

# GaN-based Power Amplifier for Magnetic Bearing Levitation | Team Levitate

Department of Electrical and Software Engineering, Schulich School of Engineering, University of Calgary and SKF Magnetic Bearings

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## 1. What's the problem?

SKF has 150,000+ magnetic bearings and electric motor solutions world-wide[1]. Why a driver re-design?

In short... Efficiency, Performance and Size

**Greater efficiency** → Less wasted energy, more money saved, less scope three greenhouse gas emissions.

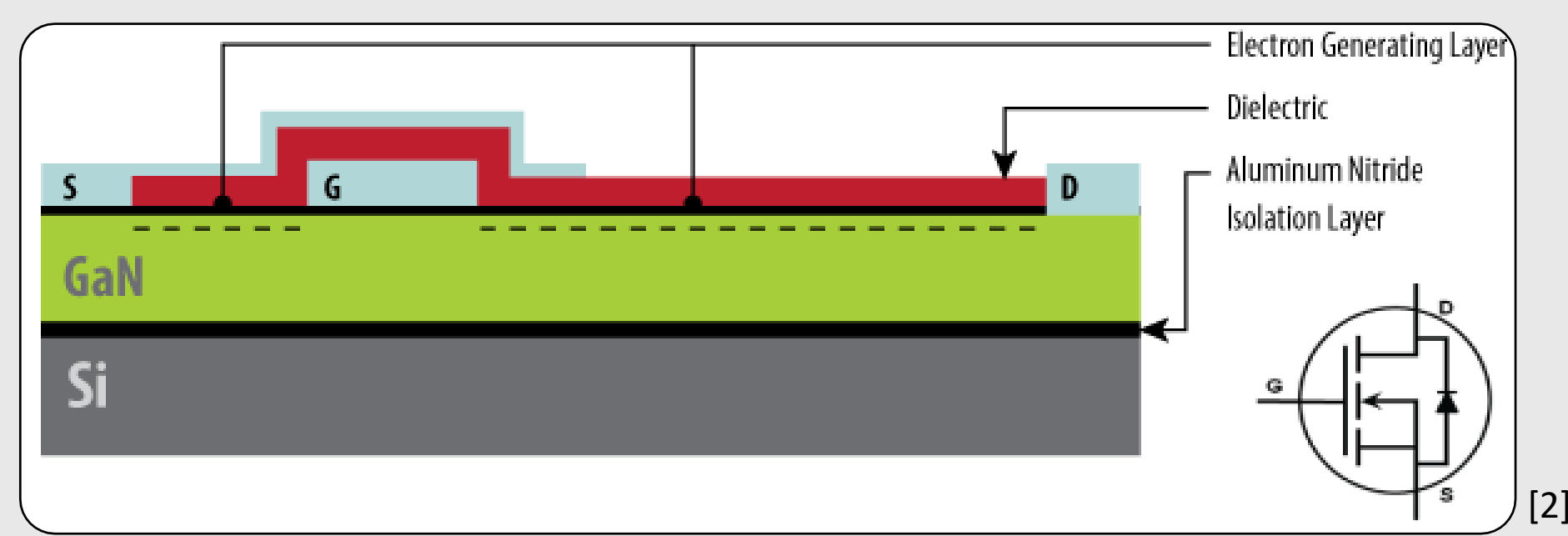
**Better performance** → More uses in higher performing customer designs.

**Smaller size** → Easier integration, smaller customer solutions.

The solution?

## 2. GaN FETs

Gallium Nitride High Electron Mobility Transistors



[2]

- Up to 10MHz switching frequency
- Low gate ON resistance
- Low gate capacitance

### ✓ Improved Efficiency

- Less wasted energy means more efficient levitation.

### ✓ Faster Switching

- Faster response times for more precise control and smaller passive components.

