AC / DC
Power Supply Choices and Safety for Timing Systems

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Updated: January 2010

Version 3.2

When electronics malfunction often the primary cause is due to power supply issues. If circuits of any system can't get the power voltage or current they need, they will fail. If something is acting up, the first element to check is the battery or external supply of what is connected to your device. The problem may be as simple as a bad battery, corroded contact, or a malfunctioning or incorrect external power supply.

In timing systems the challenge of supplying power as it relates to the wiring used to connect remote sensors (start gates, photocells etc.) makes for never-ending issues if not thought of as a system. Here's why:

Timing systems trigger based on simple signals that sense a voltage change on a timing input. Each input (timing channel) triggers when it changes its state relative to GROUND (zero-volts). ALGE and TAG Heuer systems output a low voltage of 5 volts DC. When the timer senses the voltage on a timing channel falling to a short circuit (shorted to GROUND), it triggers. This is a normally-open triggering circuit.

GROUND in any electronics or electrical system is a reference to 0 (zero) volts. In a perfect set-up it should always be 0 volts and never vary – but this is almost impossible, particularly when you attach a few kilometers of wire to inputs of the timer and then plug it into the wall (AC power). Unless the wiring is grounded at the same place in the overall system, the ground voltage used as the bigger and power reference will float. If the difference is significant enough – the timer will trigger as the ground potential fluctuates.

Again, the single most common problem with timing systems comes from incorrect, flawed or compromised power (normally leaking in from connected devices like PC's and displays) and how they interact with the long wires that the timer is connected to remote sensors. When this happens the timer behaves like a crazed, trigger-happy thug. You will suspect "hill-wiring" (because this is where the problem manifests itself, but in fact your problem is being caused by improperly grounded power connections.

This is a technical discussion that follows but here is a preliminary list of Do's and Don'ts:

DON'T

- Use ungrounded sensor wiring more than 100m long
- Ground hill or stadium wiring in more than one location
- Mix up ground connections to timing signal input pairs
- Use a battery charger as a power supply
- Use a Generator without a proper Ground
- Inject any AC powered or AC type signal into your DC-type hill/stadium wiring
- Send data RS232 signals on adjacent pairs of wires in the same cable bundle
- Send PA system signals on adjacent pairs of wires in the same cable bundle

DO

- Use opto-isolators on:
    - All timing channels connected to hill/stadium wiring
    - All data connections
        - To/From Computers
        - To Displays
- Use anti-static mats/bracelets to assure proper discharge of static shocks to properly grounds.

Every season some our timing system clients run into technical and safety trouble because they make some basic mistakes about how they power their timers or their timing sensors and accessories. There are some very important pitfalls to avoid on this power supply topic that can cause timing problems, inaccuracies, damage your equipment and even put your operators in ***serious danger*** of fire or electrical shock injury.

Any external power supply, be it a battery (DC "Direct Current") or household current adapter (AC "Alternating Current" to DC) for timing systems, needs to be carefully considered. It is also crucial to be aware of ***the basic safety requirements*** for AC current distribution in your timing building or facility.

This is a vast topic and anyone who suspects "timing system" problems should START by reviewing their AC or DC power sources for faults. **Portable generators are notoriously bad** because **users rarely ground them properly**, check or monitor the output AC sine wave frequency or DC current, or pay attention to the OTHER items that are ALSO plugged into the same generator circuit. Unless you take specific measures to limit the effects of the OTHER items plugged into the same UNGROUNDED AC system you WILL produce power problems in the form of unwanted electrical noise that backwashes into your sensitive timing electronics. An ungrounded PA system also connected to the timing AC circuit is a classic example of such a basic mistake.

A proper path to ground in any electrical service is first and foremost a SAFETY issue. Secondly, an ungrounded AC (main line or generator) service **provides no way for electrical "noise" to escape to ground and dissipate**. This is a fundamental AC concept for electronics and such adverse effects must be avoided for success. The result of a missing or faulty AC ground is that any AC noise is injected into your electronics via the AC power line. It has nowhere else to go. If you're running a toaster or a circular saw – no big deal. If you're running a PC or a timing system that detects remote timing impulses relative to ground, it's a deal breaker.

In order of preference, here is how we recommend you power your timing devices:

a) Fresh Internal Alkaline batteries.
b) External Battery (Alkaline or rechargeable Nicad, NiMh, GelCell or sealed Wet Cell)
c) External High Quality 110vac/DC Adapter (preferably the one sold by the Manufacturer)
d) Internal Rechargeable (NiCad or other) Batteries.
e) Nothing Else.

