Exercise Machine Monitoring

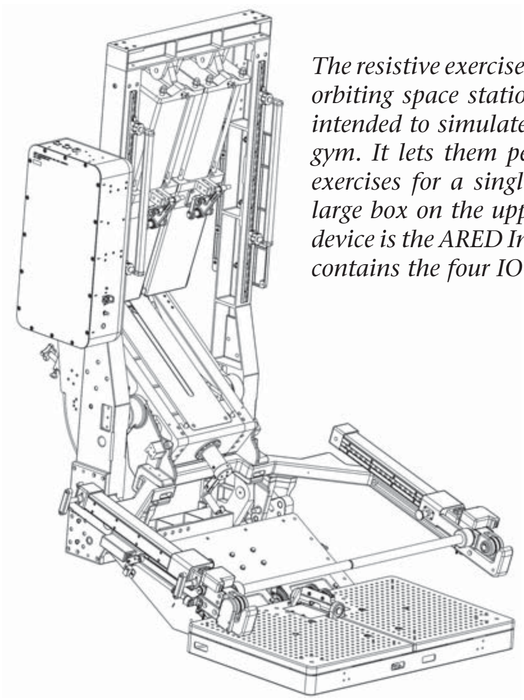
Aerospace

using the Personal Daq

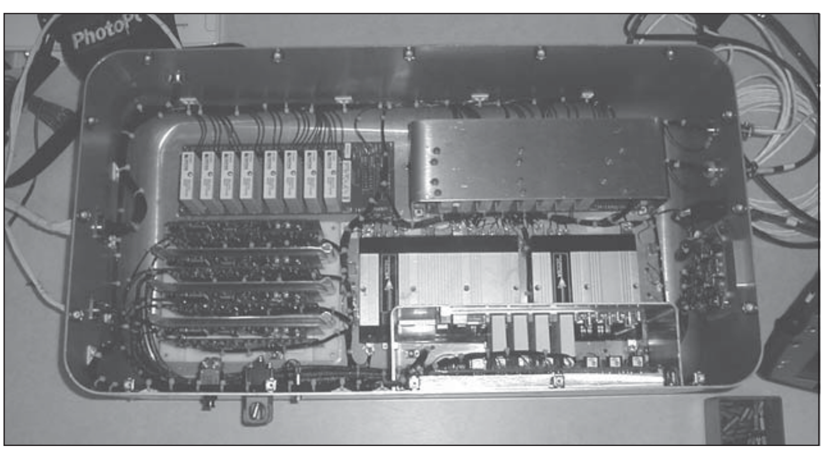
Application Note #80

Application Summary

Resistive exercising, such as weight lifting, is one of the primary ways that astronauts maintain their bone density during long-term trips in microgravity environments. Bone is a living tissue and responds to chemical messages that make it stronger when carrying its own body and other weights. In addition, tendons attached to muscles pull on the bone, which motivates the bones to grow. When muscles grow stronger, they stimulate the bone even more and build yet stronger bones. Walking, impact exercises, and lifting weights maintain bone density on earth because human bodies typically work against gravity. But onboard the International Space Station, the effect of gravity isn't felt in the free-fall environment, so the astronauts must simulate it with resistance exercise. Resistive exercising isn't usually needed on shuttle flights when the astronauts are on orbit for only a few days. But station flights can last six months at a time, so exercise is critical to the crewmembers' health.



The resistive exerciser used by astronauts on the orbiting space station is a full body exerciser, intended to simulate free weights, like a home gym. It lets them perform cable and bar-type exercises for a single hand, leg, or limb. The large box on the upper left side of the exercise device is the ARED Instrumentation Box, which contains the four IOtech Personal Daqs.



The four pairs of circuit boards in the lower left corner of the box are four Personal Daqs with cases removed and connectors replaced with direct solder connections. This is the first build of the actual hardware that is used for simulation and actual flight.

The devices on the currently orbiting space station will be replaced soon. They don't collect as much information as the scientists would like and they are wearing out, so now is an opportune time to change the aging equipment with the next-generation Advanced Resistive Exercise Device, called ARED. It is a government-furnished equipment project, which means it is being built in-house at the NASA Johnson Space Center.

The new resistive exerciser will be able to do much more than the equipment on orbit now. It can offer the astronauts more exercises and larger loads. In addition to just providing the resistive exercise, a suite of instrumentation is included to collect research data for future flights like long-term trips to Mars, and hopefully other planets. The scientists want to obtain as much data as possible so they can monitor, predict, and improve the exercise regimen. They also want to better understand the entire biological impact on the astronauts' bodies.

Potential Solution

NASA had developed numerous instrumentation systems in the past, but none were easy to adapt to this particular application. They chose to modify a commercial-off-the-shelf data acquisition system and add it to the exercise device instead of design a custom unit that would become an integral part of basic operations. NASA conducted trade studies and a vendor survey before purchasing any COTS (commercial off the shelf) hardware, which included a wide range of equipment for collecting the type of data it needed. Its primary requirements for a system depended on low power, a USB port, high accuracy, and low cost.