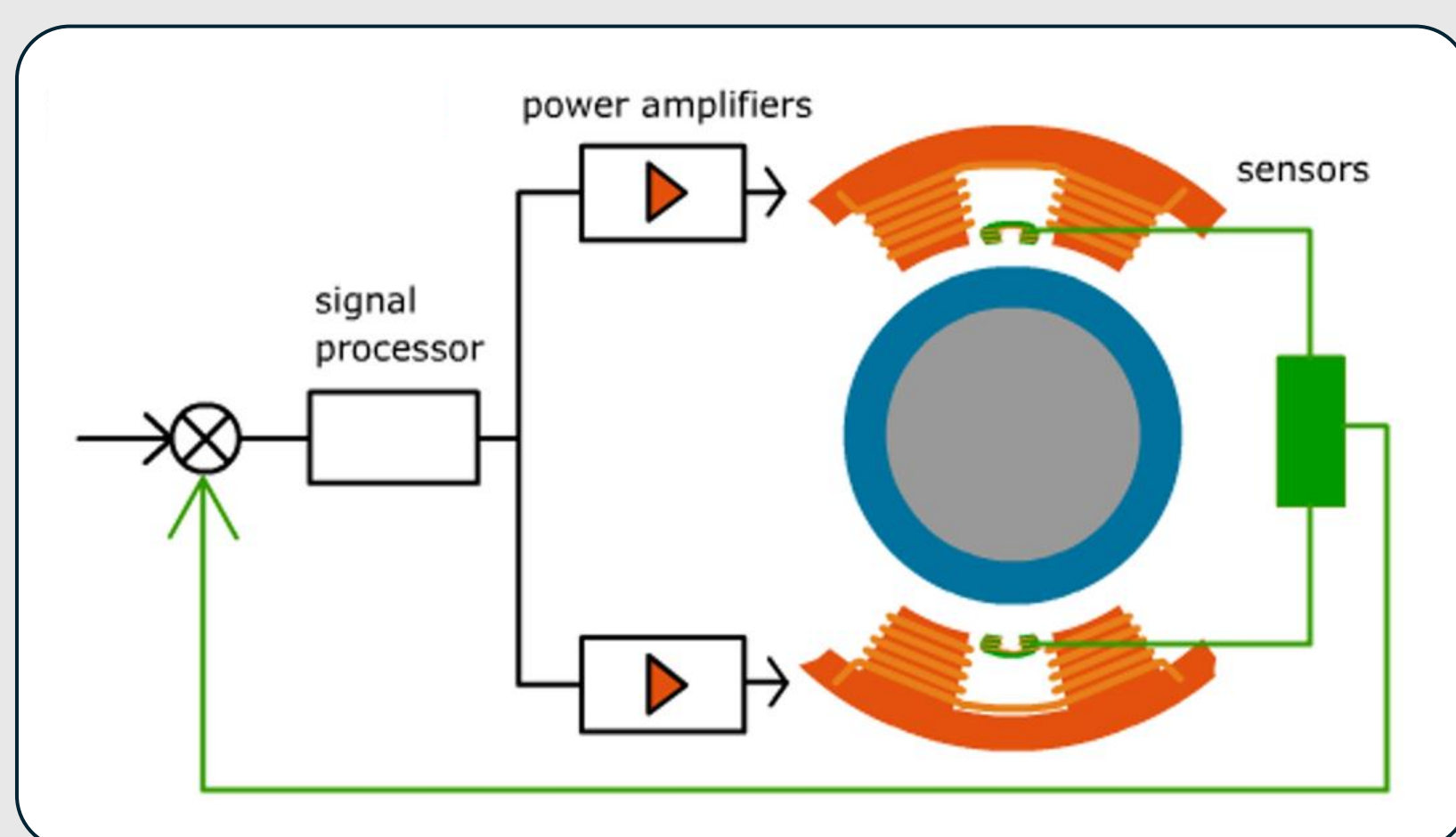
### ✓ Reduced Losses

- Less power dissipated as heat removes the need for a heat sink.

### ✓ Improved Thermal Characteristics

- Reduced thermal stress for a longer lifetime.

