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Welcome to the world of microcontrollers.

From the earliest days of integrated circuits, microcontrollers by various names evolved as an important subset of microprocessors. But as microprocessors are designed for general-purpose computing with an emphasis on cost and usability, microcontrollers are built for job-specific tasks with an emphasis on getting the job done.

As a result, microprocessors evolved horizontally, with a wide variety of on-chip features and connections to other circuits and peripherals that together become computers, while microcontrollers evolved vertically, simply becoming more powerful take-oriented devices with each generation.

The actual word "microcontroller" came from the mainframe and minicomputer industry. Companies like Digital Equipment Corp. in the 1960s used hard-wired logic chips and installed their microcode in read-only memory, so the modules which solved the floating-point math were dubbed the microcontrollers. Intel in the late 1970s borrowed the term became its microprocessor product lines were becoming too confusing and overlapping, explained technology consultant and former Intel chip architect John Wharton, who was present at the actual meeting when the microcontroller term was decided on for the 8048 and the 8051. The former chip ran the original IBM PC keyboard, and in many cases is still used in no-frills PC keyboards today. The latter became the most popular microcontroller of the 1980s, and the specifications of many modern microcontrollers still list 8051 compatibility or emulation as a feature.

"Microcontrollers can be anything from 6051 and 8051 chips in cash registers to the latest Pentium-something which is a controller in a jet fighter," Wharton said. The technology caught on quickly as customers dreamed of new applications, just as they did 20 years earlier during when transistors were new. In some early applications, customers sought technology to control stop lights, postage scales, carburetors, elevators, and more. "IBM famously claimed to be making a typewriter," Wharton recalled, when in fact they were developing personal computers.

It's also important to understand that not all microcontrollers are created equal. The majority of industrial microcontrollers today come from large public companies, such as Advanced Micro Devices, Atmel, Freescale, Fujitsu, Intel, Maxim, National Semiconductor, Philips, Samsung, Silicon Laboratories, ST Microelectronics, Texas Instruments, Zilog, and others. Hobbyists may favor more user-friendly technology like the Parallax's BASIC Stamp, but high-end industrial users may prefer more customizable systems like the Wilke Technology's Tiger series.

Like any microprocessor, a microcontroller has the basic elements – an instruction set usually between 8-32 bits, memory, I/O pins, and a power supply. Some may also contain an LCD screen, cooling fan, So now that you know what a microcontroller is, the next question is what can you do with one? If you're reading this guide, then you are most likely an engineer, student, salesman, or support technician, or you work in any other field where you need a crash course in the who, what, and why of microcontrollers. There are plenty of reference manuals and textbooks to read to learn about the actual programming and integration. But this booklet, through customer examples, aims to explain the advantages and considerations of using microcontrollers for business. All of the case studies cited here are based on the Wilke Tiger. That particular product is known for being ideal as a high-end, one-off solution and is extremely stable and well documented.

Some of the examples cited in the booklet include:

- timekeeping devices used by the U.S. military
- testing equipment from toolmaker Black & Decker
- quality-assurance testing devices for factories
- control systems for hydraulic aircraft landing gear
- environmental monitoring for agriculture and fishing
- three-dimensional manufacturing printers

After reading this booklet, you may want to learn more. There are many good resources on the Internet. To learn about Tiger microcontrollers in particular, we suggest visiting both www.wilke-technology.com and www.industrialcontroller.com. To learn more about the microcontroller industry in general, we suggest visiting any of the following sites:

- www.howstuffworks.com/microcontroller.htm (fundamentals)
- www.eetimes.com & www.industrialcontroldesignline.com (news/how-to)
- www.microcontroller.com (online news source)
- www.circuitcellar.com (print and online magazine)
- www.tinyurl.com/8pyst (Amazon.com search for "microcontrollers")
- http://www.designnews.com (online magazine)
- http://www.ecnmag.com (online and print magazine)
- http://www.global-electronics.net (online magazine)

Some microcontrollers are easier to program and integrate than others, some are cheaper or more expensive, and some are more widely available. However, we at KG Systems feel the Wilke Tiger family is not only an excellent production platform, but it's also an excellent learning platform. We encourage you to read the real-world examples in the booklet, discuss them with your peers, and even take notes on how you can copy or learn from these solutions to achieve your own goals. You'll learn that industrial microcontrollers have an amazing variety of uses.

Please contact us with any questions or comments at sales@kgsystems.com .