In all cases, how your timing system uses power is also related to the "Ground" characteristics of the timing inputs that provide timing triggers to the system. By solving one problem (power supply), you may be creating many more (false or erratic timing pulses or much worse). Although you can fix some of these power supply problems with adding other devices (opto-couplers, isolation transformers) it's best to deal with the fundamental issue rather than just treat the symptom.

Finally, in some installations where connection to photocells, start gates and any other remote sensors is done by long runs of wiring (alpine skiing, motorsports, Speed skating) there is a very real and dangerous set of issues relative to **multiple grounds** and signal balancing. This too is a vast and important topic that we have discussed in other information papers in regard to "telecommunications wiring." We would urge you not to ignore the importance of these concepts and how they affect your ability to be safe and successful in your timing and data processing installations. No venue is immune to the need to respect proper AC power and signal wiring engineering.

Not Just Power but Timing, Too

Most timing systems sense incoming timing pulses from sensors like start gates, photocells, manual buttons, tape switches and many other sources as "normally open" or "normally closed" pulses on a pair of wires. There are many other ways this can be done, but for the most part our ALGE, TAG Heuer and Swiss Timing systems use these methods. It's sure-fire and very market compatible with many other makes of high-quality

sensors. The whole concept works on how a timer senses changes in the sensor connection on the wire relative to the “Ground” of the timer signal inputs.

As described above, the “Ground” is also part and parcel of the “negative pole” of whatever your timer is using as its DC (Direct Current) power source, or the “Neutral” (and hopefully the “Ground”) side of an AC source. If you compromise the power supply of your timer, the remote sensors, display, or anything else connected to your overall system (like a PC, Laptop or printer), you are possibly compromising the ability of your timer to properly sense incoming timing signals (which defeats the whole process).

If you inadvertently use a compromised external power source (ungrounded generator for example) you will probably compromise the timer’s ability to “look” at what it assumes will be a stable “Ground” or “Zero Volts” reference point on its timing input channels. False triggering or erratic and unexplainable behaviour that looks like your timing system is “possessed” is a real threat in this case, and that may be the least of your problems.

In addition, external power supplies that do not provide a “close-to-pure” Direct Current (DC) at the required voltage will not only mess with the nature of the Ground reference for timing accuracy, they can destroy the internal power circuit and possibly affect other operational circuits of your timer. All internal circuit boards regardless of how they are externally powered all function on DC voltage. Thus, non-DC damage can occur over time or more dramatically, sooner.

As mentioned briefly above, if you also have long signal wire runs to remote sensors, how that wring network is grounded to the AC system (or not) and where this is done is a huge safety and signaling issue that cannot be ignored or misunderstood.

Internal Needs – DC (Direct Current)
Almost all electronic circuits (from cell phones to video cameras) are designed to operate on Direct Current (DC) Voltages. Even if you can plug them into the wall in your house (That’s Alternating Current – AC), inside or in a power converter external of the device the AC is converted into a useable “Ripple- free” DC current at the required voltage on the circuit boards.

The term “Ripple” in this case refers to the presence of Alternating Current (AC) on what should be a Direct Current (DC) power supply. It happens all the time and is the crux of the issue, particularly when dealing with generators or where other heavy and electrically noisy loads are present on the same AC line.

Depending on the sophistication of the device and the importance of the task, the purity of the DC current inside the device may be allowed to vary. Manufacturers may also have to be very careful about what they expect the AC voltage to be if they expect to convert it into the DC levels they need inside the device. Since typical AC supply voltage can vary greatly (household AC can be anything from 100 VAC to 140 VAC in some cases), and if you need 5 volts DC inside the device, you had better build a power circuit that can take pretty well anything in that expected range at the inputs and deliver exactly what is needed (in terms of voltage and current) for the circuit at the outputs in terms of DC. Not surprisingly this affects the cost of the power supply or power circuit that is built to do the job.

Power Supply Options
The best example of a ripple-free DC power source is a battery. Batteries are pure DC. They push electrons into your device in one very predictable direction and do so until they run out. They are also very predictable when it comes to what 0 (“zero”) volts as it refers to “ground.” The up side is they are the best DC source of energy and produce no adverse side effects (like AC “ripple”) while they do so. The down side is they have a finite capacity that is related to an increased operating cost (they eventually die and are an expensive method).

