Among the multitude of acronyms our society has become fond of (think SUV, PMS, NASA, POTUS, WYSIWYG, etc.) one that has drifted into the marine world from the manufacturing industry is PLC, short for Programmable Logic Controller. As I’ve spoken to friends and customers in the yacht industry and brought up PLCs I’ve often caught a questioning look. I know the look well because I displayed it many times when first encountering the term. As far as I could tell it was just another computer, albeit more specialized, and I’d been around computers since IBM was still using one inch tape the PC-1 had just hit the market.

Although they are the backbone of most of the process control field, where applications must run for years and where the consequences of failure are so dire that failure is very literally not an option, often little is know about them by the average person. PLCs control things as diverse as major portions of automated assembly plants for vehicles and consumer products, most high rise elevators, prison access controls, large building heating and air conditioning, and virtually all of the modern thrill rides in amusement parks. (Would you ride a PC controlled roller coaster?) Most of the products you see at the supermarket have one or more PLCs in their recent history. Something has to be in control of counting those 100 vitamins into every pill bottle…and putting the cap on…and labeling it…and heat shrinking the safety band around it…and then checking to see that it’s all been done correctly…over and over an over, sometimes for many years.

Because reliability issues often haunt the marine industry, it’s not surprising that PLCs have found their way into vessels for control of HVAC systems, generator controls, lighting systems, power management systems, and of course monitoring and alarm systems, which is where this is all leading.

PLCs and PCs, The Difference.

Although both are computers, PLCs and PCs are fundamentally very different devices with different strong points.

- Function. In simplistic terms, the PLC is a study in monotony, repeating the same general sequence of steps endlessly and starting again at the top. Much like a skier careening down a mountain, there are many options and decision points about where to turn along the way, but he inevitably ends up at the bottom of the lift and rides back up to start again.

The PC on the other hand, is a very high end graphics machine, a versatile multitasker like no other, perhaps more like putting fifty skaters on a rink.
Programs. Working with only a few hundred different commands today’s PLCs can perform a very complex array of tasks with many thousands of steps, branches, and conditional choices, then starting it all over in a matter of milliseconds. They are extremely good at what they do and usually have no hard drives or other moving parts to wear out.

The PCs nowadays have very fast processors and juggle many tasks simultaneously at super speeds, working from a great treasure box of codes and commands. They have almost unlimited storage in hard drives and other devices. The Windows environment is the best example of this incredible capability. Every day many more software programs hit the market to run on these same platforms.

Displays. The PLC product lines, though improving rapidly, often have had relatively small displays with more limited colors, usually waterproof touchscreens, designed for factory floors and industrial areas. Again, their purpose is unambiguous utility in monitoring and control, long term reliability, and ease of use by sometimes semi skilled workers.

PC monitor displays now come in almost any size imaginable and reproduce entire rainbows of color, even for the beginner. Graphics designers have a nearly unlimited palette and exotic video cards give gamers lifelike alternate worlds. We see them everywhere.

Certifications. Most PLC product lines have been tested by independent labs and addressed by one or many certification agencies such as CE, which is assigned to products that have met European Union consumer safety requirements; UL, for Underwriters laboratory that certifies electrical devices; and/or ISO 9000, which is a set of standards for quality management in manufacturing. If they are to be used in the maritime fields they usually have approvals by one or more of ABS (American Bureau of Ships); Lloyds (Lloyds Register); DNV (Det Norske Veritas); NKK (Nippon Kaiji Kyokai); or other less known agencies. Additionally their onboard use may be affected by international agreements such as MCA (Maritime and Coastguard Agency which applies to safety of large vessels) and/or SOLAS (Safety Of Life at Sea, created in 1914 following the sinking of the Titanic).

The PCs of the world are built to meet countries’ electrical standards such as CE or UL, but often nothing else. There are Lloyds approved PCs available, though quite expensive and apparently made in Europe, where we buy ours, but not to my knowledge in the U.S.

For Monitoring and Alarm Systems, Reliability Tops the List.