## 3. How Magnetic Bearings Work

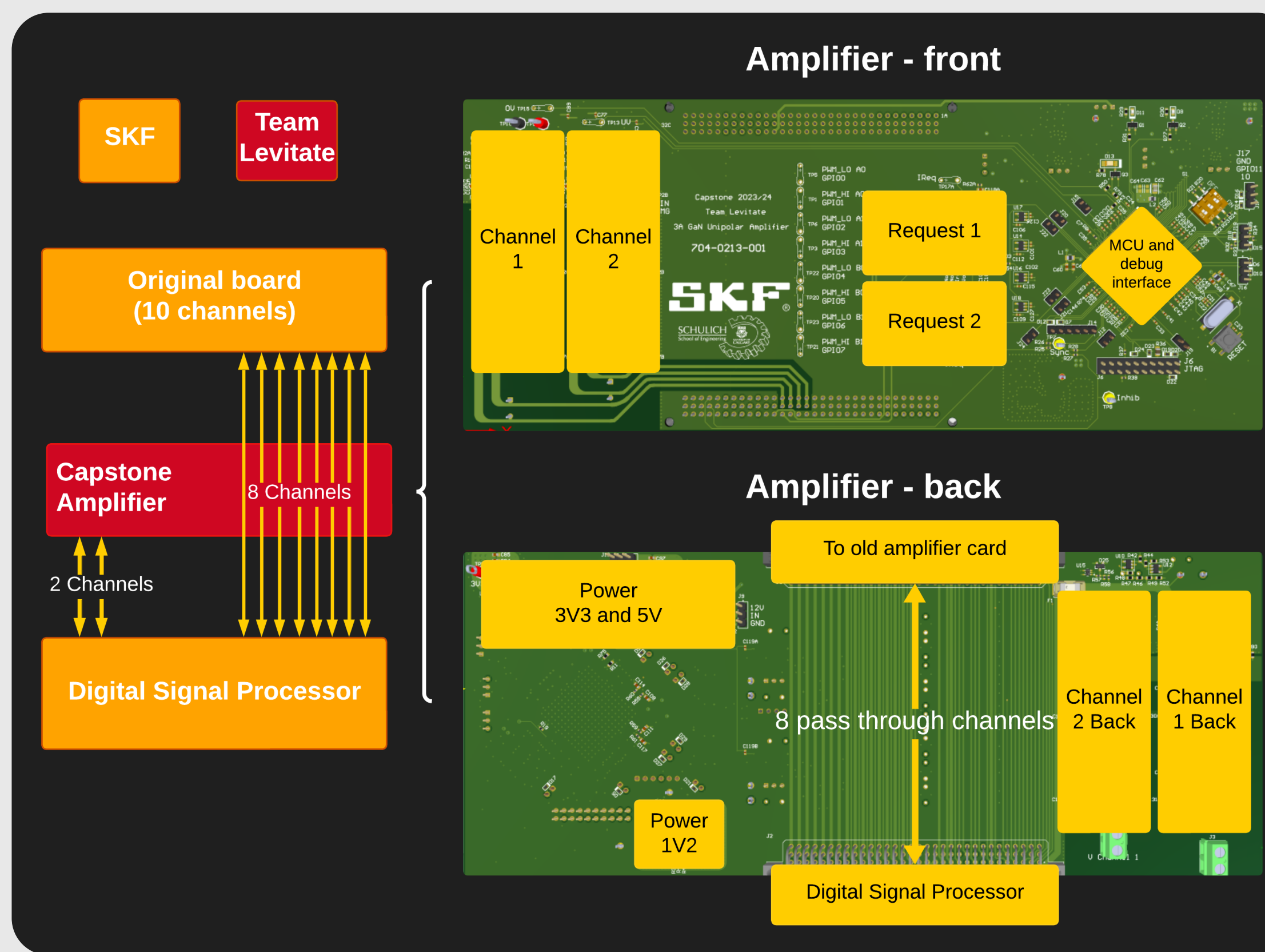


Magnetic bearings offer near-frictionless rotation and precise control.

- Use electromagnets to levitate and stabilize rotating components.
- Each axis of levitation is controlled by 2 channels, each driving one magnetic bearing.

## 4. The Project

Designing a custom board using state-of-the-art transistor technology to intercept one axis of levitation control via two power amplifier channels.