To keep you from constantly buying exhaustible batteries, a manufacturer will propose or provide a household current (110 Volts AC) adapter that allows you to plug into the wall and power your device from a now theoretically inexhaustible and relatively inexpensive Alternating Current (AC) power source. This can

take the form of a built-in circuit or more typically (and perhaps annoyingly) due to form factor, an external "wall-wart" AC/DC adapter.

Timing systems are sensitive to the power you feed them because they are trying to do very precise things. This is why we want you to use Alkaline or Lithium batteries if you have a choice. Alkaline batteries have a very predictable discharge rate (they start around 1.6 volts DC and provide useable current to around 1.1 volts). Put in new ones, watch the power LEDs or meters for readings and you can be assured you will have a complete timing session with no worries about potentially induced problems from external power sources.

Since the stability of the negative "ground" of the timing inputs is related to the quality of the power your are hooked to, you can mess up a good thing pretty easily with an inexpensive but ripple-laden AC external power supply that is supposed to be delivering nice clean DC voltage but probably isn't able to.

Even if you have a proper and correct AC/DC power converter as supplied by a quality manufacturer, a compromised AC line with electrical noise will still cause problems. Again, this is typically the case when using an ungrounded generator that serves other devices (PA systems for example) or when connected to an AC line with other noisy loads attached (Ski-lift engines, Lighting, or other large electric motors that are not electrically isolated using an isolation transformer).

The reality of what's out there
Sports venues like ski areas, arenas, velodromes or at any site where a temporary AC power is added can pose basic technical challenges for AC power. Even permanent AC installations may not respect local electrical codes or be designed and built to respect data-signaling needs.

At a ski area for example it is common to find that the timing building will be hooked into the AC power line that also services the lifts, snowmaking, lighting or general large current resort power needs. These AC lines will typically have large motors working on them driving lifts, compressors, heating or air conditioning units, refrigerators, etc. All of these large capacity motors actually feed back AC noise into the AC lines that supply them because of the enormous electrical load they represent as they operate and the nature of the electrical motors attached. This may be, and often is, the same AC line that your delicate little timer or PC may be hooked into in the timing building.

The AC feed-back noise from these large AC current users will cause the AC line to exhibit disturbing and potentially harmful characteristics that are related to AC harmonics. These feed-back harmonics are powerful electronic waves that can easily destroy more delicate electronics like your timer and/or laptop. Every situation is different and the load harmonics generated can vary enormously.

To counteract these large load AC harmonics effects, resorts and event venues use **isolation transformers** on their AC lines to isolate the large AC motors from other everyday users in the general AC loop. Again, it is not uncommon to find that, for your timing building, the ski area may have simply tapped into an existing AC line for the lift without installing an isolation transformer to protect your equipment. In many jurisdictions this is illegal and contradictory to the electrical code, but most venues allow ski clubs to build timing shacks and no one knows or cares about the electrical code (let alone the proper way to connect to the venue AC system) without causing shock risk or electrical isolation problems. After all, these isolation transformers have an associated cost (normally $1,500 and up).

Another way to look at this basic AC electrical supply challenge is in terms basic plumbing. It's like a series of hoses attached to a water main. Some hoses are bigger than others to accommodate a greater flow (current) at a particular pressure (voltage). If your timing building requirements for power were simply tapped into a much larger "hose" servicing the power needs of a lift, if the lift suddenly shuts off there will be a momentary backwash of current (flow) and voltage (pressure) into your little offshoot hose. Without some way of isolating this effect you can easily see that you're going to get more juice than you ever expected or need. In the world of electronics, trying to "drink from the fire hose" will happen within microseconds. It does not take long to generate an unwanted effect and/or cause damage. Even if the lift never shuts off unexpectedly, just being hooked into the same conduit that services that large motor will induce harmful harmonic waves back into

your little offshoot connection during normal operation, unless there is an isolation transformer dedicated to your circuit.

