

# Humanoid Robots Dexterity Powered by GaN FETs and ICs

*Marco Palma*

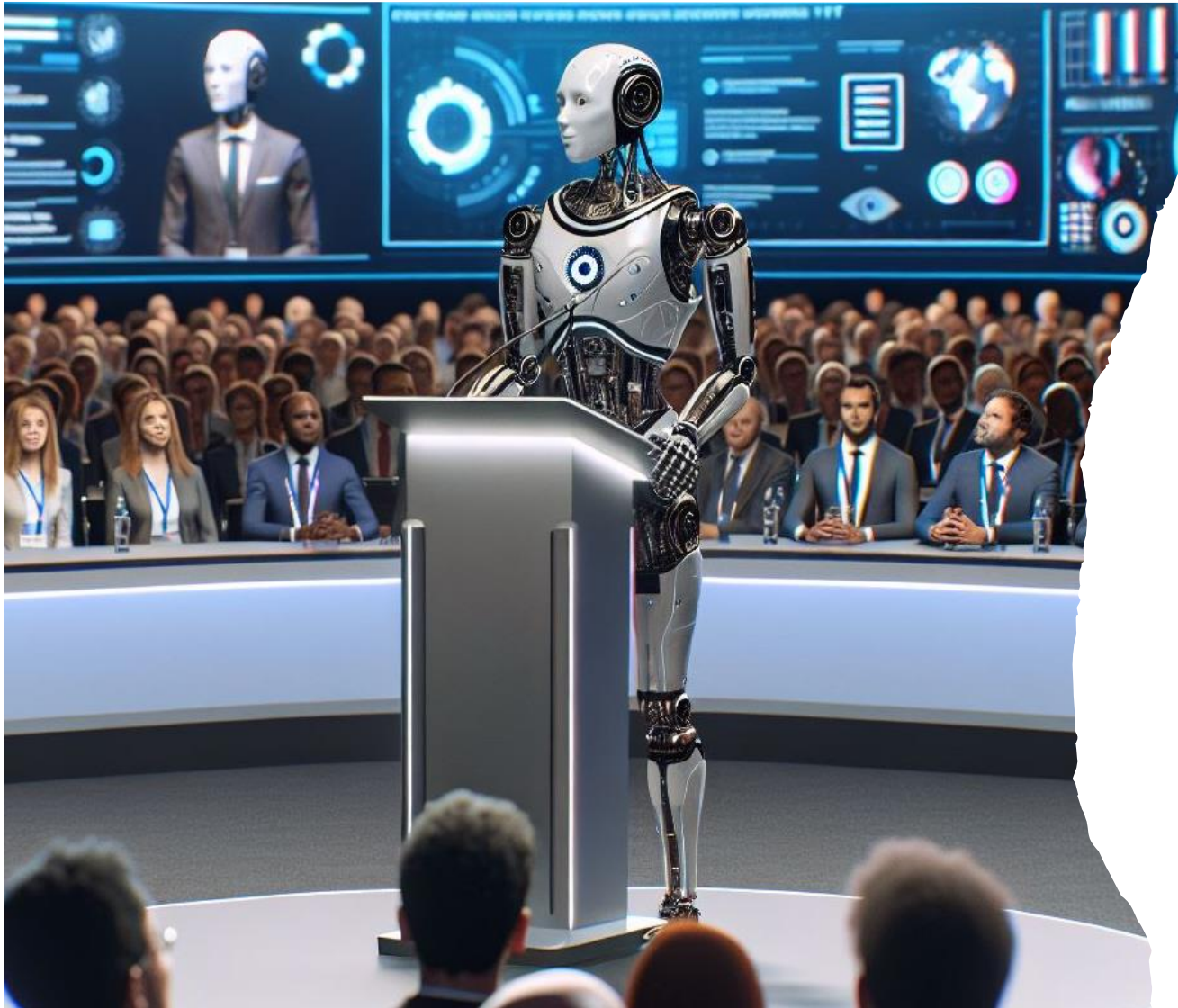
*Director of Applications, Efficient Power Conversion*