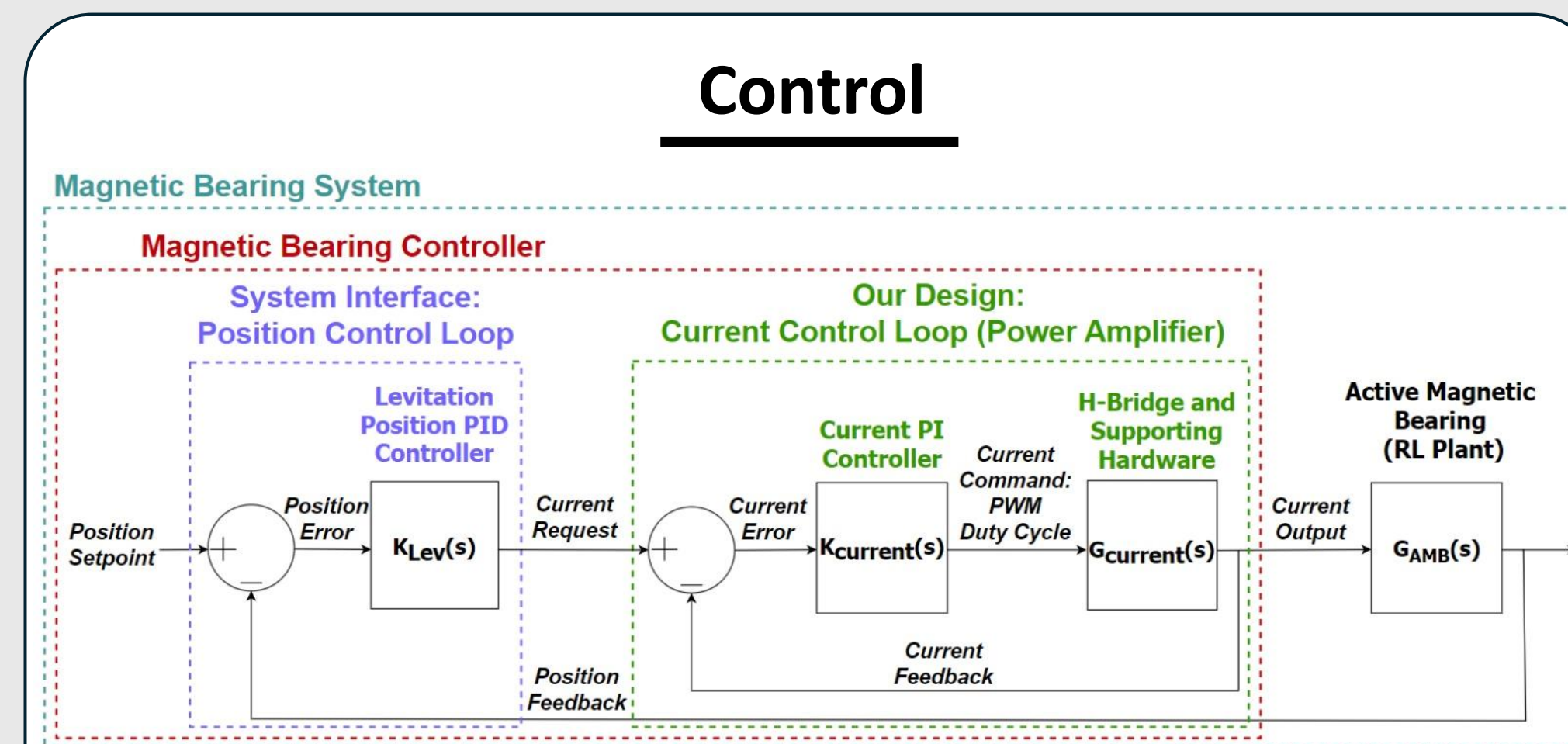


## Design Goals

- Improve device efficiency
- Increase switching frequency
- Remove or reduce audible noise
- Achieve ripple current  $\leq 0.5\%$  of the rated current
- Limit voltage ringing to  $< 10V$  above load voltage
- Accomplish overall current tracking
- Stable frequency magnitude and phase response
- Backwards compatibility for integration into current design

## 5. Our Design

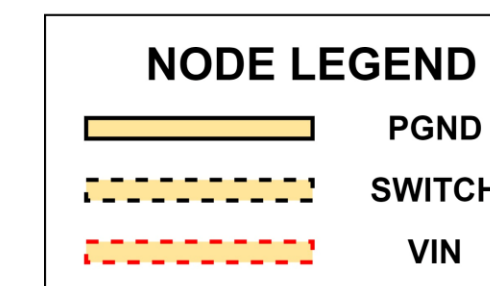
Getting into the details...