- Dan Garlen and Kenneth Kardux, KG Systems

It’s always time to make the clocks at BRG Precision Products.

John Bode, the “B” in BRG, makes advanced clockwork for companies and militaries around the world. From clocks displaying several time zones to clocks with super-large fonts, clocks attached to IP networks and even clocks using good old analog displays, he does it all. But he couldn’t do much with microcontrollers.

“We started producing public safety software in the beginning of ’92,” he explains. Sometimes customers required clocking aspects, so BRG began reselling atomic clocks, but they were of low quality and not poorly suited for commercial purposes. Commercial suppliers were eventually found, but those too didn’t meet customer needs – so BRG decided to make their own. “We now supply every U.S. military installation in the world,” he proudly notes.

The problem that led to the opportunity was that most clocks in the 1990s, even commercial models, used very simple processors. As a result, companies had to design several processors into each display to meet the customer demands, which were increasing in complexity and variety. “We had to have a controller that had a rapid development environment. We needed something very powerful, something much more powerful than the Intel 8032, that's what our supplier was using. We needed a processor that in a single display could handle 24 different time zones, plus all the lettering the goes with it,” Bode said. In early 2000, that search led him to the Tiger.

About two months later, clocks were ready. It’s an impressively quick product development cycle, but certainly wasn’t without glitches. Any language has quirks, such as crashing without stating a good reason, but that sort of thing paled in comparison to BRG’s need to interface the Tiger with Dallas Semiconductor’s real-time clock IC chips. Bode was pleased that the Tiger has built-in ways to handle that, just as it did for his display and memory choices. In fact, the Tiger had enough memory for a whole project; Intel controllers required using external memory to meet his customer’s needs.

All of the software wound up fitting in a single chip. That included control programs written in Visual BASIC and an Ethernet interface done in C++. Tiger chips are also resilient to human silliness – “you can literally take their chip and put it in backwards,” and it survives unscathed, he noted, declining to say just how many times he tried that...

Bode would still like to see the Tiger controllers get faster and have more memory. On the other hand, “We’ve looked at other modules. Some had their pros and cons, but we really didn’t find anything we liked that compared to Wilke’s Tiger.”

Wherever there's a factory, there may be Intrinsic Quality testing products.

Intrinsic Quality makes custom testing equipment for high-tech electronics producers. Their equipment can test anything from medical devices to aerospace computers, environmental controls to weaponry, audio components to computer networking gear.

For some customers, developer Larry Raymond found that Basic Stamp technology was simply too limited in its performance when Intrinsic gets hired to perform engineering and manufacturing services. "We were looking for something to upgrade that capability. What we end up being responsible to do, in many instances for our customers, is just to build them a solution They don't much care how we do it," he said. Recent products tested slot machines and commercial poison gas detectors.

With Tiger units, "The basic language is both more powerful, and consequently more complex, than some of the toys that are around," Raymond said. That allows Intrinsic to make software faster and with pulse generating and measuring. His bottom line: "The products that we can offer today, with the Tiger solution, will be half or less as expensive as the equivalent that would've been PC-based," he said. The products can also conduct data logging, motion control, and a variety of stimulus/response controls.

Intrinsic also had success with Wilke's driver software, and they found the demonstration board to be very helpful. They also preferred Wilke's programming language because of its subroutine options not offered from more mainstream competitors such as Intel-based products.

Larson Consulting specializes in developing custom electronics solutions for companies too small to develop it themselves.

With applications customers ranging from hydraulic valves to appliances, fluorescent lighting to toys, Jack Larson needs microcontrollers that are extremely flexible. He's been using Wilke equipment since the late 1980s, when the microcontrollers first began replacing logic circuits.

What explains his loyalty to this niche product line? "For a few extra tens of dollars, you get the interface problem already solved for you," which is ideal whether you're testing batteries, mechanical assemblies, or just routine cycle testing. It's highly efficient compared to the old method of racking everything together, all connected to a computer data acquisition system.

With battery testing, Larson needs to conduct discharges under load and recharging over time. With assemblies, he needs a way to test actuated pressures, torque, current, sound, and optics. And he needs to do it all with just one kind system.

"One of the things they do in the Wilke product, which gives it flexibility, is they have a way of mutliplexing the inputs and outputs," he said. Other microcontrollers may be less expensive, and may have some of the same functions as the Tiger, but users can't change the way those functions are delivered and in what combinations they'll function. Therefore, Tiger systems are worth the money.