**Bodo's  
Wide Bandgap  
Event 2024**

*Making WBG Designs Happen*

**GaN**

# Introduction



- A Humanoid Robot is
  - a general-purpose,
  - biped robot with human form factor
  - designed to work with humans to augment productivity
- With these benefits:
  - Human-Robot Interaction
  - Versatility and Adaptability
  - Productivity
  - Enhanced Safety
- And use cases:
  - Warehouse and Logistics
  - Healthcare
  - Home Assistance
  - Customer Service

# Biped Robots Design Challenges



- Mass distribution in the body
- Undesirable mechanical resonances
- Humans Safety-related constraints



- Actuators placed at each joint
- High-performance joint servo drives to reject torque disturbances
- High bandwidth and high-efficiency servo motors
- High power density and miniaturization
- Low operating temperatures
- Medium voltage operation



# GaN Benefits in Joint Servo Drives

GaN devices switch fast with  $Q_{RR} = 0$

**Higher switching frequency**



Electrolytic capacitor  
elimination and reduced  
motor losses



**High joint efficiency and smooth and accurate operation**

**Highest miniaturization**



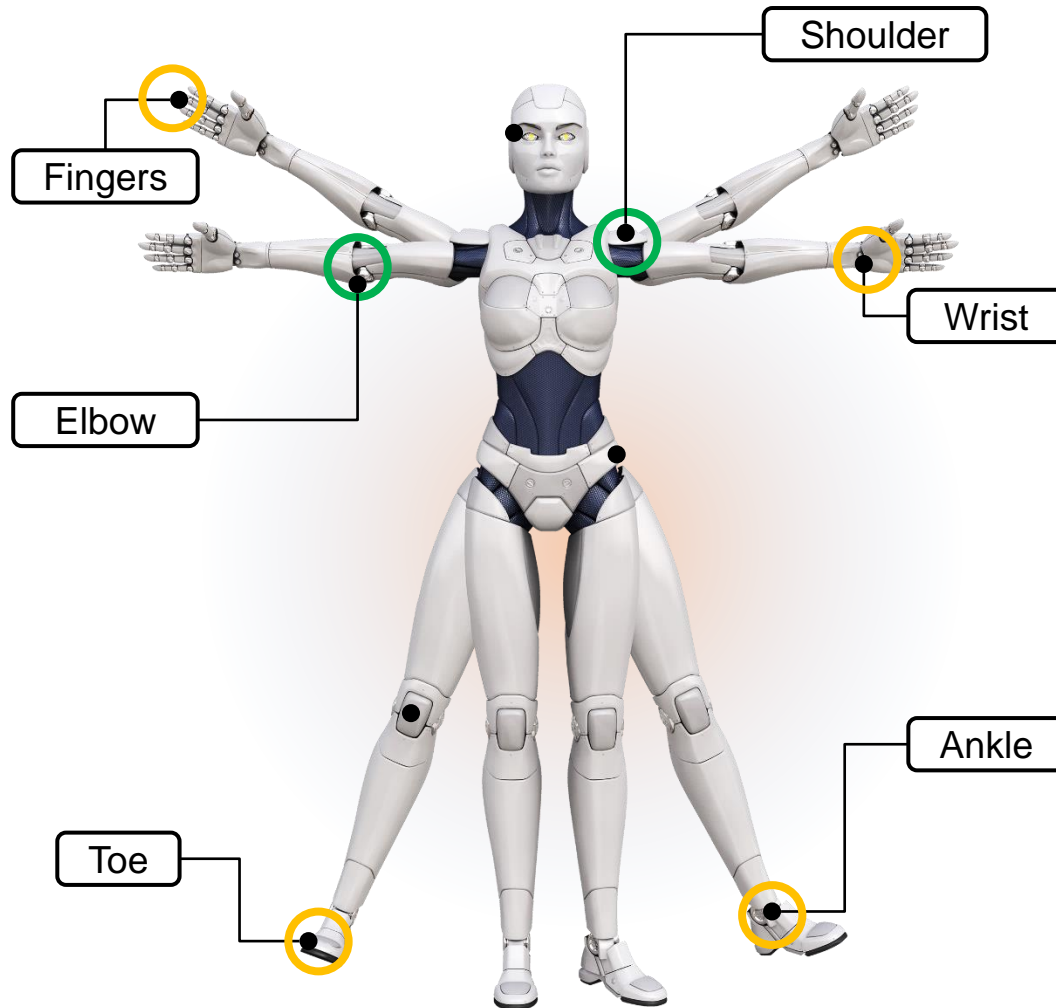
**Lower dead time**



Higher torque per  
Ampere

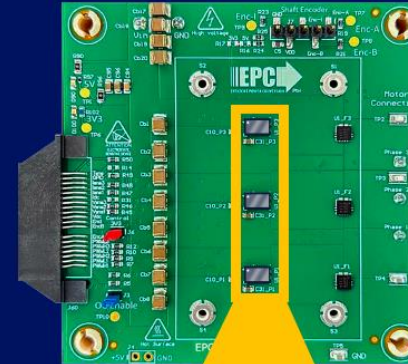


# GaN Power Stage for Micromotors



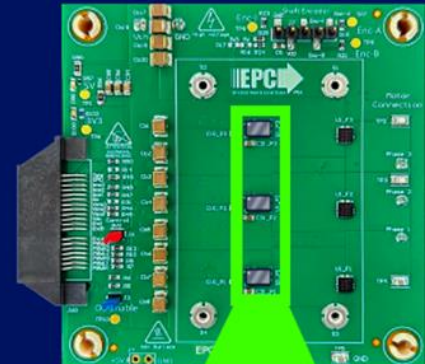
