KAROS
THE KOREAN ASSOCIATION OF ROBOTIC SURGEONS

# KAROS 2025

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# Development of an EMC-Compliant Five-Axis Motor Control Board

## EMC 대응 5축 모터 제어기 개발

Center for Bionics Research
Korea Institute of Science and Technology
University of science & Technology
Changdae Kwak, Chunwoo Kim

**Fig.1** Operating rooms are dense with EMI sources

## EMI: A Hidden Threat to Robotic Surgery

### EMI-Rich Environment

Operating rooms are full of EMI sources, including surgical robots themselves

### Signal Disruption

EMI can corrupt control signals and cause unexpected robotic movements

### Unintended Movement

unintended robotic motion,
leading to surgical failure or patient injury

## What is EMI and EMS in Surgical Robotics?

### ✔ EMI (Electromagnetic Interference)

- The electromagnetic noise emitted by the surgical robot controller.
- Can interfere with other medical devices.

### ✔ EMS (Electromagnetic Susceptibility)

- The vulnerability of the controller to external electromagnetic noise.
- Can cause control errors or unintended robotic movement.

### ✔ Impact on Surgery

- Both EMI and EMS can compromise motor control stability and threaten patient safety.

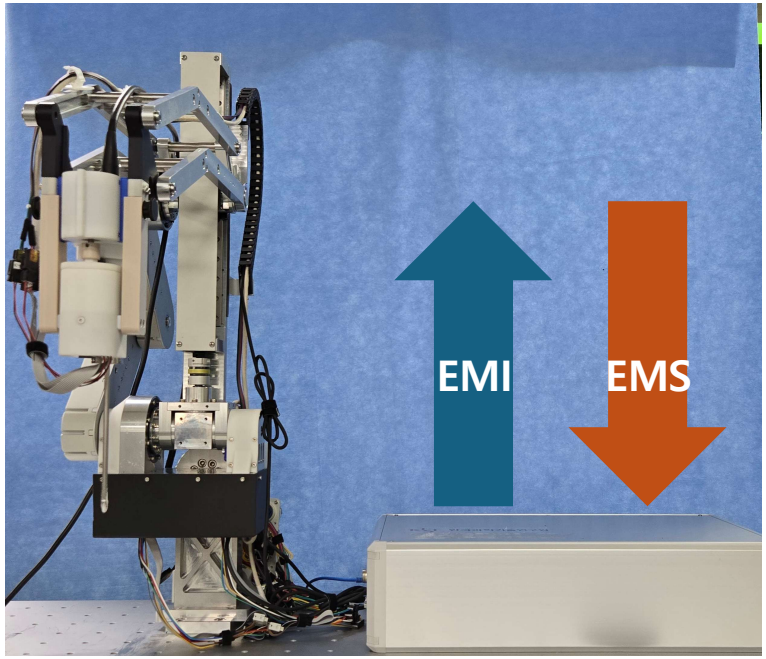



**Fig.2** External view of the spine surgical robot and its controller

## What is EMC Testing?

| EMC Test Category | Test Name | Purpose | Risk Prevented |
|---|---|---|---|
| **Emission Tests (EMI)** | **CE** (Conducted Emission) | Measure noise conducted through **power lines** | Disturbs nearby devices |
| | **RE** (Radiated Emission) | Measure noise **radiated wirelessly** | Causes wireless interference |
| **Susceptibility Tests (EMS)** | **ESD** (Electrostatic Discharge) | Test resistance to **static Electricity** | Prevents malfunction from sudden discharges |
| | **EFT / Surge** | Test resistance to **voltage spikes** | Protects circuits from unstable power |
| | **CS** (Conducted Susceptibility) | Test vulnerability to **incoming noise via cables** | Maintains control stability |
| | **RS** (Radiated Susceptibility) | Test vulnerability to **wireless noise** | Maintains stable operation under EMI |

