SNS COLLEGE OF TECHNOLOGY

An Autonomous Institution

Coimbatore-35

Department of Electrical and Electronics Engineering

23EEE307 – Embedded System Design

III BE EEE/ VI SEMESTER

UNIT 1: Introduction to Embedded Systems

In-Circuit Emulator(ICE)

TECHNICAL OVERVIEW

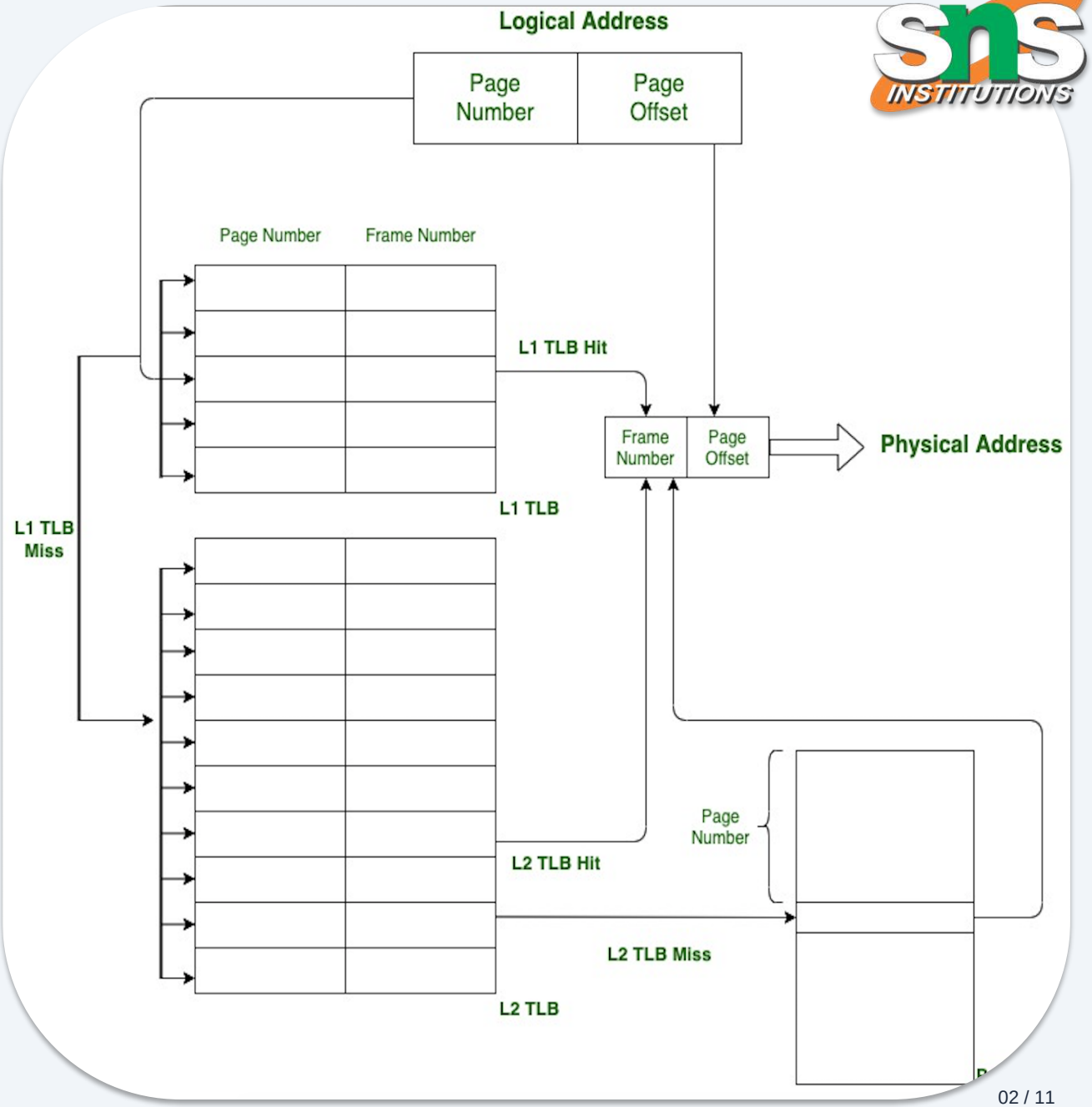
What is In-Circuit Emulator?

