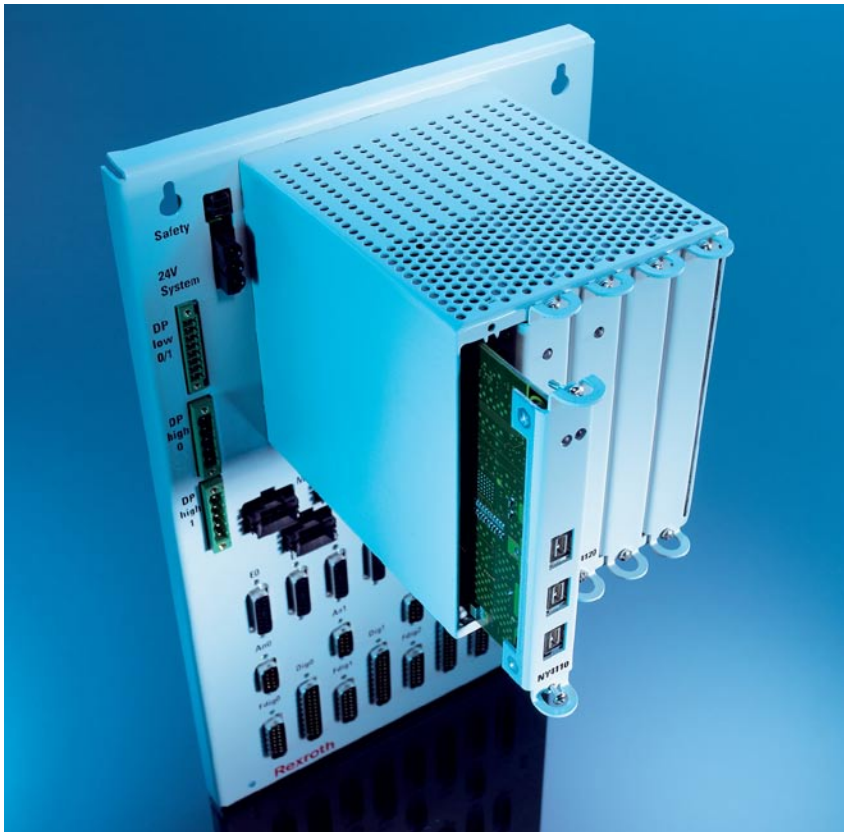
Rexroth Bosch Group

Drive & Control profile

Motion Control Requirements in Medical Imaging Systems



A modular control system like the Bosch Rexroth NYCe4000 reduces costs in design time, motion system programming, fewer components and cabling, and simplified purchasing and inventory.

Motion Control Factors in Medical Devices

- Motion control platforms help imaging OEMs control costs, streamline production
- Complex kinematics require motion control platforms that support 32 KHz servo loop update rates
- Open architecture helps with faster machine commissioning, adaptive re-use of existing motion algorithms
- Off-the-shelf motion systems such as Bosch Rexroth's NYCe 4000 offer open C/C++ libraries to speed programming, system integration
- Costs and competitive pressures are leading to standardized motion control platforms across multiple medical devices
- Single-source motion control suppliers with global support offer supply chain efficiency and improve ROI