## EPC91104

10 A<sub>RMS</sub>  
continuous  
20 A peak  
operation



## EPC9176

25 A<sub>RMS</sub>  
continuous  
40 A peak  
operation



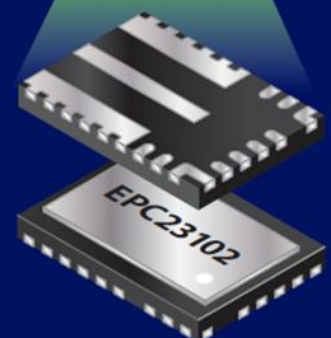
## EPC23104

100 V, 15 A  
ePower™ Stage IC

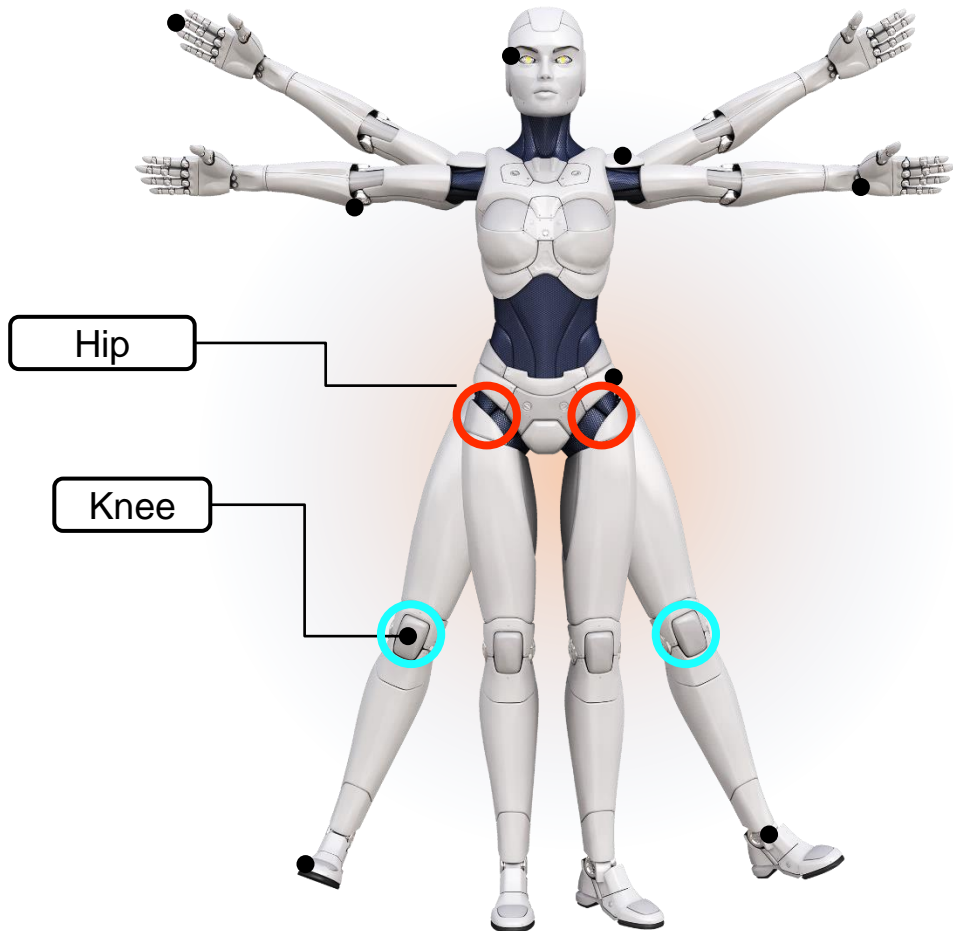


## EPC23102

100 V, 35 A  
ePower™ Stage IC

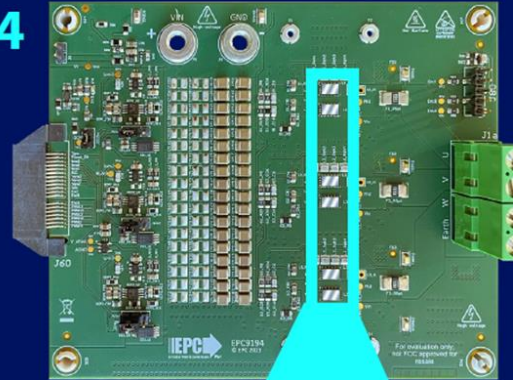


# GaN Devices for High Speed Walk/Run



## EPC9194

40 A<sub>RMS</sub>  
continuous  
60 A peak  
operation



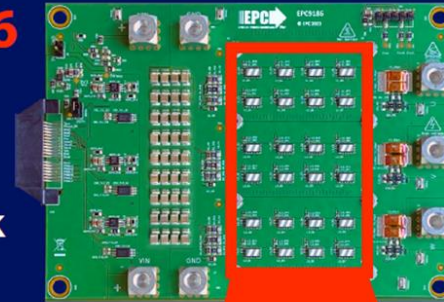
## EPC2302

$V_{DS}$ , 100 V  
 $R_{DS(on)}$ , 1.8 m $\Omega$   
 $I_D$ , 101 A  
Pulsed  $I_D$ , 408 A



