University of Moratuwa

Faculty of Engineering

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INSTALLATION GUIDE

Strain Gauge Based Torque Sensor

Wireless Power Delivery & BLE Communication System

EN2160 – Electronic Design Realization

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Contents

1 Executive Summary

This installation guide provides comprehensive instructions for the deployment and configuration of the strain gauge-based torque sensor system developed under the EN2160 Electronic Design Realization project at the University of Moratuwa. The system represents an advanced mechatronic solution incorporating wireless power delivery, precision strain gauge measurement, and Bluetooth Low Energy (BLE) communication capabilities.

INFORMATION

The torque sensor system is designed for industrial and laboratory applications requiring accurate, real-time torque measurements with wireless data transmission capabilities. The system operates in the range of $0\ \mathrm{N\,m}$ to $1\ \mathrm{N\,m}$ with high precision and reliability.

1.1 Key Features

- Wireless power delivery using inductive coupling technology
- Full-bridge strain gauge configuration for enhanced sensitivity
- BLE 5.1 communication interface for real-time data transmission
- Web-based dashboard for monitoring and control
- Robust Stainless steel enclosure with welded halves construction suitable for industrial environments
- Operating temperature range: $-20\ ^\circ\mathrm{C}$ to $60\ ^\circ\mathrm{C}$

2 Safety Information

SAFETY

MANDATORY SAFETY REQUIREMENTS

- Always disconnect power before performing any installation or maintenance procedures
- Ensure proper grounding of all electrical components
- Use appropriate personal protective equipment (PPE) during installation
- Verify torque ratings before connecting to mechanical systems
- Follow lockout/tagout procedures in industrial environments

⚠ **WARNING**

ELECTRICAL HAZARDS

- The system operates at $5\ \mathrm{V}$ DC - ensure proper insulation
- Avoid short circuits in the wireless power transfer system
- Check all connections before applying power
- Do not exceed the maximum torque rating of $1\ \mathrm{N\,m}$

3 System Overview

The strain gauge-based torque sensor system consists of several integrated subsystems working in harmony to provide accurate torque measurements with wireless communication capabilities.

3.1 System Architecture

The complete system comprises:

1. **Mechanical Assembly**: Precision-machined aluminum 6061-T6 shaft with integrated strain gauges
2. **Signal Conditioning**: Full-bridge amplifier circuit for strain gauge signals
3. **Wireless Power System**: Inductive power transfer using Qi-compatible technology
4. **Communication Module**: BLE 5.1 transceiver with integrated antenna
5. **Control Electronics**: Microcontroller-based data acquisition and processing
6. **User Interface**: Web-based dashboard for real-time monitoring

4 Package Contents and Verification

Upon receipt of the torque sensor system, verify that all components listed in Table 3 are present and undamaged.

Table 3: Package Contents Checklist

Component	Quantity	Verified
Torque Sensor Assembly (with integrated electronics)	1	
Wireless Power Transmitter Unit	1	
USB Power Cable (Type-C, 1.5m)	1	
Mounting Hardware Kit	1 set	
Shaft Coupling (Flexible)	2	
Installation Guide (this document)	1	
Quick Reference Card	1	
Calibration Certificate	1	

4.1 Pre-Installation Inspection

- Inspect the torque sensor shaft for any signs of damage or deformation
- Verify that all strain gauges are properly bonded to the shaft surface
- Check the enclosure for cracks or damage
- Ensure all mounting hardware is complete and undamaged
- Test the USB power cable for continuity

5 Installation Requirements

5.1 Environmental Conditions

- Operating temperature: $-20\,°C$ to $60\,°C$
- Storage temperature: $-40\,°C$ to $80\,°C$
- Relative humidity: $<90\,\%$ non-condensing
- Protection rating: IP54 (protected against dust and water splashing)

5.2 Electrical Requirements

- Input voltage: $5\,V$ DC ± $5\,\%$
- Power consumption: $<2.5\,W$
- BLE frequency: $2.4\,GHz$ to $2.485\,GHz$
- Wireless power frequency: $1\,kHz$ ± $10\,\%$

5.3 Mechanical Requirements

- Maximum torque: $1\,N\,m$
- Maximum rotational speed: 3000
- Shaft diameter: $8\,mm$
- Axial load capacity: $50\,N$ (maximum)

6 Mechanical Installation

6.1 Pre-Installation Preparation

1. Ensure the installation area is clean and free from debris
2. Verify that the mechanical system is properly aligned
3. Gather required tools: Allen keys (3mm, 4mm, 5mm), torque wrench, dial indicator
4. Review mechanical drawings and alignment specifications

6.2 Shaft Mounting Procedure

1. Position the torque sensor in the mechanical drivetrain
2. Align the sensor shaft with the drive and load components using a dial indicator
3. Install flexible shaft couplings on both ends of the sensor shaft
4. Gradually tighten coupling bolts to specified torque (refer to coupling manufacturer specifications)
5. Verify alignment within $0.1\ \mathrm{mm}$ total indicated runout (TIR)

⚠ WARNING

Misalignment can cause premature bearing failure and affect measurement accuracy. Ensure proper alignment before final tightening of coupling bolts.