Wilber and Orville didn't have it so good: the 1903 Wright Flyer landed on wooden skis.

Today, companies like Liebherr Aerospace manufacture cutting-edge landing gear systems, as well as air management, flight control, and hydraulic actuation systems, for customers such as Airbus, Eurocopter, and Lear. Terry Stefanski had 20 years of experience working on control systems, and got the job to test the airborne parts in the most accurate, efficient, and inexpensive way he can find.

"We manufacture a lot of different parts for commercial and military aircraft. The specific division that I work at here in Saline, Michigan is a repair facility. All large aircraft are under a continuous maintenance program, where after a certain number of hours or a certain number of cycles, every part basically comes off that aircraft and is refurbished before it goes back on," he said. "What I do is design and build test equipment."

"The testing is very specific. The first one that I implemented using a Tiger was a highly specialized data acquisition system that was added to an existing hydraulic system test bench. There were some specific requirements to collect simultaneous data from a number of sources. These data sources were already in existence so it was not justifiable to build a whole new test bench. What I did was build a system based on a Tiger that connected to a bunch of individual data collection instruments... using the Tiger and its ability to have a bunch of serial ports."

Ultimately, the data is formatted into a Microsoft Excel-compatible file and written to a media card. Engineers can then bring the card to their computers to generator test reports.

For the most part, Tiger served his need perfectly. "Tiger fills a niche between a full-blown PC application and a little tiny bit-banger. They're cost-effective enough that I'll tend to use them even if I'm only using a very small percentage of their capability. I've written in a couple of different iterations of real-time BASIC, so it was a natural for me," he said.

He does have two concerns – the lack of documentation for driver variables and the editing system. "It would be nice if their drivers in particular were much more thoroughly documented, because there's a lot of parameters that you have to take on fate that they'll work," he said. But the support for resellers is good, and the language itself is surprisingly well documented, despite some application notes existing only in German, he said. Liebherr's various test systems integrated with computers running both UNIX and Windows, he said. Regarding the editing system, it could stand a lot of improvement, he said. "It's a little clumsy, their messaging as far if you have a compiler editor and such" – system messages provide line numbers but the editing software doesn't have any that are visible. Instead, he just uses an external editor that he prefers.

Those issues were not a deal-breaker by any means. Stefanski has two systems currently in development. One is a custom measurement device that serves as an additional input into an existing piece of test gear. Its job is to measure the flexibility of landing gear components, at thousands of pounds of pressure, before they break. He elaborated: "Because of the amount of displacements involved, up to 600 millimeters or so, most of the common things that were readily (traceable?) into the existing piece of test equipment weren't applicable to those long distances. So what we did with the Tiger was take a quadrature input... and we then generate a precision analog output that the existing piece of test gear is capable of handling. It was something that I just couldn't buy off the shelf and the Tiger allowed me to develop it very rapidly."

The second system is for a flow-control valve in an aircraft's bleed-management system, where air is tapped off the compression section of a big jet engine, and then used for cabin pressurization, de-icing, and HVAC purposes. That means very high-energy sources are being channeled into just a few pounds of piping, and it's a very complicated valve. Again, he explained: "What I'm doing is programming in a full test schedule for this valve. I could do it with a PC and off-the-shelf hardware, but it needed to be small enough to fit into a piece of bench-top equipment. [Also], the requirements for the I/O, there's about 40 bits of digital I/I, and there's four channels of true 16-bit analog output that needed to be very accurate," in addition to very specific excitation requirements for the valve itself. "I could, for example, buy a device that provided that specific motor control that I needed, but that one device was upwards of $5,000. So by the time that I would've done a PC-based system for this, my amount of design time would've been pretty close to the same as it was for a Tiger-based system, and it would've been significantly more expensive."

Stefanski suggests that Tiger newcomers spend time exploring the sample programs. "With the Tiger you can write down a logical operation... if the code is well-written you can read the program and understand what it's trying to do," he noted. Cheaper and simpler microcontrollers can sometimes be too automatic for the customer's applications, preventing detailed control of what happens during specific tasks, and inhibiting much customization, he added.

Nova Technology puts its technology into the strangest places, so people don't have to go there.

"What we do here is robotics for the power industry," such as for generators and nuclear plants, engineer Richard Hatley said. Nova's expertise includes developing not just robotics, but also packaging, software, and ultrasonic systems.

