G-Force Consulting Inc. presents:

11 Guidelines for Electrical Design Success

ATV, UTV, LSV, Snowmobile and Motorcycle

11 Guidelines for Powersports and LSV electrical design success
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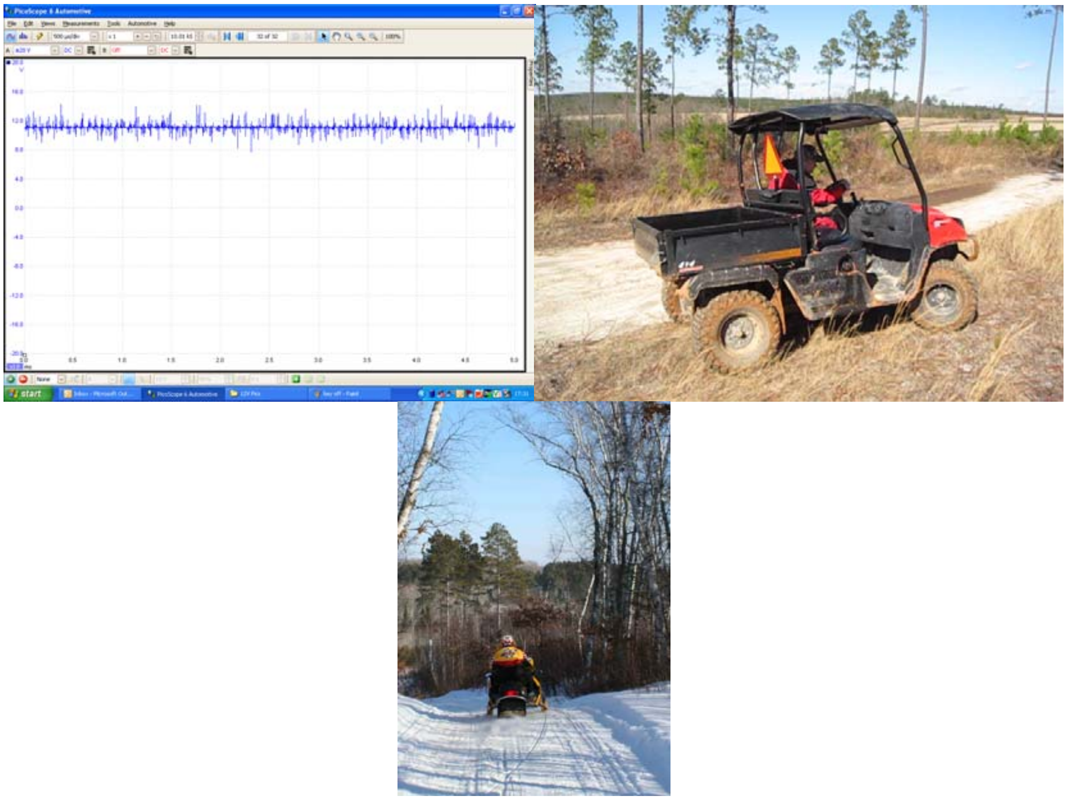
Electric drive train technology is revving up growth and change in the power sports industry. Even gas-powered units are now incorporating advanced mechatronic features like power steering assist. Unfortunately, a lot of risk accompanies the new tech. Many nascent power sports vehicle and accessory manufacturers do not have a legacy of proper electrical system development, and there are few places to turn for credible solutions to the unique challenges these systems pose. In this paper, G-Force Consulting Inc. offers an overview of some basic electrical system success guidelines based upon close to 2 decades of ORV electrical design experience. Enterprises who want to capitalize on these exciting trends can obtain more information by contacting G-Force Consulting Inc.