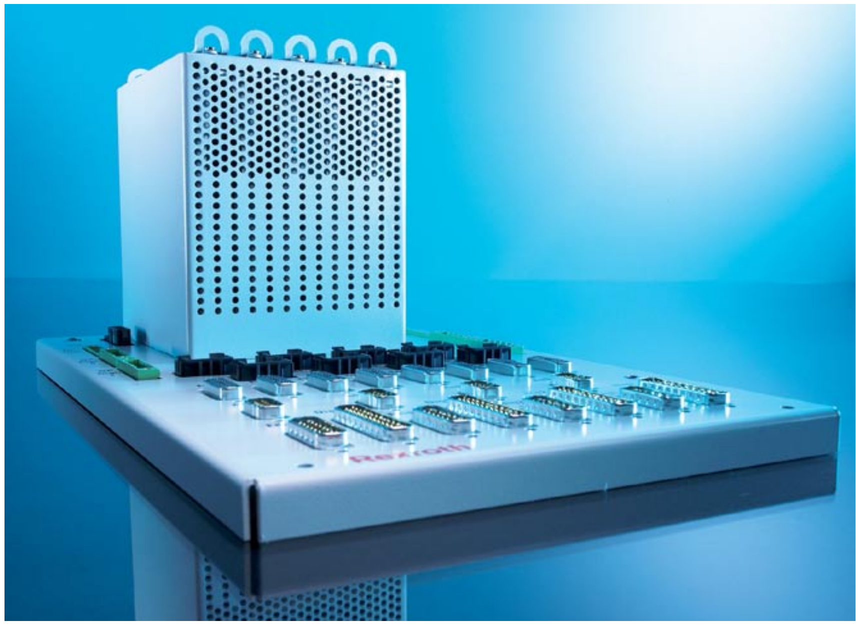
Medical imaging systems have transformed the practice of medicine in virtually every clinical category—from cardiology, to oncology, neurology, and trauma care, to name a few.

Demand for these tools continues to grow across the globe. As a result, medical imaging OEMs are turning to motion control platforms that help control costs, streamline production on a global basis, and provide systems capable of delivering the most sophisticated 2-D and 3-D clinical images possible.

The motion control requirements for medical imaging devices are driven by these goals, and the need to satisfy specific kinematics requirements of imaging systems used in both diagnostic and treatment procedures.

The industry consists of a group of major OEMs — such as GE, Philips, Siemens, and Varian — that offer multiple high-end imaging systems including:

- Cardio/Vascular X-ray
- CT — Computed Tomography
- Fluoroscopy
- MRI — Magnetic Resonance Imaging
- Nuclear Medicine
- PET — Positron Emission Tomography



A new generation of motion controllers offers off-the-shelf platforms supporting complex kinematics with features such as high-speed servo loop update rates, configuration tools, controller-level processing and open architecture.

Basic and complex kinematics

Imaging systems designers usually begin by defining the kinematics of the machine and even the specific algorithms to achieve the motion. In this industry motion control systems fit into two categories:

- Basic — single plane, horizontal X-Y movement such as a patient table moving in and out of an imaging cylinder, or raising and lowering a table for patient access
- Complex — multi-axis coordinated motion, with extremely demanding kinematics.

Complex systems typically consist of a patient table and an imaging arc or *C-arc* gantry — a large, C-shaped apparatus mounted on the floor or ceiling with the X-ray imaging beam source at one end of the arc, and the imaging detector on the opposing end.

Both elements have multiple axis of motion: the patient table moves horizontally, vertically, lifts the head or feet, and tilts side to side. The C-arc can make 180° arcs in three axes around the patient table to carry out diagnostic and clinical treatment tasks, such as real-time x-ray imaging of a cardiac catheterization procedure.

Some of the most complex kinematics are required when a test or procedure calls for isocentric motion: keeping the imaging beam on a point in the patient's body, while the imaging apparatus and patient table move independently through multiple passes to create a 360° image.

These require very demanding kinematics loop computations that are quite unique to medical imaging: up to nine axes of motion, moving through X, Y and Z planes, while retaining an extremely clear, fixed center-point image resolution that may only be a few millimeters in diameter — the size of a patient's blood vessel, for example.

In the past, motion control subsystems were custom-made by the OEMs, which required diverting valuable engineering and programming resources to motion control, rather than the machine's core image processing functions. The specific controls algorithms and kinematics are central to the

OEM — as a "must have." Now, a new generation of motion controls offers "off-the-shelf" platforms supporting complex kinematics with robust features such as:

- 32 KHz servo loop update rates
- Configuration tools that support rapid creation of complex control loops with interfaces to MATLAB™ (a numerical computing environment and programming language) and optimized functionality for features like safety routines, accurate axis synchronization, gearing and spline functionality.
- Controller-level processing to ensure tighter integration with drives, I/O and imaging functions.
- Open architecture C/C++ API

Most imaging systems use servo drives in the 500 W to 2 KW range to handle C-arc gantry loads and the patient weight loads, which can range up to 400 lbs. As OEMs strive to outsource imaging system components and even complete motion subassemblies, they are taking advantage of using single source suppliers who can provide total motion control and drive solutions.