An ICE is a hardware device that replaces or augments the target microcontroller, providing real-time debugging, code tracing, and hardware access without altering system behavior.

CORE COMPONENTS

- Test Access Port for boundary scan
- Replaces target microcontroller
- Real-time execution tracking

Enables non-intrusive debugging with full visibility into CPU registers, memory, and peripherals while maintaining real-time performance.



The 5 Stages of Design Thinking

01

Empathize

Understand developer needs, debugging challenges, and system requirements

02

Define

Articulate ICE problem statements and technical specifications

03

Ideate

Generate innovative ICE solutions and debugging architectures

04

Prototype

Build tangible ICE hardware prototypes and interfaces

05

Test

Validate ICE performance through real-time debugging

Iterative Process: Stages may loop back based on testing feedback

STAGE 1

Empathize

Understanding embedded engineers' debugging needs, pain points, and real-world challenges when developing ICE solutions.

DEVELOPER PAIN POINTS

Time Constraints

Limited debugging windows in real-time systems

Complex Bugs

Race conditions, timing issues, hardware faults

Tool Limitations

Inadequate visibility into system state

Performance Impact

Debugging tools altering system behavior

User Research Approach

Conducting interviews with embedded engineers to understand real-world debugging workflows, time pressures, and technical constraints in ICE development.

Define

Articulating ICE problem statements and technical specifications based on empathy research.

Problem Statement Framework

"How might we design an ICE system that provides **zero-latency visibility** into target microcontroller state while maintaining **real-time performance** for critical embedded applications?"

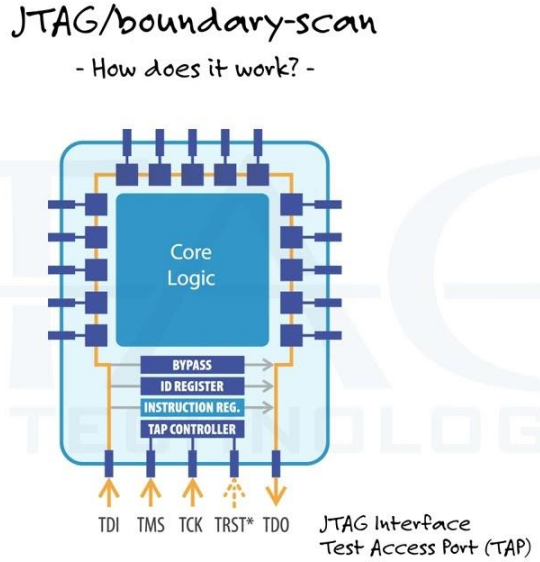
TECHNICAL SPECIFICATIONS

Debug Speed
Real-time non-intrusive execution

Memory Visibility
Full access to registers & RAM

Target Support
Multiple MCU architectures

Interface Compatibility
JTAG, SWD, and custom protocols



Clear definition prevents scope creep and ensures ICE solutions address actual embedded debugging requirements with measurable success criteria.

STAGE 3

Ideate

Generating innovative ICE solutions through creative brainstorming and systematic exploration of debugging architectures.

Creative Techniques

SCAMPER | Brainstorming | Mind Mapping | Six Thinking Hats

ICE ARCHITECTURE CONCEPTS

Hardware Trace Buffer
Non-intrusive execution history

Multi-Core Support
Simultaneous core debugging

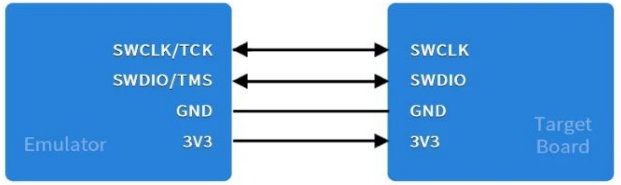
Real-Time Breakpoints
Zero-latency trigger points

Hybrid Emulation
Software + Hardware debugging

PIN CONNECTIONS

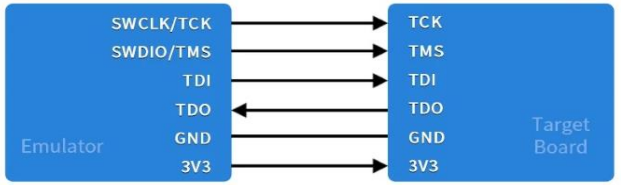
Support SWD interface

Mainstream PC debugging software, including Keil, IAR, OpenOCD and MounRiver Studio, can be debugged and downloaded online using SWD interface.