1. **Design for a surplus of charging system power**

Electrical power is needed for mechatronic systems like Yamaha's YEPS and aftermarket parts like the Symtec Heat Control Kit

Failing to prepare is preparing to fail. Insufficient charging power can result in failed batteries, sub-optimal performance and dissatisfied customers. On the other hand, <u>a maximized charging system can be the foundation for game-changing innovation and accessory sales profits</u>. For example, when Yamaha pioneered power steering assist on ATVs (concurrent to Honda) the new system required a 200-watt upgrade to their stator. Power steering is becoming ubiquitous in the market; however Yamaha and Honda's competitors were undoubtedly scrambling to update their charging systems ex-post-facto to enable their own power steering. It is far more efficient both time and resource-wise, to design a higher-output magneto charging system in advance when a new engine platform is designed. Sufficient room must be allowed in the crankcase casting for a larger stator and flywheel, and provisions for cooling the stator may also need to be made. Trying to retro-fit an existing crankcase with a major stator upgrade (meaning 100+ watts) may be technically impossible. In other words, powersports OEMs should plan ahead for increased electrical power. No customer ever complains about having too much energy available! Unfortunately, the average age of the power sports demographic is creeping upward. As riders age they become more interested in creature comforts like the aforementioned power steering, a heated seat, or an accessory cell phone charger or stereo system. By smartly up-selling a customer with branded electrical gear like these, the manufacturer can obtain a great return on their charging system investment.

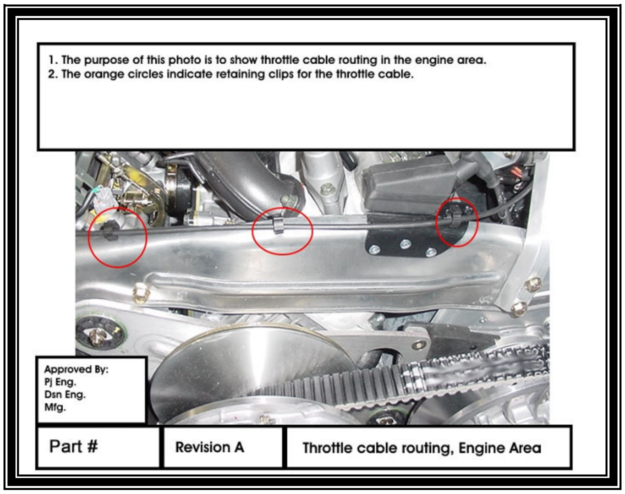
2. **Allocate sufficient resources, testing, and development time for electrical components and software**



To ensure quality, electrical systems require focused testing equivalent to that given the mechanical systems. Gary Gustafson photos

Powersports manufacturers, both accessory and vehicle, have historically maintained staffs from desk to bay that are 98+% mechanical in their expertise. Yet vehicle hardware and software content is shooting past 10% when measured by cost and is approaching 30% on electric-drive machines. This number may pass 50% if lithium-ion battery packs become common. Software and hardware need to be thoroughly vetted in both the simulation and real-world environments. In some cases, electronics testing and validation should define the critical path for a project, but organizations that lack knowledge of these systems may overlook this and suffer a quality “black eye” later. Manufacturers should stay ahead of the curve by staffing electrical designers and technicians rather than relying on their “gear heads” to do the work. The worldwide auto industry is in a feverish race to achieve leadership in electric-drive vehicles. Likewise, <u>any LSV, UTV or motorcycle manufacturer that accelerates their investment in electrical development stands a better chance of becoming the next great power sports “app”</u> that revolutionizes the off road vehicle world. The transition of the camera industry from film-based to digital is a good example of how industry leadership can permanently shift toward those with visionary and prudent product development.

3. **Plan for hose, wire and cable routes**



Basic Sample of the G-Force Consulting Inc. P.R.O. System

This wire harness is being cut by a chassis gusset

Poor hose, wire and cable routes cause warranty costs into six figures annually for major OEMs and numerous product safety recalls have been triggered for overlooking this design aspect. Among the possible failures are: Cut wires, cross-talk between high and low-power wiring that causes electronics to malfunction, wires that are chafed bare, moisture siphoning, open-battery voltage spikes and many more. Poor hose, wire and cable routes on an electric vehicle can have tragic consequences because of the enormous energy available to fuel a fire or short circuit. Historically, ATV and Motorcycle manufacturers designed the rest of the vehicle and then made a last-minute demand for their electrical “gurus” to find a place for the wiring to go. Plenty of technology exists to modernize this aspect of the design process. Manufacturers can document cable routes either with photos, CAD or--better yet--both; test cable routing right along with the rest of the vehicle; and then control the route-specifying documents the same as any other blueprint. G-Force Consulting Inc.’s P.R.O. (Placement and Routing Optimization) system helps companies manage hose, wire and cable routes along with many other complex assembly issues. <u>This kind of attention to detail is a strong part of a manufacturers “defensive” strategy against recalls and warranty.</u>

4. **Design for serviceability**

Suzuki King Quad electrical center, Gary Gustafson photo

<u>As much as 60% of all electrical warranty charge-backs are an incorrect diagnosis.</u> Service techs are generally less skilled at electronics than mechanics, so manufacturers should adhere to some basic rules to minimize needless warranty expense.