## Objective of This Development

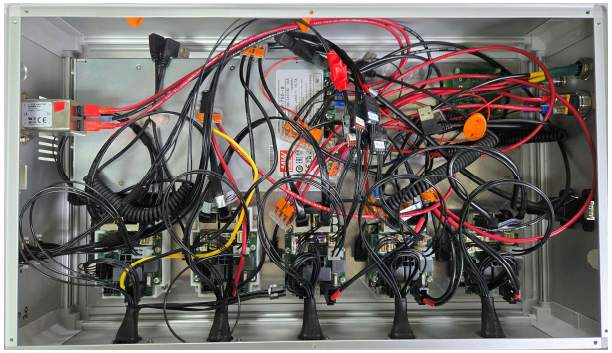


**Fig.3** Inside of the robot controller, Complex wiring increases EMI risk

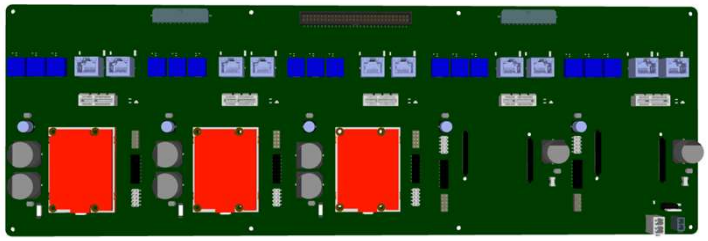
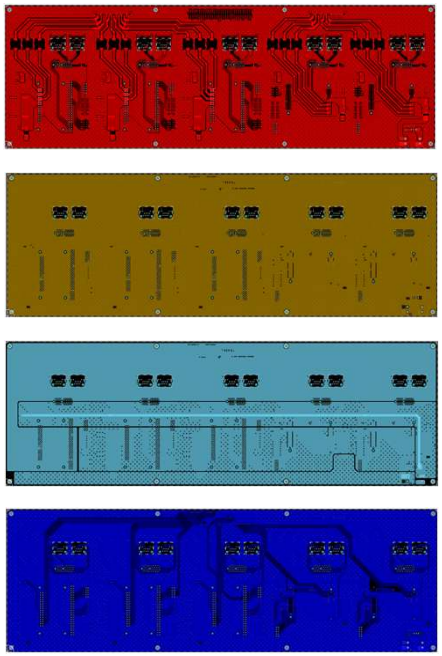


**Fig.4** Developed motor control board with reduced EMI risk.

✔ **Objective**

- Develop a motor control board optimized for surgical robotic systems.
- Achieve stability, and EMC compliance for safe operations.

## Key Design: Protecting Control Signals



**Top Layer**
(Motor Power Line)

**Inner Layer 1**
(Ground Plane - Noise Isolation)

**Inner Layer 2**
(Vcc & Logic Power Plane)

**Bottom Layer**
(Signal Routing - Optimized for Noise Reduction)

**Fig.5** Layer structure of the developed motor control board for EMI mitigation.

The four-layer PCB was designed to isolate power and signal paths, minimizing noise coupling and enhancing signal integrity under EMI conditions.