IOtech's Solution

As a result of the preliminary screening, NASA selected a new instrumentation system, which includes four IOtech Personal Daqs™ per exercise device. The suite contains 14 separate sensors, which constitute 22 channels of data exclusively for gathering position information and force from load cells.

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NASA is using four Personal Daq's mounted directly to the exercise device to increase bandwidth and gather the 22 channels of data. All the channels measure load cells except two, which are rotational displacement. NASA has several different load cells, typically 0 to 500 pounds and 0 to 1,000 pounds. The displacement sensors are variable-inductance types that measure ±60˚ of rotation.

In order to get hardware ready for flight, NASA typically repackages all COTS devices, such as the IOtech Personal Daqs, to eliminate potentially hazardous materials including plastics that outgas or support even the most remotely possible fire. In addition, it removes some of the connectors that are on the circuit boards and reconnects the wires directly to the solder pads to eliminate any chance of mechanical interface failures. In this case, NASA also mounts the bare boards in a metal enclosure along with power supply, signal conditioning, and the USB hub.

COTS electronics typically are not used for high-criticality applications because NASA frequently has difficulty obtaining the detailed information from manufacturers that's required to certify the system and address other redundancy and reliability issues. But for low-system criticality, NASA can manage it. The exercise device itself is considered high criticality but functions 100% with or without the instrumentation package. The instrumentation system is classified as low criticality since it only gathers data. As a backup, the astronauts could log some of the same information by hand, which is similar to what they do now.

About 24 Personal Daqs were purchased at one time to satisfy 15 years worth of instrumentation needs for the exerciser program. In fact, when NASA purchases any COTS hardware, it typically buys every item at the beginning of the project that is intended to be used for the duration of the program, preferably from the same lot or production line, since no one can guarantee that the same hardware (down to the individual component level) will be available again, even the following week. Certifying a specific configuration with particular hardware for flight is extremely expensive for NASA, so making subsequent changes can be costly and must be avoided when possible.

Eight Personal Daqs are scheduled to go on flight, four for the primary acquisition system and four spares available in another complete box, called an AIB (ARED Instrumentation Box), that can be simply plugged in if the primary AIB should fail. NASA engineers have written a custom software package embedded in LabVIEW® to handle all the required data acquisition tasks, which is directly interfaced to the Personal Daq. In addition, the engineers embedded a data-reduction tool — also in LabVIEW® — that pulls the data out and sends it to a flat ASCII file. When they want to actually analyze the data, they use a variety of third-party analysis software packages.

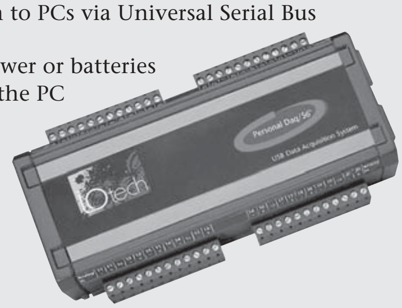
Conclusion

NASA Johnson Space Center selected IOtech Personal Daq data acquisition systems to gather in-flight data from its new Advanced Resistive Exerciser Device aboard the orbiting space station. A primary unit composed of four Personal Daqs record load and stroke data on the machine while astronauts do their daily exercise. The data will help scientists improve the exercise regimen and better understand the biological impact on astronauts' bodies for long-term trips to Mars and other planets.

Personal Daqs

Designed for high accuracy and resolution, the 22-bit Personal Daq™ data acquisition systems directly measure multiple channels of voltage, thermocouples, pulse, frequency, and digital I/O. A single cable to the PC provides high-speed communication *and* power to the Personal Daq. The Personal Daq modules are a family of low-cost, USB-based products from IOtech. Because of the strict power limitations of the USB, the modules incorporate special power-management circuitry to ensure adherence to USB specifications.

Features



- Multi-function data acquisition modules attach to PCs via Universal Serial Bus (USB 1.0 and 2.0 compatible)
- Ultra low-power design requires no external power or batteries
- Can be located up to 5 meters (16.4 feet) from the PC
- High-resolution, 22-bit A/D converter offers reading rates from 1 to 80 Hz
- Built-in cold-junction compensation for direct thermocouple measurements
- Frequency/pulse, or duty-cycle measurements up to 1 MHz
- Convenient removable screw-terminal signal connections
- 500V optical isolation from PC for safe and noise-free measurements
- Programmable inputs from ±31 mV to ±20V full scale
- Digital I/O lines with open collector output for direct drive applications
- Expandable up to 80 channels of analog and digital I/O
- Up to 100 Personal Daq modules can be attached to one PC using USB hubs, for a total capacity of 8,000 channels
- Digital calibration—no potentiometers or adjustments required

Software

- Personal DaqView™, spreadsheet-style software for *Out-of-the-Box*™ setup, acquisition, and real-time display
- eZ-PostView™, for post-acquisition data viewing
- Support for Visual Basic®, C/C++, LabVIEW®, and DASYLab®