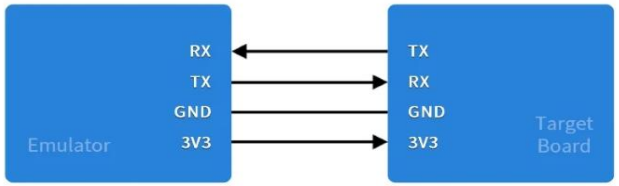
Support JTAG interface

4-wire connection (ARM, TCK, TDI and TDO) is used to debug and download ARM series chips online with TDO software.



Support USB to TTL serial port

The simulation debugger has a serial port, which is convenient for debugging and output.



STAGE 4

Prototype

Building tangible ICE hardware prototypes to validate design decisions and functionality in real embedded debugging scenarios.

PROTOTYPING PHASES

Emulation Core Design
FPGA-based MCU replacement

Trace Buffer Implementation
High-speed capture memory

JTAG TAP Controller
Boundary scan interface

Probe & Connector Design
Adapters for various MCUs

Iterative Prototyping

From breadboard concepts to PCB production, rapid iteration enables validation of ICE functionality, timing accuracy, and compatibility with target microcontrollers.

STAGE 5

Test

Validating ICE performance through comprehensive real-time debugging tests to ensure reliability, accuracy, and system compatibility.