"The very first project that a Tiger was used for at Nova was on a robotic bar taping machine," Hartley said. It was used to wrap mica insulated tape around copper rods in generators. People could do this too, but it's more slower that way, and often the generators are in places that are dangerous or just difficult for people to reach.

But robots have limitations of their own. "We had one thing that it didn't do well. We built a handle bar measuring machine, it was like a pair of calipers. It graphed every eighth of an inch. The problem we encountered was, we used a linear encoder on the jaws, and you couldn't snap the jaws open fast enough to read it. It would outrun the Tiger," he explained. They needed one pulse per every micrometer, but the Tiger was only counting 25,000 times per second. Luckily, a later-model Tiger runs faster.

In other projects, Nova used the Tiger's ability to connect with Ethernet, in a physical space where there wasn't enough room for traditional wires or where too many moving parts were nearby that could cause entanglement. "We basically put another I/O module out in this other bladder. We had five analog inputs on that, about 10 high-current outputs, and four digital inputs," he said. "We did this on a machine that's running through a 24-inch diameter pipe, where there's a lot of mechanical moving parts, things that don't like wiring." Then, the Nova machine connected with a 600-foot fibre-optic cord to a controller in a safer location.

Chuck Ashbaugh uses microcontrollers to give the world fresher fruit.

Ashbaugh's company, Sasco, entered the marine electronics business in 1987. Radar and radio is ordinary stuff, but everything changed with the commercial availability of global positioning systems in the 1990s. Overnight, commercial shipping companies working in places like Africa and Central America installed GPS technology in deep-sea vessels, for safety and tracking purposes. But could the same technology help ensure the integrity of the cargo?

Fast-forward to farming life. Stone fruit, also known as drupe, ripens in a very specific temperature range. On the long journey from the tropics to your kitchen, the fruit can get too much oxygen and ripen too soon. It can get not enough oxygen and rot. Either way, if it's not just right, then it doesn't get sold, and money is lost.

So companies developed special shipping containers. The containers have oxygen-adjusting technology, but ship travel if a rough-and-tumble life, and sometime the containers develop leaks. "The problem is, no one's really sure if one of the containers has a leak in it or not," Ashbaugh explained. He saw Tiger microcontrollers as the solution.

"The microcontroller took all of the data, and we actually ran a program that polled the actual oxygen controller," he said. The program polled for carbon dioxide as well and handled up to 20 containers at once. The data is transmitted to biologists, who make the necessary tweaks to the oxygen controllers.

Building the controller and its program taught Ashbaugh much about the technology in general. He liked its ability to multitask and the speed at which programs are written. In theory, the technology could be built cheaper with more generic controllers, but the sacrifice would be having to code in the C language. "Trying to do it all in C is expensive and time consuming. Very often the customer doesn't really understand what he wants. By the time we get it written they want it changed. Doing that in C is tough. BASIC is nimble," at least for low-volume custom purposes, he observed. He also could have used programmable transceivers, but that would have limited the customization ability – it's better to use dumb transceivers and interface to them, he said.

Radio interference was a concern, Ashbaugh added. "One of the things that worries me a little bit is that the Tiger's very fast, and we have it relatively close to radio equipment. Let's say you're running a 5-volt regulator. If the Tiger was to take a negative spike... the Tiger's already rebooting. It's not very forgiving." The reboots couldn't be changed because they are mandated by governmental commerce laws. To deal with that, "What we've got to do is move the antennas far away to keep the energy out of there. I'm in the process of trying to change antennas to work out some kind of additional shielding," he said. Sending more serial data through RS-485 signals instead of traditional RS-232 signals is an emerging possibility to solve the radio issue, he added.

He also builds custom circuit boards for the controllers. "We make sort of a motherboard that has a bunch of pins so that we can plug a bunch of things into it. The kinds of sensors that we need to incorporate are specific to certain projects" – that lets him use similar code and similar interfaces for different tasks, such as for the U.S. Army Core of Engineers.

Off-the-shelf adhesives and surface treatments don't suffice for exceptional customer demands, and that's where Tantec products shine.

"M company consists of three different product lines – surface tension, electrostatic surface treatment, and static control," measurement engineer Jeff Schuller explained. "We produced for a time a surface tensioner to measure the surface tension of liquids. You can determine whether or not the liquid will wet out on the solid." The term "wetting" refers to how liquids will flow and spread, which is vital information to manufacturers and quality-control engineers.