## EPC9186

150 A<sub>RMS</sub>  
continuous  
200 A peak  
operation



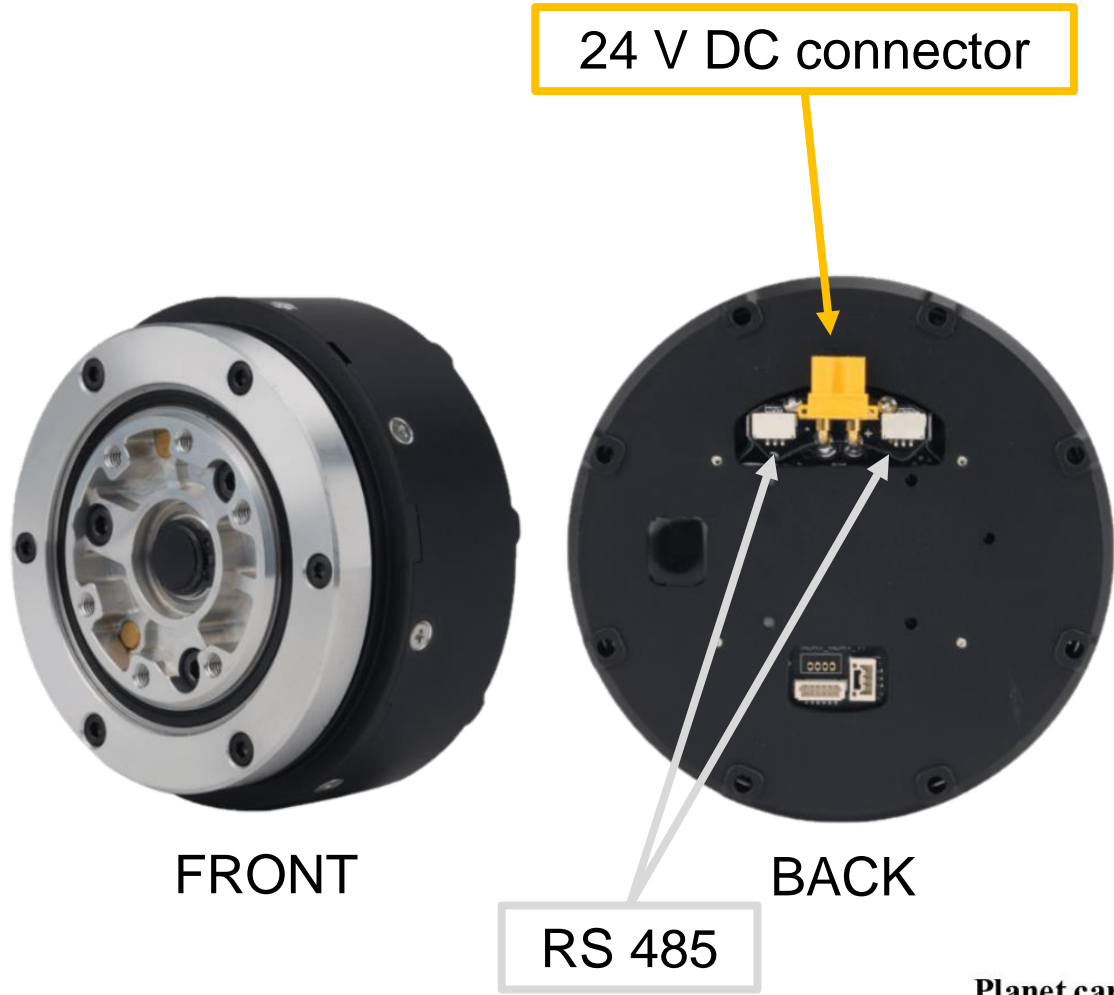
## EPC2302

$V_{DS}$ , 100 V  
 $R_{DS(on)}$ , 1.8 m $\Omega$   
 $I_D$ , 101 A  
Pulsed  $I_D$ , 408 A