If a monitoring system has the same reliability as the equipment being monitored then it’s a 50-50 chance which may fail first. If the monitoring equipment has 10 times better reliability the odds improve dramatically but will never be perfect. It’s strange to me that
over years of discussing these issues with owners and captains very few customers have shown more than a passing interest in the true reliability of their alarm systems, focusing more on pretty graphics, cost, or meeting their legal requirements. The key difference in hardware for monitoring applications of course is the PLC’s advantage in running for many years, tolerating wide ranges of temperature and voltage in often hostile environments. Although I don’t have up-to-date numbers for the current product line we use in our monitoring systems, the CPU of the maker’s previous model had a calculated MTBF (Mean Time Between Failure) of 467,000 hours, or 53.3 years running 24 hours per day. Our earliest full-boat system has been running now for about ten years with no failures.

On the PC side, reliability has improved substantially over the years but it hasn’t been that long since I could crash my desktop machine trying to run three printers at once. In retrospect that was probably my own fault somehow, but I think there are few people out there who haven’t made upgrades, repairs or modifications to their PCs within just a few years of use...inexpensive components fail, hard drives crash, software makers issue endless service packs to repair glitches in the original. In an office environment these are mostly minor inconveniences compared to world traveling vessels whose insurance requires that they meet certain monitoring safety standards in order to leave port.

Makers of both PLCs and PCs constantly work to improve their product reliability for demanding applications by using simultaneous parallel processing, special network protocols, and more exotic methods for error checking. Early on NASA used three parallel computers in places and if there was a difference the two outvoted the one.

**Monitoring Vessels with PLCs.**

Though varying among manufacturers, almost all PLC hardware is a snap-together set of modules selected according to the needs of the particular application. There will usually be a power supply, a processor, and various other modules for analog or digital inputs, network communications, interface with data busses running engine or electrical information, measuring temperatures or pressures, or output controls for any of a multitude of devices from indicators to high horsepower motors. The processor talks to each of these modules as needed in its endless cycling through its program. Everything runs on multiple 24 volt power sources so the system is immune to generator crashes.

Major steps in setting up to monitor a vessel are similar, whether using a PLC or a PC, though in detail the actions can be very different. Working from a point list agreed upon between the customer and the builder, a system arrangement is planned, an I/O table or list is generated, and programming begins. At the same time graphics and interface programming for the displays are begun. Eventually hardware is assembled, the various programs are loaded, and bench testing begins.

Vessel monitors which may track a few hundred or even a thousand parameters are usually very simple compared to industry’s applications where multilayered PLCs and networks can span not only factory floors but multiple buildings in different locations with masses of data reported to central offices.
The Point List.

One of the first steps in creating a full vessel system is creation of a “point list” defining everything to be monitored. With a new build this is usually a consolidation of classing requirements as defined by safety regulations and naval architects, electrical engineering specifications, and captain’s and engineer’s wishes. In the case of a refit the existing wiring and monitoring has to be taken into consideration as well. Although we can build to almost any requirement, our systems for 150 foot yachts typically run around 300-400 points of which some come in groups, such as engine data, or electrical information which may be a stream of many parameters coming in on a single data buss. Systems for workboats and fishing vessels are usually smaller and more utilitarian, and of course less expensive, plus having different types of points. On these hydraulics and refrigeration can become paramount in addition to the usual fire alarms, bilges, etc. One of our systems included monitoring the temperature of every freezer, reefer, bait well, and fish tank on board with high and low alarm sets for each.

A good point list is quite highly detailed and becomes the primary, agreed upon, reference between the customer and the monitoring system designer. A good list is usually in a spreadsheet format with each line defining: the parameter to be measured, its electrical description (normally open or closed for switches, 4-20 milliamps, 0-10 volts, etc. for analog), range of measurement for analog values (i.e., 0-100psi, 0-300 degrees, etc.), location of sensor on vessel, alarm level requirements, classing authority if needed (i.e., Lloyds PT 16, CH 1, SECT 2, PAR 2.3.11), display requirements (where, what, how, colors, alarms, etc.). Some yards and architects will also include ship’s cabling nomenclature, raceway info, yard specifications, yard test memos, and others.

System Arrangement.

For new builds or major refits, system approaches can vary widely, ranging from home-running all sensor wiring to a central point, which was very popular in earlier European systems, to having a single central processing point and a loop of cabling running through the boat interconnecting a series of remote sensors and modules in Christmas light fashion. Complexity increases, of course, with the size of the vessel. Each company making monitoring systems may have its own engineering approach and none are automatically right or wrong. They, along with their customers, must take into consideration the initial build costs, installation costs, ease of future troubleshooting and maintenance, long term reliability, possible upgrading and add-ons, and some sort of failure analysis based on how much data do you lose if this or that module or cable fails. If cutting one cable takes out 30% of your data it’s a lousy design.