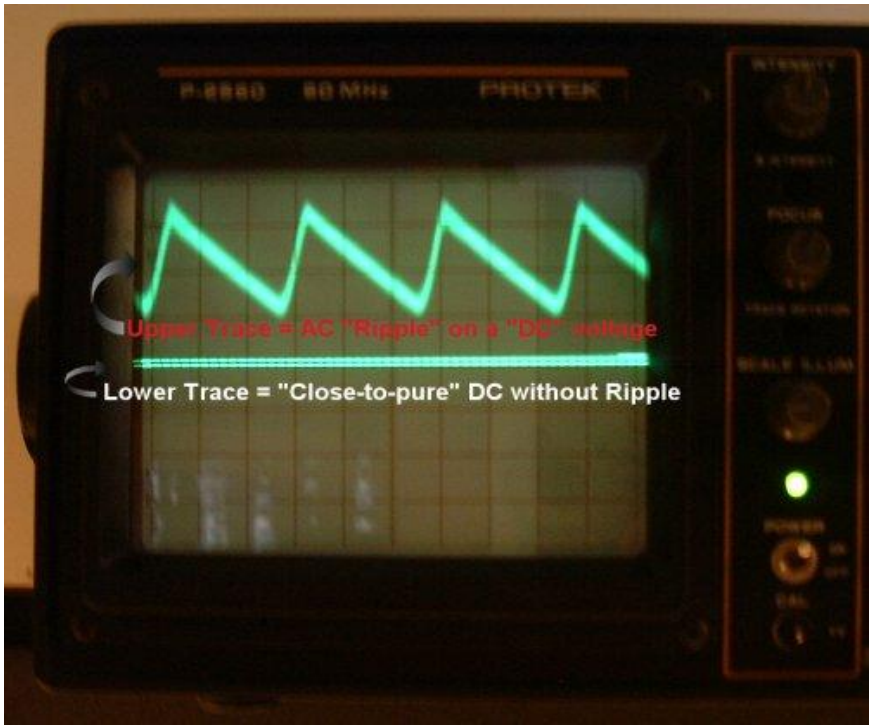
Generating Interest
AC generators are often no better a solution as they have their own inherent problems. The most common problem is the **absence of proper grounding.** Unless you work with a high quality generator installation or with someone who has already survived a generator shock accident (look for the guy with the Tilly Hat that features the charred hole on the side) this is going to be the rule rather than the exception. Even a generator that is specifically made to work well with computers and electronic equipment needs a proper ground to work as designed. In most cases, the AC current and voltage you get will vary tremendously, and the actual quality of the AC wave-form being produced (known as an AC Sine Wave) may not be what your power adapter can handle. There are no exceptions to this.

More commonly and dangerously, **generators are almost never properly grounded** by the people who use them. People haul them up to the timing building, pour in the gas and fire them up. There is no thought of a proper ground rod, no way for a ground fault to travel to ground or for AC noise to dissipate to ground. The EXPECTED result (as described in every Generator manual ever written and never read) is to discharge through delicate equipment or worse, through people, to ground. Electricity will always flow to ground through the best available path it finds.

NOTE AGAIN: Unless properly grounded as described in the operator's manual of your generator, any fault to any attached electrical equipment can potentially destroy the device or even worse can cause severe electric shock that may KILL or injure you or others.

Be extra cautious when using any device hooked to an external AC source like a generator. Either the quality of the AC adapter is an issue, or the characteristics of the AC source itself can be compromised. If you don't know what you're doing in this regard (and most people don't), get a qualified electrician to assess your venue's AC lines or generator installation and be in compliance with all local electrical codes.

Practical Suggestions
Timing system manufacturers like TAG Heuer and ALGE sell you specific AC adapters that are designed to meet their criteria for DC delivery of power to your timing system. Not all AC adapters are created equally, and like most things in life, it is the hidden qualities that make the difference. They cost more because they are excellent AC to DC adapters, capable of filtering out most, if not all, of the AC ripple (as long as the AC system is GROUNDED) and likewise capable of delivering the required DC output voltage irrespective of current demand by the timer or Input AC voltage supplied from the wall or generator.



Some of our clients get creative and buy cheaper AC to DC power supplies, even simple battery chargers, and hook them up to their timers as the external DC source. For these people they incorrectly assume that a $9 AC to DC 12 volt power adapter will do what it says it will do. Incorrect! Just because it says 12vdc on the box does not mean that's exactly what you are going to get when you plug it into the wall socket.

Included here is an oscilloscope screen picture of the unseen difference quality makes and proof that things are not always as advertised on the box. The photo shows two trace lines. One is flat; the other is jagged (understatement). The lower flat line is a trace of almost pure DC being delivered from a TAG

Heuer AC to 12VDC power adapter. The upper jagged trace is that of another power supply source that is supposed to be “DC” delivered by an “off the shelf” AC to DC adapter of lesser quality.