- Vehicles with a CAN bus and/or fuel injection should incorporate a diagnostic protocol like OBD II for connecting diagnostic tools
- Centralize components into an electrical center
- Keep wiring diagrams up-to-date
- Locate electrical connections where they can be reached with minimal labor time
- Use the same wire color for the same electrical function consistently across all models. Continuity in wire color functions will help technicians to grow their familiarity with evolving electrical systems. On models with complex control like fuel injection, allow each wire color one chassis function and one control function
- A diagnostic information display can sometimes be added at no cost to a new speedometer design if it has a high number of inputs and outputs

5. Protect electrical connections from water and dust

Gary Gustafson photos

There are 2 approaches to protecting the electrical system from water, dust and mud—the simple and the detailed. High-volume, well-established OEs with experienced electrical designers can afford to consider each connection, vehicle by vehicle and location by location. Start-up or low-volume manufacturers (including accessory producers) should seriously consider a simple approach, that is; using sealed connectors for nearly all electrical connections carrying ½ amp or less. However, even higher-current connections may require or can afford a sealed connector. There is a generic standard known as IP for "Ingress Protection" that is a useful reference. ATVs usually need to have connectors that are located from seat-height downward protected approximately per IP67—a waterproofing specification nearly equal to a personal watercraft. This is because many ATVs are driven in submerged or extremely dusty conditions. Motorcycles need to have IP67 protection in areas where they will be directly exposed to water spray or dust, but in other areas sealing comparable to IP56 may suffice. Although a snowmobile may never be driven in water, care must be taken to seal the wiring from melted snow-water, even several feet away from the electronics themselves. This is because melted snow can be "pumped" through the wiring when under-hood electronic modules are alternately heating and cooling.

A poorly shielded instrument cluster circuit board and battery from a UTV. Gary Gustafson photos

6. Design for nighttime operation

Do these headlights safely reveal the tree lying on the trail? Gary Gustafson photos

Test drivers and engineers for ATV, LSV and motorcycle OEMs work the typical day time hours of any other industry. However, consumers often ride at night. This disconnection between builder and user can be very significant. Cycles and snowmobiles from major brands sometimes have lighting that is so poor that riding at any speed over 30mph is a frightening experience. Speedometer LCD segments may be readable when ambient sunlight illuminates the gauge, but at night when back lighting is in use, the design is so poor that consumers must lean their head 2 feet to the left or right of center for the segments to be distinctly legible. If handlebar controls are not backlit, they can be difficult to operate in the dark. There is no question that design and testing for nighttime use should be a mandatory part of a new product development process. Just one evening spent on an evaluation ride can be enough to expose design flaws, giving the manufacturer an opportunity to address them before production.

7. **Understand that electrical components can be very different from one another**

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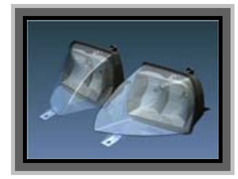
≠  ≠ 