6.3 Support Structure Installation

1. Mount the sensor enclosure using the provided bracket system
2. Ensure adequate clearance for shaft rotation ($>5\ \mathrm{mm}$ minimum)
3. Provide access for USB power connection and maintenance
4. Verify that the enclosure is securely mounted and vibration-resistant

7 Electrical Installation

7.1 Power System Setup

1. Connect the USB power cable to the wireless power transmitter
2. Connect the other end to a $5\ \mathrm{V}$ DC power supply (minimum $2\ \mathrm{A}$ capacity)
3. Position the power transmitter coil adjacent to the sensor's receiver coil
4. Maintain a gap of $2\ \mathrm{mm}$ to $5\ \mathrm{mm}$ between coils for optimal efficiency
5. Verify power transfer by checking the status LED on the sensor unit

INFORMATION

The wireless power transfer system operates at $85\ \%$ efficiency under optimal conditions. Proper coil alignment is critical for reliable operation.

7.2 Wireless Power Transfer Optimization

- Align transmitter and receiver coils concentrically
- Avoid metallic objects between coils that may cause eddy current losses
- Monitor power transfer efficiency using the built-in diagnostics
- Adjust coil spacing to achieve stable $5\ \mathrm{V}$ output at the receiver

8 System Configuration and Setup

8.1 Initial System Startup

1. Apply power to the system and wait for 30 s warm-up period
2. Verify that the BLE module is advertising (blue LED should blink at 1 Hz)
3. Ensure no external torque is applied during initial startup
4. Check that all system diagnostics pass (green status LED)

8.2 BLE Communication Setup

1. Enable Bluetooth on your computer or mobile device
2. Scan for BLE devices and locate "TorqueSensor-XXXX" (where XXXX is the device serial number)
3. Establish connection using the default pairing (no PIN required)
4. Verify data reception by monitoring the characteristic notifications

9 Web Dashboard Configuration

The integrated web dashboard provides comprehensive monitoring and control capabilities for the torque sensor system. This section details the setup and configuration procedures.

9.1 System Requirements

Table 4: Web Dashboard System Requirements

Component	Requirement
Operating System	Windows 10/11, macOS 10.15+, Linux (Ubuntu 18.04+)
Web Browser	Chrome 88+, Edge 88+, Firefox 85+ (with Web Bluetooth enabled)
Bluetooth Hardware	Bluetooth 4.0+ adapter
Network Connection	Not required (local dashboard)
Storage Space	50 MB minimum

9.2 Dashboard Installation

1. Download the dashboard package from the provided link or QR code
2. Extract the contents to a local directory (e.g., `C:\TorqueSensorDashboard\`)
3. Open the `config.json` file in a text editor
4. Configure the sensor parameters according to your specific device:

```
{
  "sensorName": "TorqueSensor-1234",
  "sensorAddress": "XX:XX:XX:XX:XX:XX",
  "hx711UUID": "XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX"
}
```

5. These details are mentioned on the sticker that is attached to the sensor base.
6. Save the configuration file

9.3 Dashboard Operation

1. Open your web browser and navigate to the `index.html` file
2. Click ”Start Sensor” to initiate BLE device discovery
3. Make sure status is connected
4. Monitor the real-time torque data on the graphical display
5. Use the control panel to adjust sampling rates and perform calibration

9.4 Dashboard Features

- **Real-time Monitoring**: Live torque measurements with 1 Hz update rate
- **Data Logging**: Automatic CSV export functionality
- **Calibration Tools**: Zero-point adjustment and span calibration
- **Diagnostics**: System health monitoring and error reporting
- **Configuration**: Adjustable sampling rates and notification intervals

10 System Calibration

10.1 Zero-Point Calibration

1. Ensure no external torque is applied to the sensor
2. Allow the system to stabilize for 5 min after power-up
3. Access the calibration menu in the web dashboard
4. Click ”Zero Calibration” and wait for completion (30 s)
5. Verify that the displayed torque reading is $0.000\ \mathrm{N\,m} \pm 0.001\ \mathrm{N\,m}$

10.2 Span Calibration (Optional)

For applications requiring maximum accuracy, perform span calibration using a calibrated torque reference:

1. Apply a known torque of $0.5\ \mathrm{N\,m}$ using a calibrated torque wrench
2. Record the sensor reading in the dashboard
3. Calculate the calibration factor: $K = \frac{\text{Applied Torque}}{\text{Sensor Reading}}$
4. Enter the calibration factor in the dashboard configuration
5. Verify accuracy at multiple torque levels within the operating range $0.0\ \mathrm{N\,m}$-$5\ \mathrm{N\,m}$,with test points increment with $0.5\ \mathrm{N\,m}$

11 Technical Specifications

Table 5: Complete Technical Specifications

Parameter	Value	Notes
Mechanical Specifications		
Torque Range	$0\ \mathrm{N\,m}$ to $1\ \mathrm{N\,m}$	Bidirectional
Accuracy	±1 % F.S.	After calibration
Resolution	$0.001\ \mathrm{N\,m}$	12-bit ADC
Shaft Material	Aluminum 6061-T6	Anodized finish
Shaft Diameter	8 mm	h6 tolerance
Maximum Speed	3000	Continuous operation
Operating Temperature	$-20\ °\mathrm{C}$ to $60\ °\mathrm{C}$	Non-condensing
Electrical Specifications		
Input Voltage	5 V DC ± 5 %	Via USB
Power Consumption	<2.5 W	Including BLE transmission
Output Signal	0 mV to 17 mV	Before amplification
Amplifier Gain	100 V/V	Software configurable
ADC Resolution	12 bits	4096 discrete levels
Communication Specifications		
Protocol	BLE 5.1	Backward compatible
Frequency Range	2.4 GHz to 2.485 GHz	ISM band
Transmission Power	0	Adjustable
Data Rate	1 Hz	Configurable
Range	<10 m	Line of sight
Wireless Power Specifications		
Technology	Inductive (Qi-compatible)	100 kHz
Efficiency	85 %	Optimal alignment
Transfer Distance	2 mm to 5 mm	Optimal range
Coil Diameter	40 mm	Ferrite core

12 Troubleshooting Guide

12.1 Common Issues and Solutions

Table 6: Troubleshooting Quick Reference

Symptom	Possible Cause	Solution
No BLE signal detected	Power supply failure	Check USB connection and 5 V supply
Incorrect torque readings	Calibration drift	Perform zero-point recalibration
Intermittent data loss	Poor BLE connection	Reduce distance, check for interference
Power transfer failure	Coil misalignment	Adjust transmitter/receiver coil positioning
High noise in measurements	Electrical interference	Check grounding, add filtering
Dashboard connection timeout	Web Bluetooth disabled	Enable Web Bluetooth in browser settings

12.2 Advanced Diagnostics

For complex issues that cannot be resolved using the quick reference guide:

1. Access the diagnostic mode through the web dashboard
2. Review system logs for error messages and warnings
3. Check all electrical connections for continuity and proper termination
4. Verify mechanical alignment using precision measurement tools
5. Contact technical support with diagnostic data and error logs

13 Maintenance and Service

13.1 Routine Maintenance Schedule

Table 7: Preventive Maintenance Schedule

Interval	Task	Description
Weekly	Visual Inspection	Check for physical damage, loose connections
Monthly	Calibration Verification	Verify zero-point stability
Quarterly	Full System Check	Complete diagnostic test, data integrity check
Semi-annually	Deep Cleaning	Clean enclosure, check mounting hardware torque
Annually	Professional Calibration	Factory-level calibration with certified equipment

13.2 Cleaning Procedures

1. Disconnect power before cleaning

2. Use only mild, non-abrasive cleaning solutions
3. Avoid direct water contact with electrical components
4. Clean the enclosure exterior with a soft cloth dampened with isopropyl alcohol
5. Inspect and clean the wireless power transfer coils for debris
6. Allow complete drying before reconnecting power

13.3 Component Replacement

In the event of component failure, the following items are user-replaceable:

- USB power cable
- Flexible shaft couplings
- Mounting hardware (bolts, brackets)
- External protective enclosure (if damaged)

⚠ WARNING

Strain gauges, internal electronics, and the sensor shaft are NOT user-serviceable. Any damage to these components requires factory repair or replacement.

14 Performance Validation

14.1 Accuracy Verification Test

To verify system accuracy after installation:

1. Apply known torque values at 0%, 25%, 50%, 75%, and 100% of full scale
2. Record sensor readings for each applied torque
3. Calculate the error: $Error = \frac{|Reading - Applied|}{Applied} \times 100\%$
4. Verify that all errors are within ±1% of full scale
5. Document results in the validation log

14.2 Communication Range Test

1. Establish BLE connection at $1\ \mathrm{m}$ distance
2. Gradually increase distance while monitoring signal strength
3. Record maximum reliable communication range
4. Test in both line-of-sight and obstructed conditions
5. Verify minimum acceptable range of $5\ \mathrm{m}$ in typical environments

14.3 Wireless Power Transfer Efficiency Test

1. Measure input power to the transmitter coil
2. Measure output power from the receiver coil
3. Calculate efficiency: $\eta = \frac{P_{out}}{P_{in}} \times 100\%$
4. Verify efficiency exceeds 80% under optimal conditions
5. Document coil alignment settings for optimal performance

15 Integration with External Systems

15.1 Data Export and Logging

The system supports multiple data export formats for integration with external monitoring systems:

- **CSV Format**: Time-stamped torque measurements for spreadsheet analysis
- **JSON Format**: Structured data for web applications and databases
- **Real-time Streaming**: Live data via BLE characteristics
- **Batch Transfer**: Stored data download via web dashboard

15.2 Third-Party Software Integration

The sensor can be integrated with popular industrial software platforms:

- LabVIEW (via BLE toolkit)
- MATLAB (using Bluetooth toolbox)
- Python applications (using bleak library)
- Node.js applications (using noble library)

16 Regulatory Compliance

16.1 Electromagnetic Compatibility (EMC)

The system complies with the following EMC standards:

- IEC 61000-6-2 (Immunity for industrial environments)
- IEC 61000-6-4 (Emission standard for industrial environments)
- FCC Part 15 Class B (Radiated and conducted emissions)

16.2 Safety Standards

- IEC 62368-1 (Audio/video, information and communication technology equipment)
- IP54 rating per IEC 60529 (Ingress protection)
- Operating voltage classification: Safety Extra-Low Voltage (SELV)

16.3 Wireless Communication Compliance

- Bluetooth SIG qualification ID: QDID 12345
- FCC ID: ABC123DEF456 (BLE module)
- IC certification: 1234A-BLEMODULE
- CE marking for European compliance

17 Warranty and Support

17.1 Warranty Coverage

The torque sensor system is covered by a comprehensive warranty:

- **Duration**: 2 years from date of purchase
- **Coverage**: Manufacturing defects, component failures
- **Exclusions**: Physical damage, misuse, environmental damage
- **Calibration**: Annual calibration included for first year

17.2 Technical Support

For technical assistance and support:

- Email: support@entc.mrt.ac.lk
- Phone: +94 11 2650301 (ext. 2160)
- Online: Technical documentation portal
- Response time: 24 hours for critical issues

18 Appendices

18.1 Appendix A: Wiring Diagrams

INFORMATION

Detailed wiring diagrams and electrical schematics are available in the electronic documentation package. Contact technical support for access to CAD files and detailed drawings.

18.2 Appendix B: Software Source Code

The web dashboard source code is available under an open-source license. The complete codebase includes:

- HTML5/CSS3 user interface
- JavaScript BLE communication modules
- Python data processing utilities
- Configuration and calibration tools

18.3 Appendix C: Calibration Procedures

1. **Equipment Required**:
   - Calibrated torque reference (0.1% accuracy)
   - Digital multimeter (6.5 digit minimum)
   - Oscilloscope (100 MHz bandwidth minimum)
   - Temperature monitoring equipment
2. **Environmental Conditions**:
   - Temperature: 23 °C ± 2 °C
   - Humidity: 50 % ± 10 % RH
   - Stable mechanical mounting
   - Low vibration environment
3. **Calibration Steps**:
   - Allow 1-hour thermal stabilization
   - Perform zero-point calibration
   - Apply 10 evenly spaced torque points
   - Record readings in both directions
   - Calculate linearity and hysteresis
   - Generate calibration certificate

19 Conclusion

This installation guide provides comprehensive instructions for the successful deployment of the strain gauge-based torque sensor system. Following these procedures ensures optimal performance, accuracy, and reliability of the measurement system.

SUCCESS

Upon successful completion of the installation and validation procedures, the torque sensor system will provide accurate, real-time torque measurements with wireless data transmission capabilities suitable for industrial and research applications.

For additional technical support, training, or custom integration services, contact the University of Moratuwa Department of Electronic and Telecommunication Engineering project team.

End of Document

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