My personal preference is a compromise. I like all of the active electronic components in a small number of dedicated waterproof enclosures, usually called DAUs for Data Acquisition Units, along with minimizing long cable runs as much as
possible. This means locating DAUs at strategic places and running all sensor cables to the nearest unit. For a 150 foot boat this would typically place one below forward, one in the machinery spaces somewhere aft of the forward engine room bulkhead, and the main computational PLC/DAU in or near the pilothouse where it has the best and safest environment. For smaller boats one or two DAUs works well and up to five on a 200+ footer. All DAUs have active PLC processors which communicate on a redundant pair of networks with automatic throw-over if a network becomes unreliable. It is also possible with PLCs to have many remotely connected interface modules instead of housing them in DAUs. This is common in industry, but I tend to worry about this approach on vessels as the number of items exposed to the salt environment increases which then can require more watertight boxes scattered around.

- **The I/O List.**

With the customer’s point list and a system arrangement in hand an I/O (Input Output) spreadsheet is created with everything necessary for the programmer to begin the sometimes daunting task of creating the programs for one or more PLCs such that raw data is gathered from the right places, stored as needed, often scaled in the case of analog values, and correctly processed for the displays.

The I/O list, supported by the system hardware design, becomes the primary reference document for the PLC programmer, the display programmer and the engineering department which creates the test documents, wiring and installation drawings, and operating manuals.

- **Data Programming.**

Programming the PLC is where the greatest difference appears compared to PCs. Although there are several methods for PLC programming, the most common is generally called “ladder logic” where the sequence of steps is treated like descending down the rungs of a ladder, a step at a time. When the last step is reached the program begins at the top again. Design of these ladders is usually accomplished with software provided by the hardware seller. In reality, this ladder sequence can become very convoluted as each step can be as simple as an ADD command to sum the data in two memory locations or can involve complex arithmetic processing of an entire table of values. Moreover, there can be steps in the ladder which branch to and from subroutines, selectively skip certain steps, or perform small repetitive tasks for a certain number of times, but it’s always basically a step at a time. Our typical system for a 150 foot yacht has about 17,400 steps. Repeat cycle time is around 20 milliseconds.

A note here on programmers. Although common in manufacturing fields, PLC programmers are, I think, very much a small subculture in the computer field, many of them evolving from industry techs and junior engineers in departments where PLCs were either presently used or newly needed. If they move they can only take
their special skillset to another industry manufacturer. If they move to the yacht industry they may come with an excellent knowledge of remote data gathering and control but may have to learn about the nature of marine equipment. PC programmers, on the other hand, are everywhere. The entire world sometimes seems awash with them, especially in a sagging economy. The good side of this is that there is a gigantic pool of PC programmers for monitoring companies to choose from. The problematic side is the challenge of finding programmers with an industrial machinery background and hopefully some knowledge of marine equipment and the marine environment, especially the long term reliability and fail-safe issues.

Display Programming.

The displays are the only thing the user normally sees of the monitoring system on his ship. They are the human connection to the hidden equipment constantly reading the vitals and health of his entire vessel and as such have stringent requirements. The hardware should be extremely reliable and appropriate to the environment. Graphics should be programmed for use with little or no user training, unequivocal identification of alarms and locations, minimal “drill down” through multiple screens to get to important information, and brightness and contrast must be appropriate to the location. In addition to the pilothouse, displays can often be found in the crew mess, the machinery spaces, the captain’s and engineer’s quarters, and other places.