Most medical imaging systems also use a range of human-machine interfaces (HMIs) such as touchscreens, switch and dial panels, and joystick and handheld controls. Joystick control is similar to a teach pendant or handheld controller used in traditional robotics or industrial automation applications. In medical, the imaging system's "main" C program, which is responsible for executing the whole machine (imaging, motion, I/O), also translates the joystick motions/buttons into functions for the motion control.

Open architecture

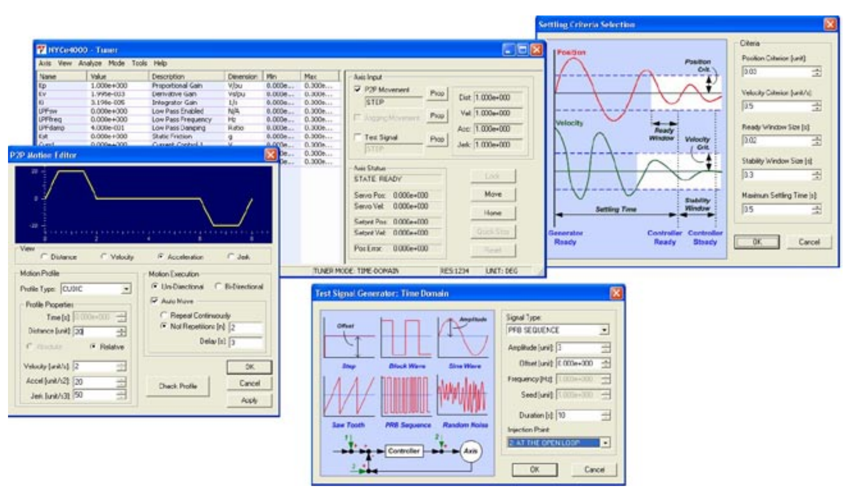
With the wider use of off-the-shelf motion control platforms, there are advantages to selecting systems with open software architectures that support adaptive re-use of existing algorithms and IP (intellectual property).

Unlike motion control in automotive and machine tools, which typically use the nearly universal IEC 1131 programming, medical imaging systems need platforms with control loops optimized for complex applications such as isocentric motion. Plus, they need tight integration of other system functions such as I/O, safety systems, and operator controls. This advanced functionality is often implemented via a C/C++ API by the system programmer.

For example, the Bosch Rexroth NYCe 4000 platform has full-featured C/C++ libraries that let programmers efficiently import existing motion control code, easing integration with the imaging system and ultimately reducing time to market for the OEM.

Motion control platforms that use open communications protocols, such as the FireWire/IEEE 1349B protocol optimized for complex industrial applications, can also help speed motion control/imaging machine integration, and deliver added operational advantages.

For example: FireWire lets imaging system builders create a network ring topology — host PC to controller nodes and back to host PC. This supports loop healing: if there is a cable or interface failure at any point,



Medical imaging systems need motion platforms with control loops optimized for complex applications such as isocentric motion.

motion control resets while maintaining communications among all nodes, without risk of sudden interruption.

FireWire is suited to very fast, multi-axis applications. It implements a high-performance serial bus supporting throughputs of up to 400 megabits per second, and a real-time deterministic architecture that ensures the latency necessary for the kinematics demands of imaging systems.

Modular control systems have more value

Modularity is a key design consideration for imaging motion control platforms. As design, engineering and manufacturing teams are frequently distributed around the globe, they seek modular systems that simplify engineering, reduce development costs, and make final assembly on-site more efficient.

Modular design also enhances engineering flexibility. Control systems with flexible plug-in slots for drive and CPU interfaces, and flat panel backplanes with multiple drive, controller and I/O interfaces mounted for convenient access are preferable.

A modular backplane lets engineers specify their choice of connectors that serve a specific application best. There's no need to design extra breakout boards or special interfaces to connect controllers to other components such as encoders, sensing devices or drives.