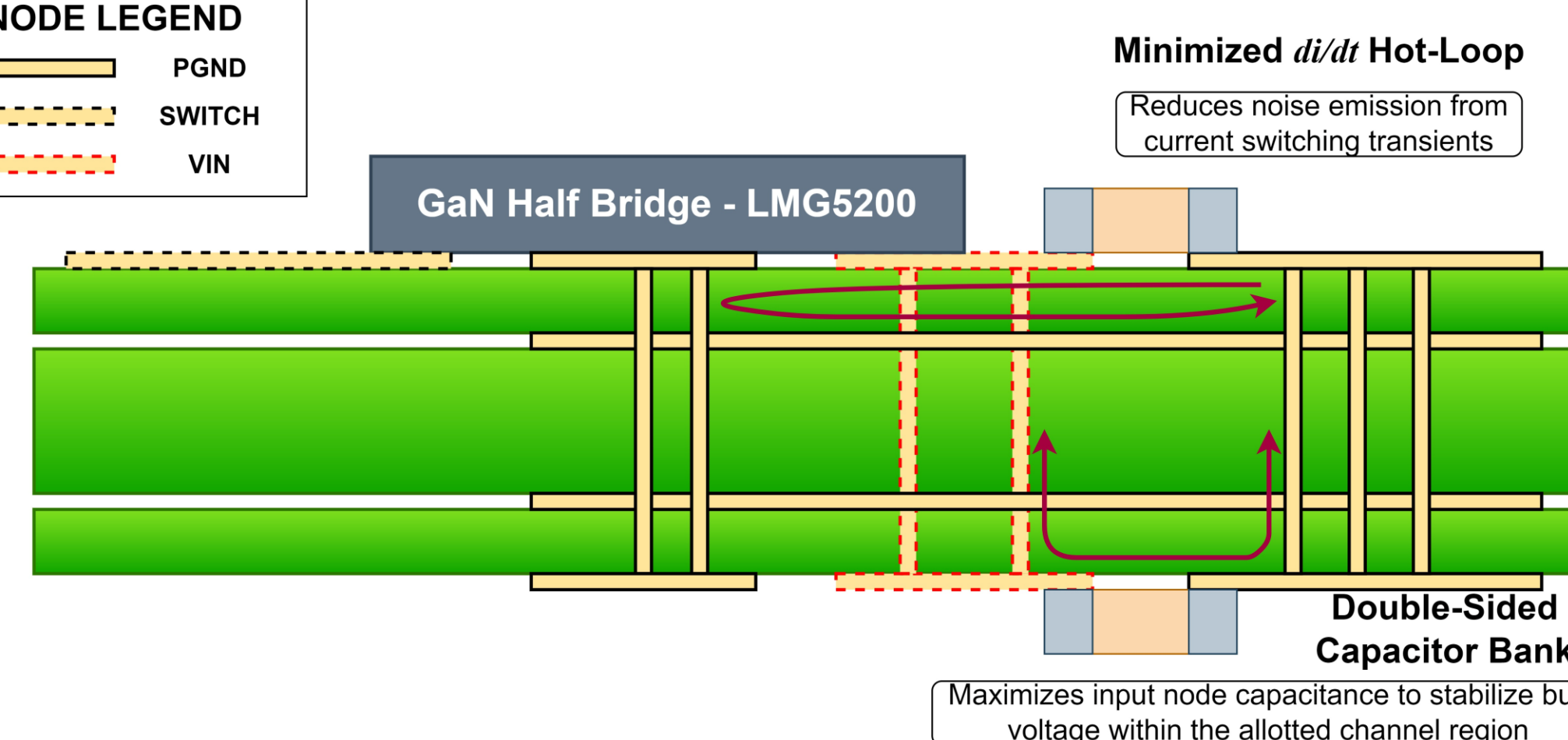
- Tuned PI controller using Ziegler-Nichols method.
- Used PSIM simulations to verify design.
- Discretization of PI controller using Backward Euler method for digital control on an MCU.

### PCB Design

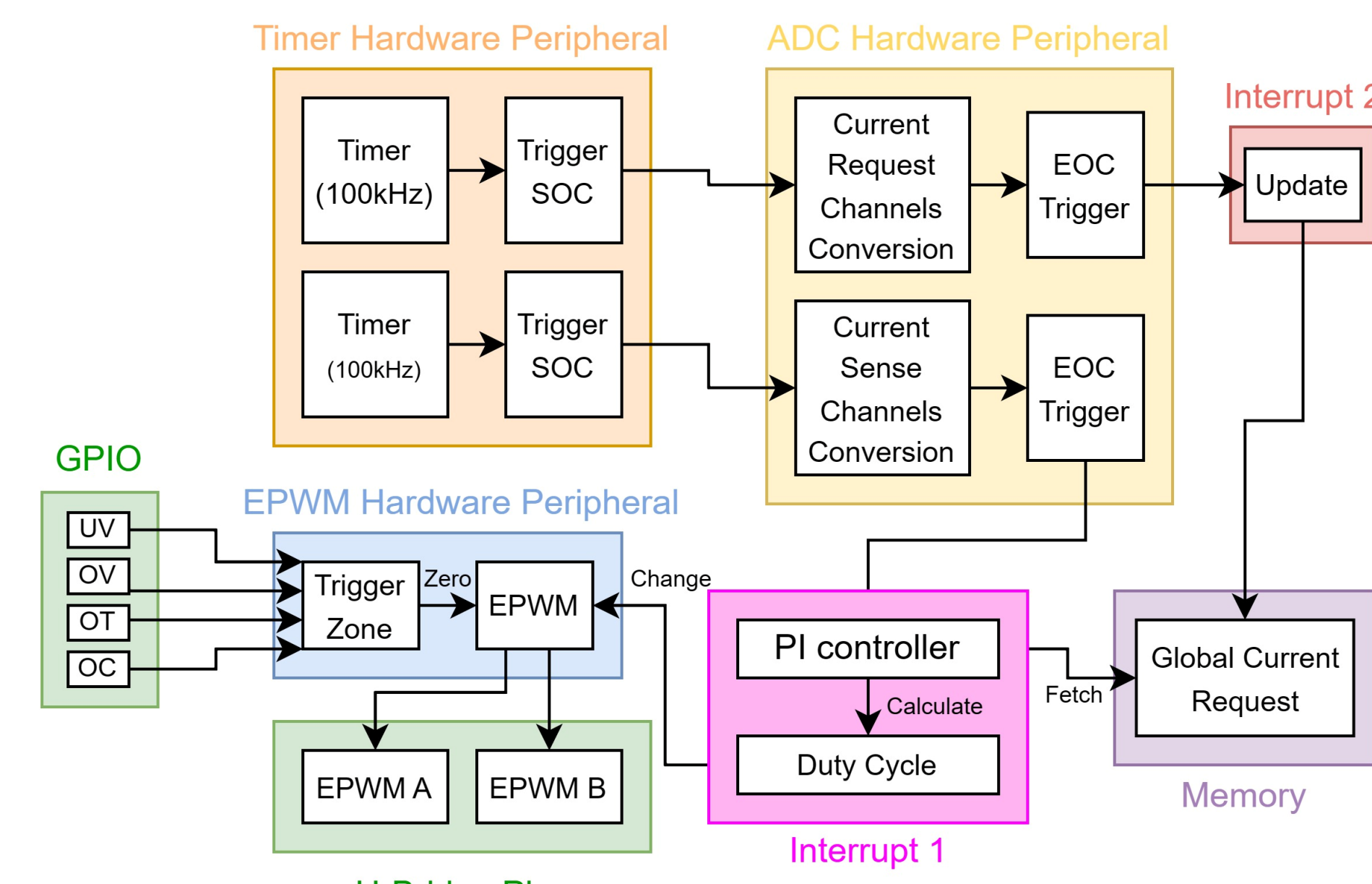
- Intercepts and drives two channels in the existing power amplifier design to validate the proposed GaN-based solution.
- 8-layer PCB with 4 internal plane layers and strategic routing, reducing cross talk between sensing and PWM lines.
- Three ultra-low EMI regulators for 5V, 3.3V and 1.2V rails – offering large supply range (5V-36V).
- High-density component placement, demonstrating feasibility of a 10-channel design in a PCB of equal dimensions.