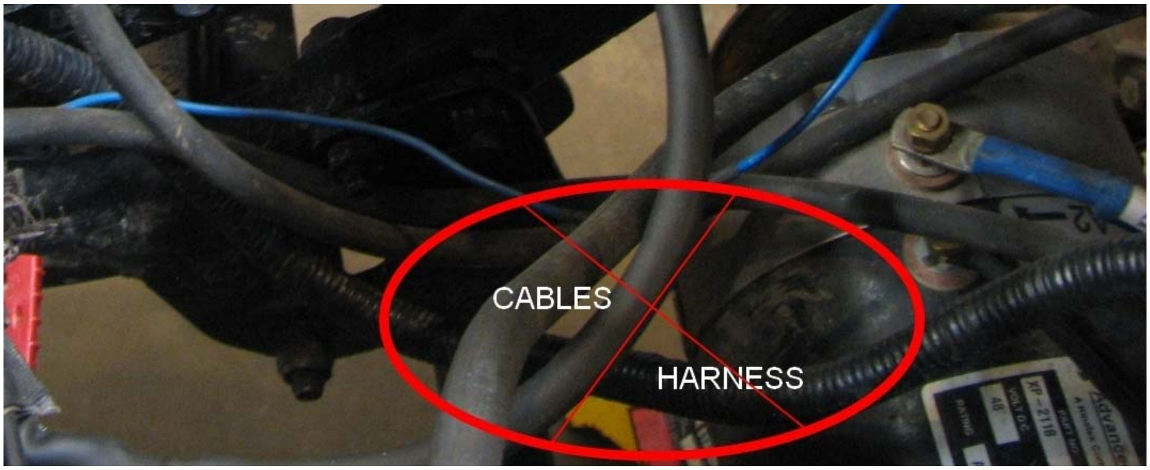
"With respect to having a central nervous system, and the ability to feel pain, a rat is a pig is a dog is a boy"—Ingrid Newkirk, President of People for the Ethical Treatment of Animals

With all due disrespect to Ms. Newkirk, power sports manufacturers should *not* assume that "A key switch is a wire harness is a headlight is an ECU". Mechanically oriented design and management teams at powersports manufacturers often divert anything that carries electrical current to the same member of their lean (or non-existent) electrical design staff. This approach may work if the individual(s) has an exceptional combination of theoretical knowledge, experience, and great vendor relationships. However, in some cases a highly skilled electrical engineer will be very capable at circuit board design and entirely uneducated in components that have a heavy mechanical design element to them such as a headlight. Even the most brilliant engineer will have a learning curve on developing something new, and he may need extra resources for developing the new system. Some electrical development projects such as instrument clusters are surprisingly labor intensive. It may be advantageous to look for temporary engineering help to be sure that new designs are created properly. Management should listen to input from their experienced engineers, technicians and vendors when it comes to budgeting time and money for new electrical projects.

8. Be knowledgeable of suppliers and costs for electrical components

People fear what they don't understand. However, avoiding knowledge of electrical component costs and suppliers will cost manufacturers money. For example, if a motorcycle or LSV manufacturer is utilizing an "off-the-shelf" automotive part or sub-component, it is critical that all parties in the supply chain understand the long-term availability of the part. Powersports companies have sometimes received notice that the electrical part they designed into an assembly is no longer available because an automotive company stopped ordering the part, triggering the supplier to stop making it. In one notable case like this, a major ATV manufacturer was forced to order about a two year supply(!) of an electric motor, to give themselves time to either change major power train tooling or source and validate a different motor that fit the existing tooling. Another critical area for manufacturers to take control of is the interface circuitry between components. Never assume that components from different suppliers will automatically work well together, even if they test okay. Have a summit meeting either remotely or in person for the various suppliers to "look beneath the surface" and review the interface specs, voltage levels, and system schematic diagrams to ensure that no dangerous surprises are lurking. And last, value engineering is a money-saving opportunity for manufacturers who examine their electrical costs. One approach is to ask for an itemized cost breakdown of electrical assemblies such as wire harnesses. Surprisingly lucrative cost reductions may be available by asking the right questions. Sales reps themselves may not know what cost reductions are available until pressed to find them. Good questions for a manufacturer to investigate include: Where is the product designed and where is it manufactured? Is my annual usage volume small or large relative to the manufacturer? Have the components ever been used in the kind of physical environment they will be used in this application? What voltage transients aka "spikes" exist within my system and will the component withstand them?

9. Maintain spacing between sensitive electronics and electrically noisy devices



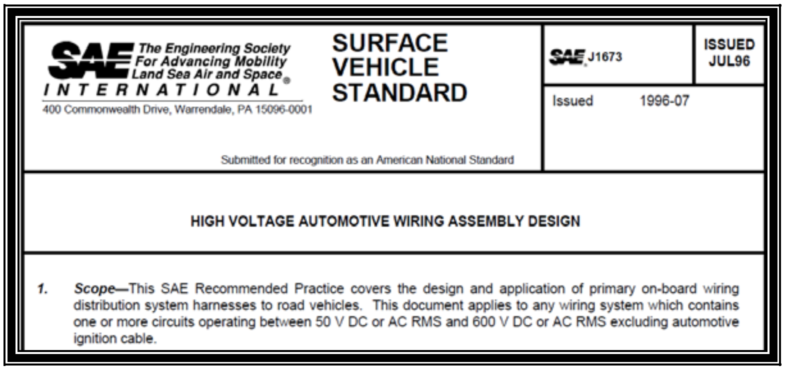
When it comes to sensor wires and high-power cables, familiarity breeds contempt.