# Key Design: EMI Countermeasures

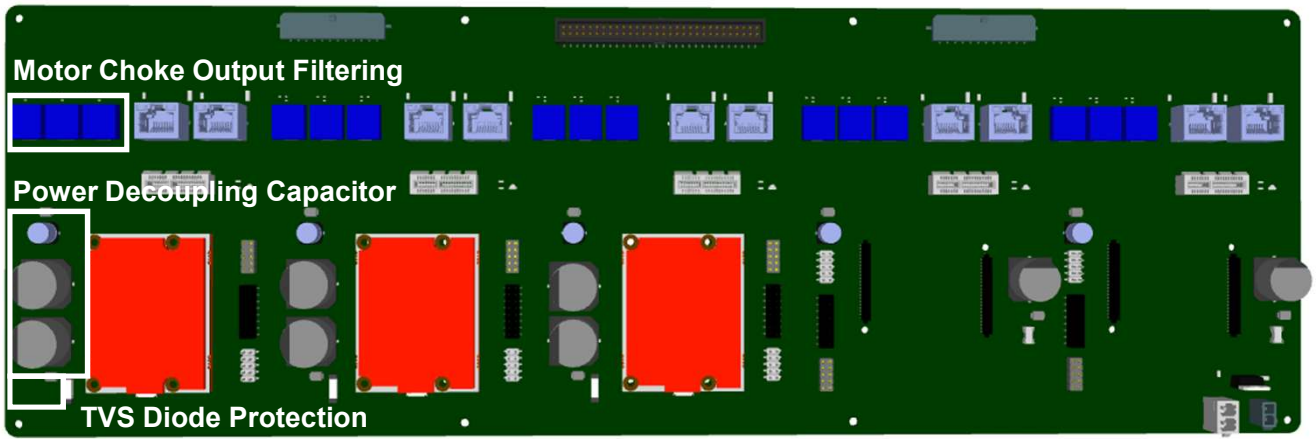



**Fig.6** Key EMI countermeasures implemented on the motor control board.

| Countermeasure | Purpose | Relevant EMC Tests |
|---|---|---|
| Power Decoupling Capacitor | Stabilizes voltage and suppresses noise | CE, CS, EFT |
| TVS Diode Protection | Redirects ESD and surge energy safely to ground | ESD, Surge, EFT, CS |
| Motor Choke Output Filtering | Suppresses switching noise and back-EMF | RE, CE |

## Implementation: Final Board

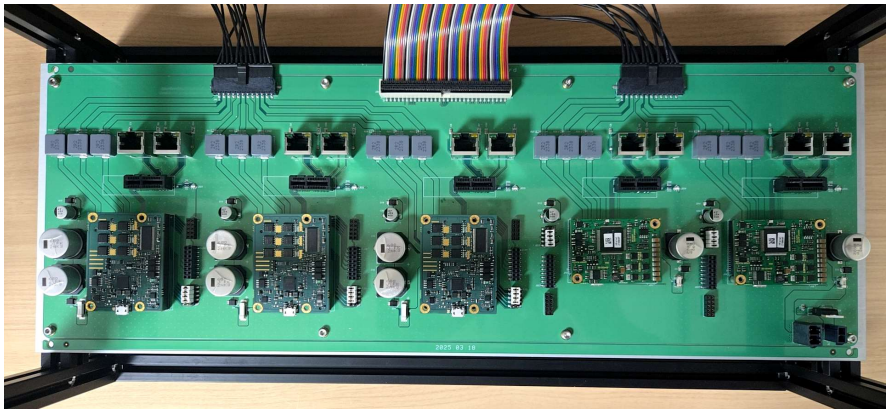


**Fig.6** Fabricated five-axis motor control board optimized for EMI resistance.

- ✓ Fabricated a five-axis motor control board for surgical robotics.
- ✓ Integrated motor drivers, current sensing, and EMI protection circuits.
- ✓ Designed with noise-optimized layout for EMI compliance.

## Validation Plan: Testing for Safety

| Item | Description |
|---|---|
| **Standard** | Medical Device EMC, Class B (MFDS) |
| **Test Items** | • CE (Conducted Emission)<br>• RE (Radiated Emission)<br>• ESD (Electrostatic Discharge)<br>• RS (Radiated Susceptibility)<br>• CS (Conducted Susceptibility)<br>• Surge and EFT |
| **Current Status** | Fabrication completed / Pre-compliance testing scheduled |

Validation ensures signal integrity and control stability under EMI conditions.

## Conclusion

### Final Achievements

- Developed a five-axis motor control board with integrated EMI countermeasures.
- Enhanced signal integrity and control stability in EMI-rich surgical environments.

### Future Steps

- Integrate the board into the surgical robotic system.
- Perform EMC pre-compliance testing for MFDS Class B certification.