For display hardware, major PLC makers usually offer a marine approved line of panel mounted touchscreen displays up to around 12 inches and often a series of larger industrial PC monitors with an integral PC on the back which may or may not have approvals. Their graphics software these days is very good but still doesn’t approach that of high quality SCADA (Supervisory Control and Data Acquisition) programs. New builds these days specify pilothouses where “glass bridges” have half a dozen, sometimes very large, identical monitors which are usually provided by the navigation equipment supplier to show charting, radar, CCTV and other monitoring functions. This is where the PC shines. A high quality industrial PC, perhaps Lloyds approved, can gather blocks of raw data from the PLC(s) and use a modern SCADA software program to create some of the finest graphics imaginable on whatever size monitor the vessel has been supplied with. This also applies to vessels large enough to have a control room in the machinery spaces with space for a large multi-monitor console. This method assures that the high reliability of the core PLC system has not been compromised, the industrial touchscreen displays and the audible alarms are unaffected, and the pilothouse has a large display readable from across the room (and, in the case of yachts, the owners have great bragging rights). In a worst case scenario of loss of the pilothouse display all it takes to haywire one of the touchscreens in is 24 volts and an ethernet cable.

Thoughts on screen colors: Today’s world of office monitor displays in various shades of generic gray has accustomed users to these dull colors in well lit rooms. When a pilothouse monitor running these programs is fully dimmed for night running on a moonless night, critical data can disappear along with the background. Opinions will vary, but mine is for high contrast, mostly primary colors against a
black background for the pilothouse, displayed on a monitor dimmable to near black and using either an embedded mouse or a top quality touchscreen. For utility areas a waterproof touchscreen with the same colors and little or no dimming works best. Most industrial screens can be internally programmed to go to black after a preset time and relight when touched or when an alarm or other event occurs. We use this in officer’s staterooms.

Once a system is assembled in the shop, programs loaded, and exhaustive testing completed, it is shipped to the vessel for installation. Usually the shipyard installs the hardware and pulls the cable, wire termination may be done by the yard if they have the expertise, by the seller, or in some cases by a subcontracting electronic service provider. When the system is ready to light off the maker will normally come to the vessel for actual commissioning.

One modern wrinkle which has become common for larger systems is performing troubleshooting or upgrades via the internet while the boat is underway anywhere in the world. So many vessels have full time internet access via satellite that it’s rarely necessary for a tech person to fly to some foreign port to solve a problem. We have about a dozen cruising vessels, mostly in the Mediterranean, on which we can access our systems in minutes if there is a call about a problem. Such calls are infrequent, and almost always lead to wiring or sensor difficulties not of our making, but the captains and engineers are always pleased to have us assist in the troubleshooting process.

Another item to come on the market is the alarm cellphone text messenger which texts from the boat to a series of user selected phone numbers when a problem occurs, a real boon to the many yachts which sit in marinas without full time crew and workboats parked during downtime. There are also alarm systems which send email messages though these may be less useful as they are dependent on the user having his PC or ipod turned on.

**In the case of Refits.**

Most PLC based systems installed today are on new builds which allows all of the sensor wiring to be laid in before spaces get closed up, though we have provided systems for several vessels going through major refits when the boat was stripped out to where pulling in new wiring was practical. When a refit is planned, whether workboat or yacht, it may be helpful to have some monitoring companies review the plan to see if an upgrade makes sense. One special case where upgrading becomes very practical is in older vessels which have all sensor wiring homerun to a single pilothouse or engine room panel loaded with annunciator lights and gauges. In many cases a new PLC system with a single waterproof touchscreen can be located in the same void and existing wiring can be used with little modification. We’ve provided these upgrades for a series of Alaskan fishing vessels for a fraction of the cost of a total system. Remember when reusing old sensors however, that they may have hundreds or thousands of hours of sea time and may not be as trustworthy as you might wish. The price and inconvenience of failure may have to be balanced against new hardware costs.
Workboats and Smaller Vessels.

For a long time production boats in the 40-60 foot range have stayed with basic switches and lights for alarms and simple gauging for tanks and other analog measurements. The initial cost is low, which becomes very important in products with multilevel distribution, and there is less concern about long term reliability.

Tugs, crewboats, and other workboats also tended toward simple, bare bones systems which got the job done with a minimum of fuss and cost. They generally worked close inshore where an alarm failure was an inconvenience to be handled in port and regulatory controls were liveable.

Today there is a rapid conversion going on where these users are demanding better graphics and more monitoring. Initially this has led to PC type monitoring, which is considered more visually attractive and least expensive. Meanwhile, PLC prices have fallen rapidly and builders and refitters have become aware of their advantages. Today, the PLC based systems with their longevity and near bulletproof programs are hard on the heels of the PCs. They still can cost a bit more but pay dividends many times over during the life of the boat.