The obvious difference you can see is that the what-is-supposed-to-be “DC” coming from the upper trace example is really not very good DC voltage at all. The jagged line represents AC ”ripple” noise that is sitting on the “DC” wave that has not been entirely eliminated from the wall AC source. Not only that, the voltage is nowhere near the as-advertised 12 volts and is in fact closer to 17.6 volts. Although most timers have voltage regulators on board to handle a range in input DC voltage, the timer expects and demands close-to-pure DC to operate properly. In the case of the “off-the-shelf” adapter, it is being subjected to damaging AC ripple and noise. It’s hard to tell what the voltage would be because that would depend on the load. At the very least this can cause false triggering on the timing inputs (remember that the zero-volts “Ground” of the inputs is directly related to the negative side of the DC power supply). If connected to data devices like a PC, printers or a display, AC ripple like this can easily disturb the data signals and cause data to be dropped or to become unintelligible at certain transmission speeds. Over time this presence of AC ripple on what is supposed to be a pure DC supply voltage can damage the internal timer circuits.

Note that this power phenomenon also pertains to any device you hook into your system. That goes for sensors, display boards, voice communication, computers and printers, etc. Any time you add a device to your timing system that is in some way connected to AC “household” current, you’re injecting a suspect point of potential trouble, damage or failure. They all connect together via the ground side of your data or sensor triggering connections.

All Charged Up with Nowhere to Go

A classic case of this cascading problem is found when people try to charge large automotive 12vdc batteries with car chargers when their displays, PC’s or timers are also connected to them. Some deranged logic suggests that it’s “ok” to attach a $50 charger to a car battery and your $ 3,500 display simultaneously. As a result we get one or two charred remains of circuit boards from displays or timers each year. The damage is caused by the “DC” chargers that are doing their best to jam AC laden current into the DC battery leads while the race is going on. This is fine if you want to make toast, not so good if you’re into accurate timing and the long life of your electronics investments. The charger is not at fault, but the operator is. If it says “charger” on the box, use it for charging only, not as a substitute power supply during operation.

NiCad / NiMh / Gell-Cells and Other Options

If you just can’t bring yourself to trust alkaline batteries or DC Powered external power supplies, please contact your dealer to get the appropriate AC to DC adapter, or opt for an external rechargeable Gel-Cell battery and the correct DC power cable. In some cases you can use rechargeable NiCad batteries that may be able to be charged in the timing device, or you may have to charge them in a separate charger. I would warn you however that you should in all cases stay away from rechargeable Nickel Metal Hydride (NiMH) batteries for severe low temperature applications. NiMH batteries are fine for temperatures above 5C but NiCad is more predictable better in the cold. Again, rechargeable high-capacity (1 Ah or more) NiCad is a good option, but be advised that they have a nasty tendency to fail quickly in terms of capacity and it is virtually impossible to gauge their voltage vs. capacity state since they start at 1.2 volts and fail rather abruptly just below that value. There are all kinds of excellent battery conditioners on the market that will allow you to trust you NiCad or other battery systems.

UPS and FILTERS

There are no shortcuts in this area. If you have an ungrounded AC system or one which is compromised by AC noise from large motors or other high-load devices on the same power connection, **no off-the-shelf UPS (Uninterruptible Power Supply) or Power Bar is going to replace the need for an Isolation Transformer**. In fact, the UPS may not stay on or may not keep quiet if plugged into such a system. A good UPS detects ground faults or the absence of ground on the neutral side and will tell you so by squawking and complaining until it gets what it wants (or smokes and dies). This is what it is designed to do, so pay attention to what it’s complaining about and FIX the basic problem before you destroy equipment or injure someone.

Summary

If you have a timing system problem that crops up, investigate the power sources first. Most erratic triggering problems or strange behaviors are related to bad AC adapters or the compromised nature of the AC source itself. Avoid the urge to come up with a cheap power solution or a slap-happy generator stuck in the snow like a cheap construction site.

You must also make sure your AC supply system is properly GROUNDED. **If it's not correctly grounded no AC supply system is safe** and you will have timing system problems related to AC noise that has nowhere else to go but back into your timer. It is also possible to have **too many grounds** in an AC system. Such an occurrence may be safe but it wreaks havoc with data signaling as ground potentials differ at various points in the power system and unwanted current flows through signal wires (and your PC or timing equipment) to try to correct the ground potential imbalance. This is where the smoke normally comes from.

This is the area where our clients tend to have the most self-imposed problems, if they have problems at all. Dead batteries, bad AC power, inappropriate use of rechargeable batteries, incorrect external power cables, absence of path to ground, and not understanding the effects that other devices that are connected to the same AC power may have on the timing system as a whole. In fact, most of our clients treat this news with an astonishing degree of skepticism and disbelief; however a quick Internet Search on the topic of "AC system safety and electronic noise" will yield more information that you probably thought possible.

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