Modular motion control systems can have a major ripple effect on machine costs, too, helping drive down total cost of ownership (TCO). Given the multi-million dollar cost of some imaging machines, hospital and medical end-users have stringent requirements for reliability and usability. For example 10-12 years is not unusual for a product to be guaranteed from parts obsolescence.

A modular control system standardized for use across multiple imaging platforms (CT, X-ray, MRI, etc.) reduces costs in several ways: design time, motion programming, fewer components and cabling, and simplified purchasing and inventory.

Form factors

As with many other industries, imaging OEMs are constantly striving to make their machines more compact. The machines are inherently large, and hospital and lab floor space can be limited and expensive — especially in urban medical centers and university hospitals with limited room to expand.

Off-the-shelf motion control systems designed with form factors specifically to fit into tight machine spaces can help keep the imaging system footprint smaller. However, the motion control system must build more functionality into an extremely compact package — typically smaller than an industrial PC.

Compact motion control elements can also help improve imaging machine design aesthetics. This has important therapeutic value: Imaging machines are deliberately designed to have smooth flowing, sculptured lines which provide a more comfortable environment for patients.

Safety matters most

The safety and well-being of the patient is of paramount importance. Machine designers have implemented stringent safety technologies to protect patients, physicians, and operators — anyone who may be present within the arc of motion for any imaging component.

Safety features on most imaging machines include proximity sensors and emergency stop controls to instantly halt any motion that could come in contact with a person. Motion control plays a critical role here; the control loop must deliver microsecond response in a smooth-flowing and controlled fashion. For example, for the detection of an obstacle such as a human hand, the actual motor currents are monitored, which generates a real-time event and local response to bring the axes to a swift controlled stop.

Given these requirements, controller-level complex loop processing provides the safest, surest architecture. Since safety control loops are typically machine-specific, platforms that support fast, custom algorithm development and local real-time C sequences on the motion node can save valuable programming time.

Off-the-shelf motion control platforms should comply with healthcare and environmental regulations (in the U.S., FDA and FCC.) At the electronic level, this typically includes Class B certification for low noise and electrical grounding. Components should also be hardened and shielded from potential effects of long-term use with high-energy and exotic electromagnetic sources such as X-rays, MR magnets, gamma ray and positron emissions.

Motion control and the global supply chain

Costs of high-end imaging systems can run into the millions. To stay competitive and sustain R&D investments in the next generation of systems, OEMs must integrate multiple product lines, technology platforms and engineering groups located across the globe. Increasing standardization, especially in motion control, and improving global supply chain management are crucial to improving their return on investment.

For example, one major device manufacturer has 20 different patient tables each with a unique design. Most OEMs now depend on multiple cross-border design, engineering and manufacturing teams to build a single machine: For an MRI machine, one team in The Netherlands may handle the patient table, a team in the UK engineers the imaging apparatus, and the finished system must be integrated into a suite in Houston by a third team.

An efficient integrated global supply chain must deliver and assemble the finished imaging system with the assurance that all elements have been tested and verified ready for use — before they're shipped to Houston. To help achieve this goal, OEMs are trying to implement, as much as possible, standard motion control platforms across multiple product lines and markets.

Partnering delivers motion control advantages

Many medical OEMs have found it more efficient to partner with single-source motion control suppliers that have true global reach and experience. This includes partners with:

- Engineering and support resources present in all major system design, development and manufacturing locations.
- Proven expertise successfully working with cross-border and cross-functional teams.
- In-depth expertise implementing, installing and supporting motion control platforms in markets on every continent.

Global partnering with suppliers generates additional supply chain optimization. Standardizing machine components across multiple product lines — motion control, drives, and even complete motion subassemblies — gives design teams more opportunities to simplify machine architectures, reduce component count, and drive further design standardization. This approach frees medical OEMs to concentrate engineering resources on the imaging technologies that give them clear market differentiation, and partner with motion control and component suppliers who have expertise to do the rest.

Rexroth
Bosch Group

FORM MedMC_Tech (0807)

Bosch Rexroth Corporation
5150 Prairie Stone Parkway,
Hoffman Estates, IL USA 60192-3707
Telephone (847) 645-3600
www.boschrexroth-us.com