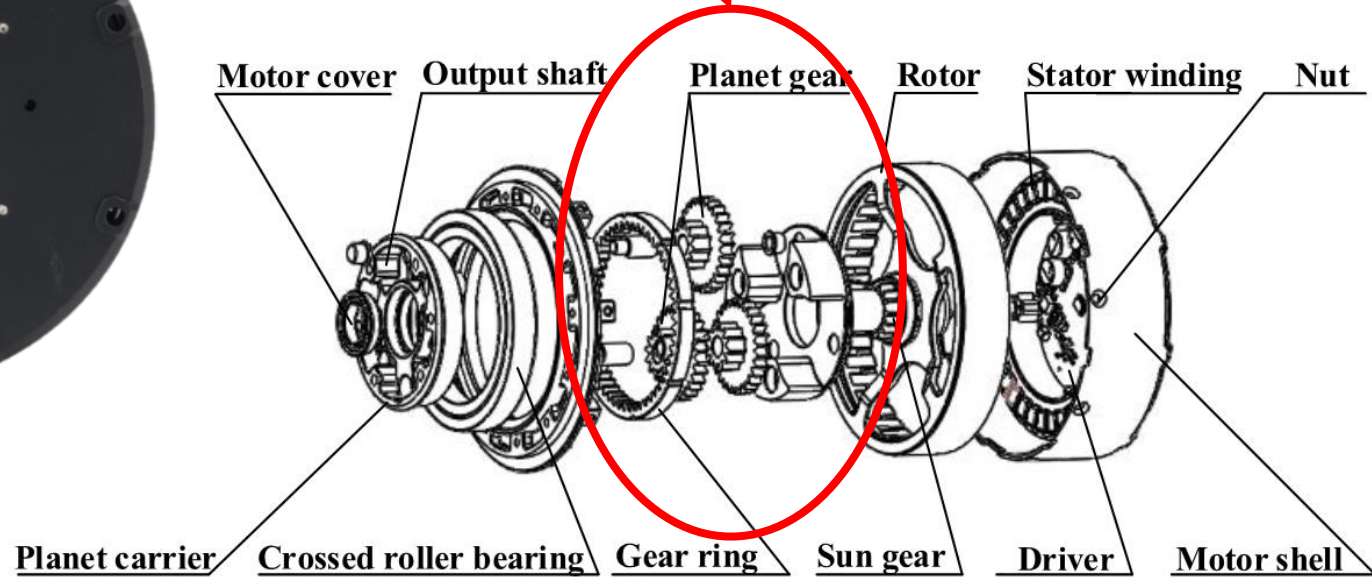




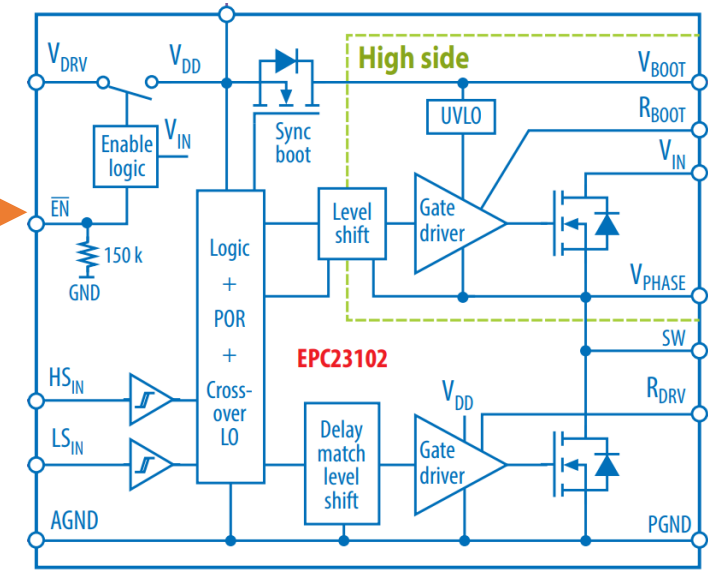
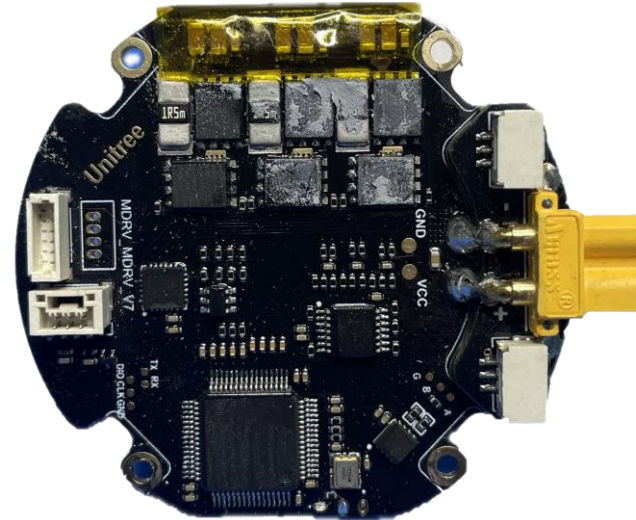
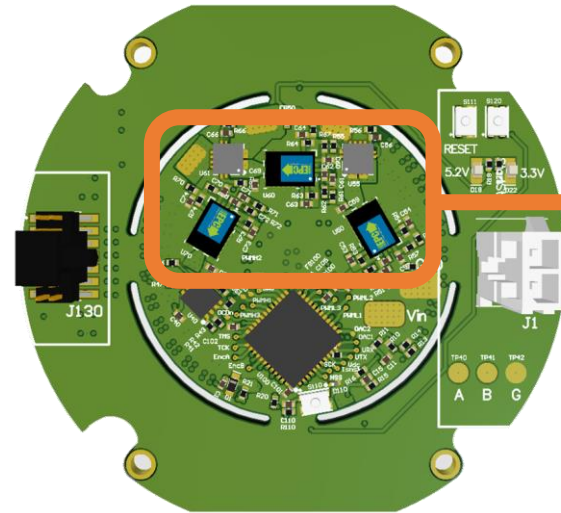
# Joint Motor Example