### Half Bridge Layout Cross Section

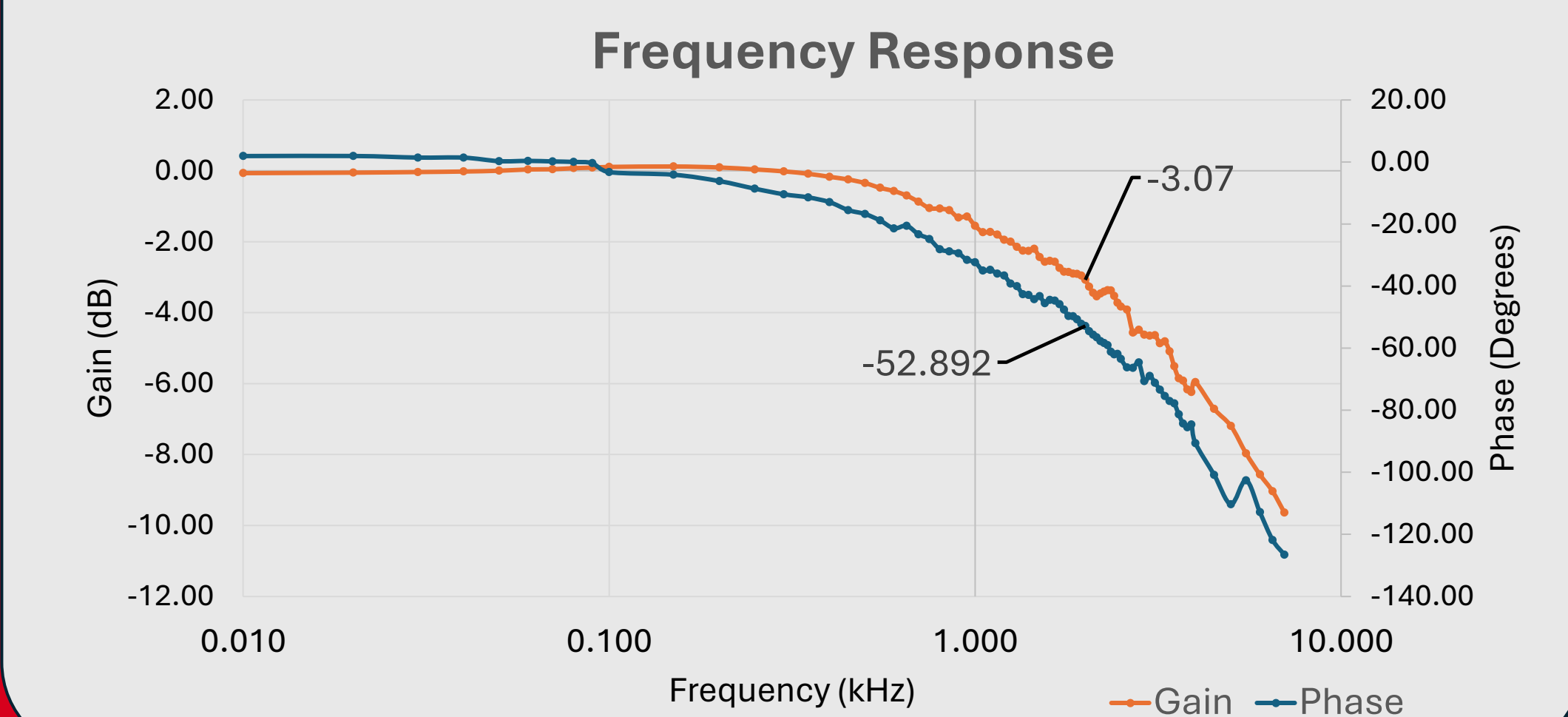
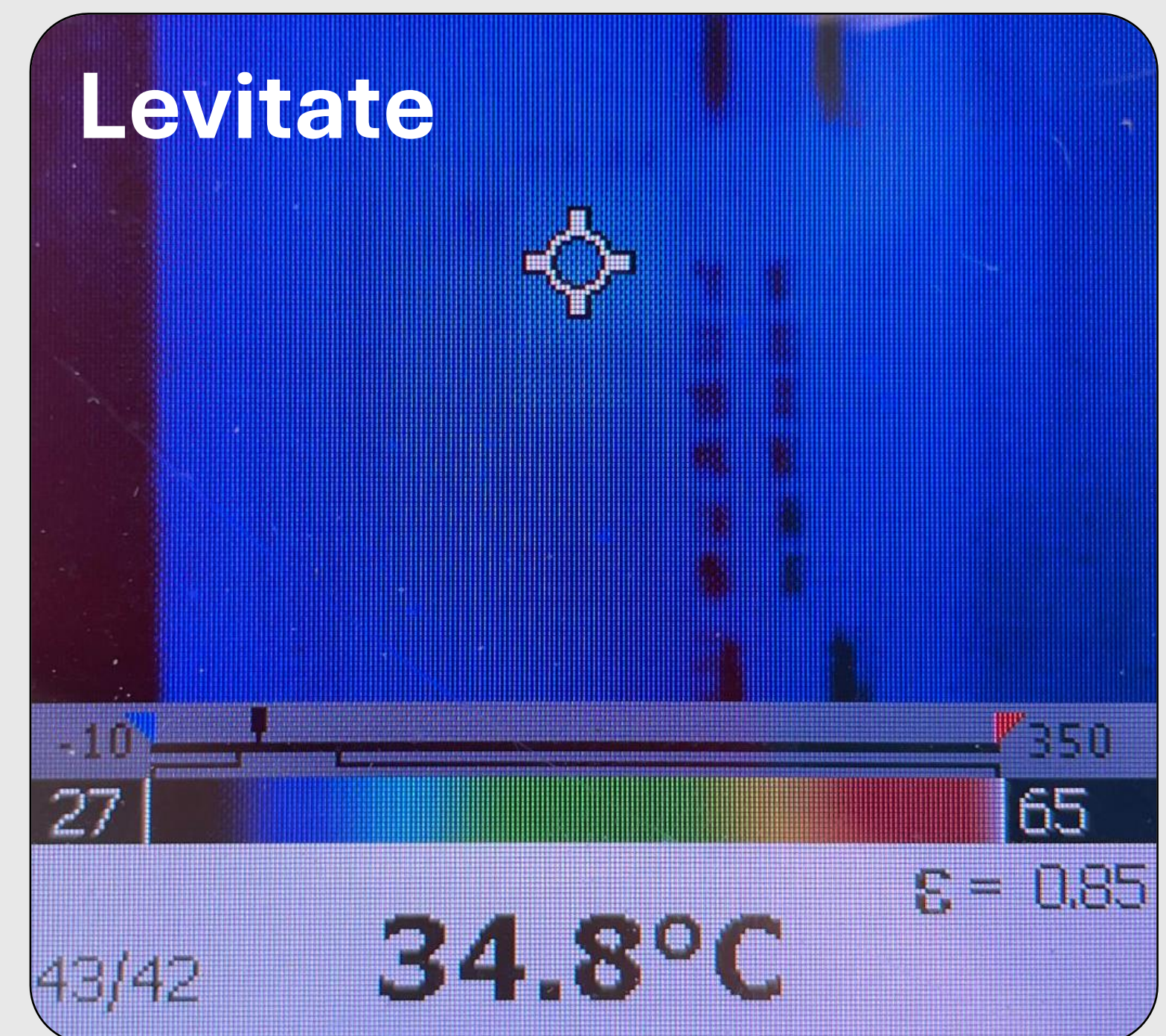
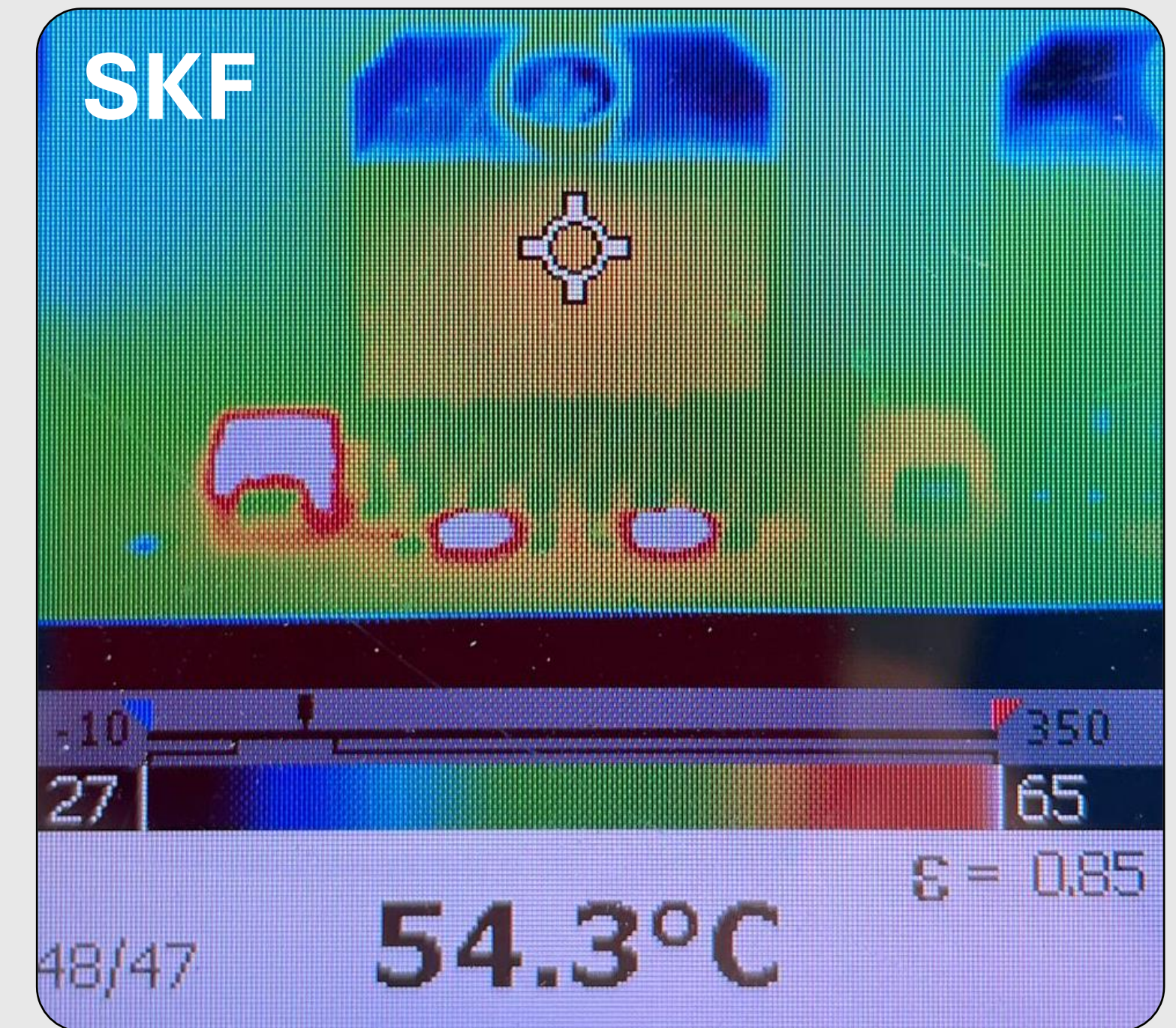


### Firmware



## 6. Results

- ✓ 5W Reduction
- ✓ 100kHz+
- ✓ Reduced
- ✓ 0.5% Ripple
- ✓ 10V Ringing
- ✓ Achieved
- ✓ Stable/0dB Gain
- ✓ Levitates



## 7. Conclusion

- One of the first groups ever to integrate state-of-the-art GaN technology into a magnetic bearing application.
- Paved the way for SKF to begin integrating GaN technology into their products to be able to provide customers worldwide with magnetic bearing solutions that are:
  - **More efficient** → Less wasted energy, more savings.
  - **Higher performing** → More potential uses.
  - **Smaller** → Easier integration, more space saved.

Sponsored by:

