Complete 5-Day AI/Digital Twin Training Program

Electronics & Instrumentation Engineering - Smart Factory Applications

Program Overview

Duration: 5 days, afternoon sessions only (1:00 PM - 4:00 PM)
Total Training Hours: 15 hours
Target Audience: Electronics & Instrumentation Engineering students
Focus Areas: Smart Factory, AI+IoT, Industry 5.0 applications

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Day 1: Foundations & Setup (1:00 PM - 4:00 PM)

Session 1.1: Introduction to Industry 5.0 & Smart Manufacturing (45 minutes)

Learning Objectives:

- Understand Industry 5.0 principles and human-centric automation
- Identify key technologies: AI, IoT, Digital Twins, Cyber-Physical Systems
- Learn instrumentation role in smart manufacturing

Content:

- **Industry Evolution (15 min):** From Industry 1.0 to 5.0
- **Smart Factory Architecture (15 min):** Sensors, PLCs, SCADA, MES, ERP integration
- **E&I Engineer Role (15 min):** Instrumentation, control systems, data acquisition

Hands-on Activity: Explore sample smart factory dashboard (pre-built demo)

Session 1.2: Development Environment Setup (45 minutes)

Technical Setup:

```
# Complete environment setup script
conda create -n smart_factory python=3.8
conda activate smart_factory
pip install streamlit plotly pandas numpy simpy tensorflow opencv-python scikit-learn
```

Tools Installation:

- Anaconda Navigator
- VS Code with Python extension
- Git for version control
- Streamlit for web apps

Verification: Run sample "Hello Smart Factory" app

Session 1.3: Digital Twin Concepts (45 minutes)

Theory (20 minutes):

- Digital Twin definition and components
- Real-time data synchronization
- Predictive modeling and simulation

Practical Demo (25 minutes):

- Live demonstration of PCB assembly line digital twin
- Explore sensor data flows
- Understand model-reality synchronization

Session 1.4: Quick Project - Simple Dashboard (45 minutes)

Implementation: Students create their first monitoring dashboard

- **Template Provided:** Basic sensor data visualization
- **Customization:** Add their own KPIs and alerts
- **Business Context:** Motor health monitoring

Deliverable: Working dashboard with real-time charts

Day 2: Predictive Analytics & AI (1:00 PM - 4:00 PM)

Session 2.1: Machine Learning for Manufacturing (45 minutes)

Core Concepts:

- Supervised vs Unsupervised learning in manufacturing
- Feature engineering from sensor data
- Model selection for different use cases

Manufacturing-Specific Applications:

- Predictive maintenance (classification & regression)
- Quality prediction (defect detection)
- Process optimization (parameter tuning)

Session 2.2: Hands-on ML Implementation (60 minutes)

Project: Predictive Maintenance System

```
# Sample implementation structure
class PredictiveMaintenanceSystem:
    def __init__(self):
        self.models = {
            'fault_classifier': self.build_classifier(),
            'rul_predictor': self.build_regressor(),
            'anomaly_detector': self.build_anomaly_model()
        }

    def extract_features(self, vibration_data):
        # Time domain features
        # Frequency domain features
        # Statistical features
        return features
```

Students Learn:

- Vibration analysis fundamentals
- Feature extraction from time-series data
- Model training and validation
- Real-time prediction implementation

Session 2.3: Computer Vision for Quality Control (60 minutes)

Implementation: Defect Detection System

- **Image Processing:** OpenCV basics for manufacturing
- **Deep Learning:** Transfer learning with pre-trained models
- **Real-time Classification:** Live camera feed processing

Business Application:

- PCB inspection automation
- Surface defect detection
- Component presence verification

Session 2.4: Integration & Testing (15 minutes)

System Integration:

- Connect ML models to dashboards
- Real-time data pipeline setup
- Performance monitoring

Day 3: Digital Twin Implementation (1:00 PM - 4:00 PM)

Session 3.1: Digital Twin Architecture (45 minutes)

Design Principles:

- Physical asset modeling
- Data synchronization strategies
- Real-time vs batch processing

- Edge vs cloud computing

PCB Assembly Line Case Study:

- Equipment modeling with SimPy
- Sensor integration patterns
- Data flow architecture

Session 3.2: Process Simulation Development (75 minutes)

Implementation: Complete digital twin of manufacturing process

```
class PCBAssemblyLine:
    def __init__(self, env):
        self.env = env
        self.stations = {
            'solder_paste': self.create_station('Solder Paste', 15),
            'pick_place': self.create_station('Pick & Place', 45),
            'reflow': self.create_station('Reflow Oven', 180),
            'inspection': self.create_station('AOI', 30)
        }

    def run_production(self, num_boards=100):
        # Complete production simulation
        # Real-time data generation
        # Equipment health modeling
```

Students Build:

- Multi-station production line simulation
- Equipment degradation models
- Quality control integration
- Energy consumption tracking

Session 3.3: Real-time Dashboard Creation (60 minutes)

Advanced Visualization:

- Multi-level dashboards (overview, detailed, diagnostic)
- Real-time KPI monitoring
- Alert and notification systems
- Historical trend analysis

Business Metrics:

- Overall Equipment Effectiveness (OEE)
- First Pass Yield (FPY)
- Mean Time Between Failures (MTBF)
- Cost per unit analysis

Day 4: Advanced Applications (1:00 PM - 4:00 PM)

Session 4.1: Energy Management Systems (45 minutes)

Implementation Focus:

- Real-time power monitoring
- Peak demand management
- Energy cost optimization
- Sustainability metrics

Technical Components:

- 3-phase power measurement
- Power quality analysis
- Load forecasting algorithms
- Demand response automation

Session 4.2: Student Project Implementation (90 minutes)

Individual Projects (Choose 1 from 10 options):

1. **Motor Health Monitor** - Vibration analysis with ML
2. **Process Digital Twin** - Chemical reactor simulation
3. **Quality Vision System** - Defect detection with deep learning
4. **Energy Optimization** - Smart power management
5. **Maintenance Scheduler** - AI-driven maintenance planning
6. **Process Optimizer** - Multi-variable optimization
7. **Anomaly Detection** - Multi-sensor fusion system
8. **Production Simulator** - Line balancing and optimization
9. **Smart Inventory** - RFID-based tracking system
10. **Sustainability Monitor** - Carbon footprint tracking

Each Project Includes:

- Pre-built template with working code
- Business case and ROI analysis
- Ready-to-use datasets
- Step-by-step implementation guide

Session 4.3: Testing & Validation (45 minutes)

Quality Assurance:

- Model validation techniques
- Performance benchmarking
- User acceptance testing
- System integration verification

Day 5: Integration & Presentation (1:00 PM - 4:00 PM)

Session 5.1: System Integration Workshop (60 minutes)

Integration Patterns:

- API development with FastAPI
- Database integration (SQLite for demo)

- Real-time data streaming
- Security and authentication basics

Deployment Options:

- Local deployment with Streamlit
- Cloud deployment considerations
- Edge computing scenarios
- Industrial IoT integration

Session 5.2: Project Presentations (90 minutes)

Student Presentations (10 minutes each):

- Problem statement and business case
- Technical implementation walkthrough
- Live demonstration
- ROI analysis and business impact
- Q&A session

Evaluation Criteria:

- Technical implementation quality
- Business understanding
- Presentation clarity
- Innovation and creativity

Session 5.3: Industry Connections & Next Steps (30 minutes)

Career Pathways:

- Industry 5.0 job opportunities
- Required skills and certifications
- Continuous learning resources
- Professional networking

Follow-up Resources:

- Advanced project templates
- Industry case studies
- Open-source contributions
- Internship opportunities

Complete Project Code Repository

Repository Structure:

```
ai_digital_twin_training/
├── docs/
│   ├── pitch.md
│   ├── 5_day_training_program.md
│   ├── main_demo_case_study.md
│   └── 10_student_projects_detailed.md
├── platform/
│   ├── .env.example
│   ├── requirements.txt
│   └── setup.py
├── projects/
│   ├── day1_dashboard/
│   ├── day2_ml_system/
│   ├── day3_digital_twin/
│   ├── day4_student_projects/
│   └── day5_integration/
├── datasets/
│   ├── sensor_data/
│   ├── images/
│   ├── process_data/
│   └── energy_data/
└── templates/
    ├── dashboard_template.py
    ├── ml_template.py
    ├── vision_template.py
    └── integration_template.py
```

Pre-configured Development Environment

- **Anaconda Environment:** All required packages pre-installed
- **VS Code Settings:** Optimized for Python development
- **Git Repository:** Version control and collaboration ready
- **Docker Containers:** Alternative deployment option

Ready-to-Use Datasets

- **Sensor Data:** 1 million data points from 50 sensors
- **Image Data:** 10,000 labeled images for quality inspection
- **Process Data:** 6 months of production data
- **Energy Data:** 1 year of power consumption profiles

Assessment & Certification

Daily Assessments:

- **Day 1:** Dashboard creation and basic visualization
- **Day 2:** ML model implementation and evaluation
- **Day 3:** Digital twin simulation and real-time monitoring
- **Day 4:** Individual project development
- **Day 5:** System integration and presentation

Final Project Evaluation:

Technical Implementation (40%):

- Code quality and modularity
- Functionality and performance
- Innovation and problem-solving

Business Understanding (30%):

- Problem definition and scope
- ROI analysis and business case
- Industry knowledge application

Presentation & Communication (30%):

- Technical presentation quality
- Live demonstration effectiveness
- Q&A handling and technical discussion

Certification Levels:

- **Bronze:** Completed all daily exercises
- **Silver:** Completed individual project with business case
- **Gold:** Exceptional project with industry-ready implementation
- **Platinum:** Additional contributions to open-source repository

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Industry Partnerships & Mentorship

Guest Speakers:

- **Day 1:** Industry 5.0 transformation leader
- **Day 3:** Digital twin implementation expert
- **Day 5:** Smart manufacturing consultant

Mentorship Program:

- Assigned industry mentors for advanced students
- Weekly follow-up sessions (optional)
- Internship placement assistance
- Career guidance and networking

Company Collaborations:

- Real-world problem statements
- Data sharing agreements (anonymized)
- Internship and job placement partnerships
- Continuous curriculum updates based on industry needs

Success Metrics & Expected Outcomes

Student Learning Outcomes:

- **Technical Skills:** Python programming, ML/AI implementation, data visualization
- **Domain Knowledge:** Smart manufacturing, digital twins, predictive analytics
- **Business Acumen:** ROI analysis, problem-solving, industry applications
- **Soft Skills:** Presentation, teamwork, technical communication

Program Success KPIs:

- **95%** student completion rate
- **90%** positive feedback rating
- **80%** students demonstrate working project
- **60%** students pursue advanced training or internships

Industry Impact:

- **Partner Companies:** 5+ industry collaborations established
- **Job Placements:** 40% of students receive internship offers
- **Curriculum Adoption:** 3+ universities implement similar programs
- **Open Source Contributions:** 50+ GitHub repository contributions

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Getting Started Checklist

For Instructors:

- [ ] Set up development environment on all student machines
- [ ] Download complete code repository and datasets
- [ ] Test all demo applications and templates
- [ ] Prepare industry guest speaker presentations
- [ ] Set up assessment rubrics and evaluation tools

For Students:

- [ ] Install Anaconda and required Python packages
- [ ] Clone training repository from GitHub
- [ ] Complete Day 1 environment verification
- [ ] Choose individual project for Day 4 implementation
- [ ] Prepare final presentation template

For Institutions:

- [ ] Ensure adequate computer lab resources
- [ ] Set up network access for cloud services (optional)
- [ ] Coordinate with industry partners for guest speakers
- [ ] Prepare certificates and assessment documentation
- [ ] Plan follow-up advanced training sessions

Continuous Improvement & Updates

This training program is designed as a living curriculum that evolves with industry needs and technological advances. Regular updates include:

- **Quarterly Content Reviews:** Update with latest industry trends
- **Annual Partner Feedback:** Incorporate industry partner suggestions
- **Student Feedback Integration:** Continuous improvement based on learner experience
- **Technology Updates:** Keep pace with AI/ML and IoT advances
- **New Project Templates:** Add emerging use cases and applications

Version: 1.0
Last Updated: January 2025
Next Review: March 2025

This comprehensive training program prepares Electronics & Instrumentation Engineering students for the Industry 5.0 transformation with hands-on experience in AI, digital twins, and smart manufacturing technologies. The forenoon-only format maximizes learning efficiency while providing practical, industry-relevant skills that directly translate to career opportunities.