9.1 gear reduction  
Speed divided by 9.1  
Torque multiplied by 9.1



# Joint Servo Drive Example



GaN Power stage includes

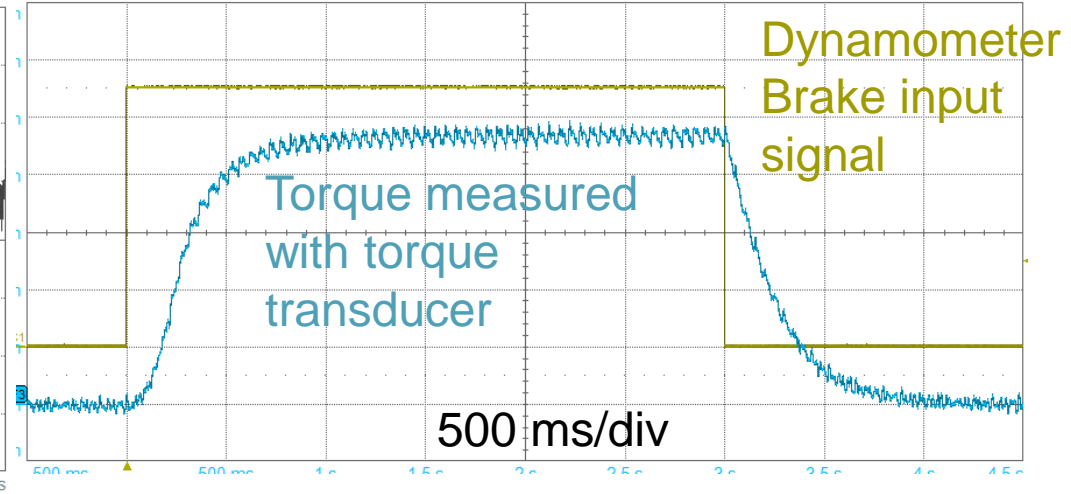
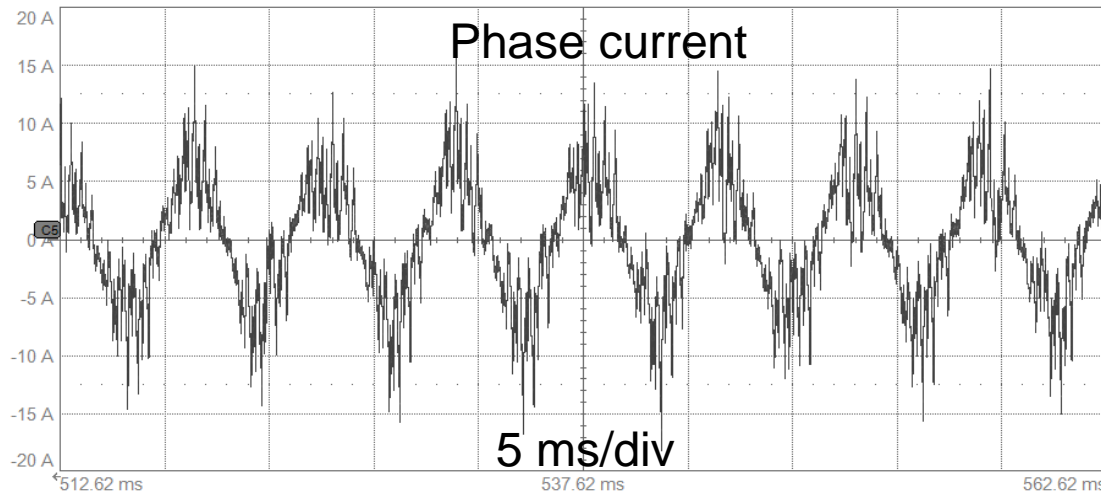
- GaN Gate driver
- Sync Bootstrap function
- 6.6 mohm Power GaN FETs
- 3 x 5 mm QFN package
- Very low top cooling Rth



# Comparison – Preliminary Exp. Results

## Original MOS inverter

Sinusoidal modulation  
40 kHz PWM frequency  
High current ripple  
High torque ripple



## GaN inverter

Sinusoidal modulation  
80 kHz PWM frequency  
No current ripple  
No torque ripple