"The first thing we tried was to do a pendant drop measurement system which would basically take a picture of a droplet hanging off a syringe. But then we found that the accuracy you need for the drops we were producing, you just couldn't get cheap enough," he said. Tantec eventually chose a "Wilhelmy plate" which is a sturdy, easy method to calculate contact angles.

Still, Tantec needed a way to extract data from the measuring technology and transport it into some useful format. "What we basically used Wilke for was getting the data in from our weight cell and being able to calculate the surface tension from the force. They were the only people that we looked at for that specific service," Schuller said.

There was one glitch in developing that technique: the weight cell kept blowing out the Tiger boards. But Tiger's reseller supported the customer until more than two dozen units were reliably operating. A memory upgrade was available halfway through the first production run, which turned out to be very timely.

Now, Schuller said he'll definitely consider using Tiger boards again in future products. "I found the Tiger very versatile. For certain applications I could see where it'll be useful."

Z Corporation converts inkjet printing technology into rapid prototyping gear.

Also known as "3-D printers," Z Corporation makes several models of the latest rapid prototyping gear. Walter Zengerle is directory of engineering and explained how microcontrollers are used in the process of making plastic powder shoot through precision nozzles and become real products.

The machines were introduced in the mid-1990s at about $60,000, and today cost from $25,000-$50,000, depending on features. Instead of feeding sheets of paper, Z Corp.'s products spread layers of powder with adhesives mixed in. It's a proprietary mix of plaster and water-based materials, which customers then dip into epoxy or wax for hardening. In fact, while designing the printers, they actually printed parts of themselves.

The wax hardening process isn't always so simple. "We commissioned it. They had done the electronics badly but they had this Tiger on it, and they had code that didn't work," Zengerle said. It was expensive, too. It needed to control four or five different kinds of heaters, it needed to make a display, and it needed to have a decent user interface.

"This outside consultant basically screwed up on us. So me and one mechanical engineer were left to do the whole thing... in about 12 weeks. I looked at the Tiger thing and said, wow, it's almost done already because Tiger had all these different drivers," and that was back in 1998, he noted. "We ordered up a Tiger development kit. I had figured it was going to be a big deal but it went very quickly."

The electronics were actually finished early because of that, he said, and Z Corp.'s used it for other tasks since then. For example, Tiger was used to keep track of print heads on the second-generation product. It tracks temperatures, cycles various power supplies, and control the head sequencing. Such functions help Z Corp. save on support costs – basically, "we'll ship out parts and they'll fix them themselves," he said.

"It generally works very well. Mostly I use RS-232 to communicate with the other parts of the system. They're pretty rugged, I'm not sure we've ever had one die," he said. Nor does the plastic powder interfere with Tiger controllers. The powder gets everywhere, but the high-end printers have vacuum cleaners built-in, he said.

Some of the Tiger driver software was too speedy. "The one thing that got me, sort of tripped me up, was you have these drivers and they're pretty quick, but because the code you have is semi-interpreted, it's a lot slower," he said. Without low-level code access, that can cause external integration challenges. Tigers in the printers link to Pentium 3 motherboards. In short, "Some of the stuff that made it so easy to get up and running made it harder to do some of the advanced stuff. By being clever, I could read it only when I needed it to and just cached the results... so we did eventually get it going."

Eventually, Z Corp. moved to Texas Instruments' MSP430 controller instead of using Tigers. Tigers, he explained, become less cost-effective once you're in mass production and no longer need to do much customization. The TI product is programmed in C, so it's more tedious to get started with. Also, it requires a 3.3-volt source, and there are problems with the serial port reliability, Zengerle said.

The future of Wilke Technology

Wilke Technology, based in Germany, is very much a hands-on company: founder and electronics engineer Jurgen Wilke is intimately involved with all aspects of the Tiger product's development and support.

"We are now in the second gen of Tigers," Wilke said. This generation is backward-compatible, is three to four times faster than the older models, has more memory and I/O channels, is physically smaller, and is less expensive. It also supports graphical displays instead of just text.

From industrial espionage to military applications, an important part of any modern industrial electronics product is security. "Tigers are secure for a number of reasons. When you program a tiger, we ourselves cannot read it out. In some cases there are even hardware constraints. You can also have a password in the Tiger. So the intellectual property is quite safe in the controller," Wilke added.

Other recent developments include a touch panel and the ability to connect a full PC, such as the small but sturdy Min-ITX style, for input-output controls.

For more information, please visit www.wilke-technology.com and www.industrialcontroller.com.