditional measurements with two auxiliary rods.

The Model 6418's large oblong measurement head can clamp around bars up to 1.18 x 1.57" (30 x 40mm). Its memory function records measurements for later viewing.

The instrument's OLED (Organic Light Emitting Diode) display screen is easy to read, even in direct sunlight.

Features include:

- Ground integrity measurement
- Designed for clamping onto ground bus bars
- Loop indication warning of the possible incorrect measurement
- Large multi-function bright yellow organic LED display (OLED)
- Storage of measurements (Ω and/or A, with time-stamping)
- Alarm function with adjustable set point and buzzer for quick field checks for amps and ohms
- Rugged Lexan® head and body construction resists breakage
- Alarm settings and stored memory information are saved during shutdown
- Noise icon and buzzer alert user to the presence of dangerous current levels
- Designed to EN 61010-1, 100V CAT IV (150V Cat III) safety standards

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