Good fences make good neighbors. This saying is fitting for the relationship between low-current devices and noisy components. O_2 sensors, accelerator pedal sensors, speedometer pick-ups and other sensors operate at very low currents and voltages. These items are extremely sensitive to magnetic fields and capacitive energy from high-voltage or high-current devices like ignition coils or battery and motor cables. Some voltage regulator designs are also notoriously noisy. Keep sensitive, low-current signal wires at least 3-4" away from noisy, high power devices, and/or utilize grounded shielding on sensor wires if the minimum spacing can't be maintained. Otherwise, electrical interference may introduce gremlins that can be extremely frustrating and expensive to resolve. Some major OEMs that violated this rule have suffered through expensive recalls as a result.

10. Integrate electrical designs properly with other internal departments.

Many internal departments will have to be involved with an electrical design for the project to succeed. Engineering must consult regularly with these other internal stakeholders to ensure success. The author once led a new instrument cluster program at a major OEM. Initial quality audits were poor, and an inspection of the parts revealed a failure on the speedometer circuit board. The problem was actually caused by an electrical test station on the vehicle final assembly line, where they occasionally connected the temporary 12-volt power supply backwards while the ATV was in gear and the all-wheel-drive switch was on. It was a freak circumstance that did not happen in the field. Once the root cause was determined, Quality Assurance was instructed to bill any such failed parts back to the line as scrap, and to stop reporting these particular failures as a supplier defect. Once the assembly line started getting charged for the problem rather than the vendor (causing the scrap budget for the line to hit their daily limit), the line fail-safed the process and the problem went away. Lessons learned—engage beyond the cubicle walls to ensure the success of a new electronics project. And sometimes to get an internal or external partner to improve they have to feel it in their pocket book.

11. Be aware of high-voltage safety and regulatory requirements



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SURFACE VEHICLE STANDARD

SAE J1673 | ISSUED JUL96

Issued 1996-07

Submitted for recognition as an American National Standard

HIGH VOLTAGE AUTOMOTIVE WIRING ASSEMBLY DESIGN

1. *Scope*—This SAE Recommended Practice covers the design and application of primary on-board wiring distribution system harnesses to road vehicles. This document applies to any wiring system which contains one or more circuits operating between 50 V DC or AC RMS and 600 V DC or AC RMS excluding automotive ignition cable.

SAE Standards may be purchased at www.sae.org

Some manufacturers entering the LSV and Electric Terrain Vehicle markets (Ranger EV and Bad Boy Enterprises type vehicles) are implementing higher-voltage drive trains such as 72-volt systems. However, a myriad of regulations and safety considerations come into play once the drive train voltage is raised above the traditional 48-volt levels used on golf cars. There are Federal LSV standards such as 49 CFR 500.571, industry standards including SAE J1673, and dozens more that may or not apply to a new development program. New players in this market should consider consulting services to avoid overlooking a critical requirement. Most importantly, passenger safety should never be taken for granted, especially with the scrutiny that power sports manufacturers come under. Theoretical analysis for worst-case short circuit paths, ground return loops, capacitive coupling, etc followed-up with plenty of field testing are all necessary to help ensure passenger safety on ATVs, ETVs, motorcycles, and LSVs. Those who forget the past, such as the now-banned three-wheeler, may be doomed to repeat it. When designing new electronic tech, power sports companies must keep in mind that the future of not just a company, but the entire industry could be at stake.

Gary Gustafson designed electrical systems for Polaris and Arctic Cat before founding G-Force Consulting Inc. of Bemidji, Minnesota. G-Force Consulting Inc. assists UTV, Motorcycle, LSV, snowmobile and accessory manufacturers. G-Force Consulting specializes in new product development, specialized market research, financial markets consulting, and third-party opinions on power sports manufacturer mergers and acquisitions.
Visit www.gforceconsulting.com for more information.