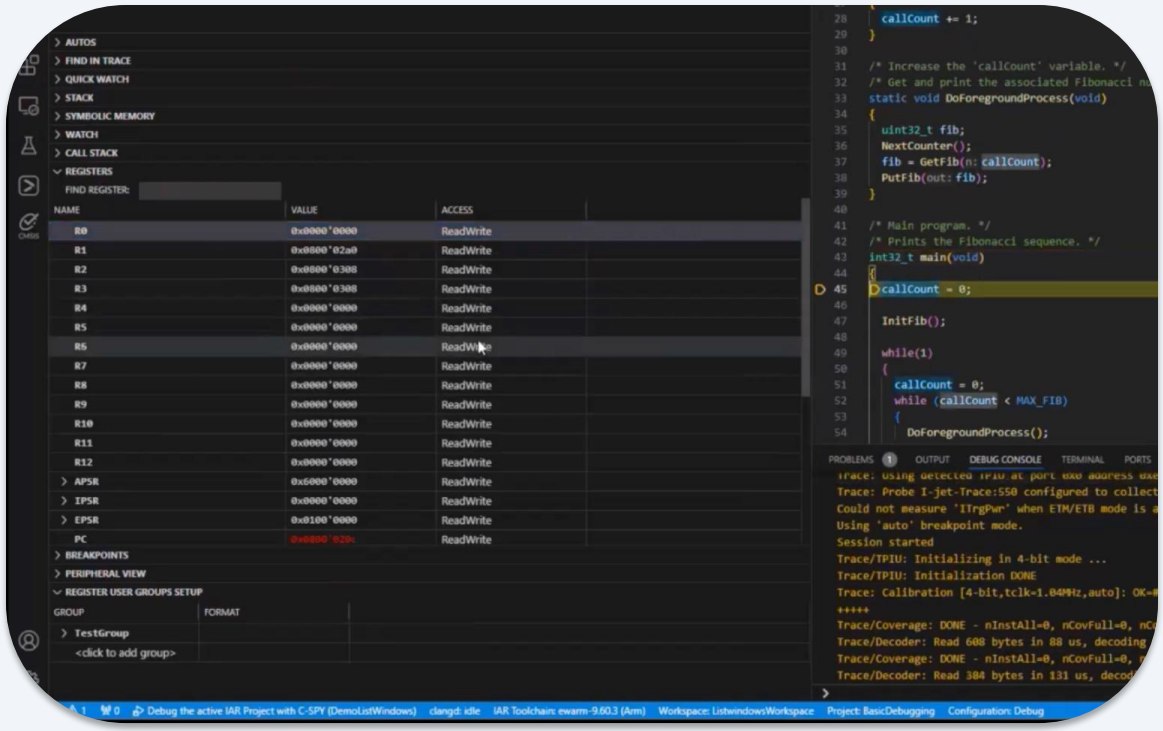
VALIDATION PHASES

Breakpoint Accuracy
Zero-intrusion trigger points

Trace Buffer Testing
Execution history integrity

Real-Time Performance
Timing accuracy verification

Multi-Core Debugging
Simultaneous core validation



Comprehensive Validation

Test against known debugging scenarios, edge cases, and stress conditions to ensure ICE meets all embedded debugging requirements with measurable success criteria.

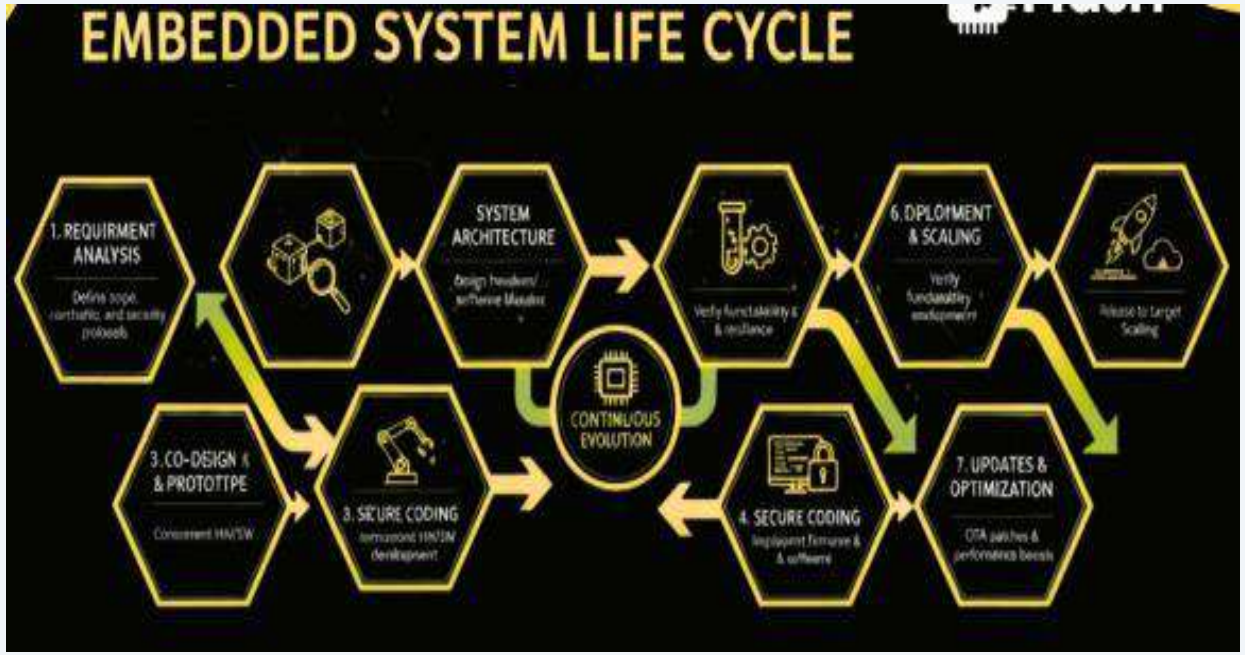
Practical application of 5-stage framework throughout embedded system debugging lifecycle.

Real-World Implementation

Automotive ECU debugging: Applied empathize to understand timing constraints, defined real-time requirements, ideated hybrid ICE solutions, prototyped FPGA-based emulator, and validated with 100+ test scenarios.

INTEGRATED DEVELOPMENT PROCESS

1. **Empathize**
   Interview engineers • Analyze debug logs
2. **Define**
   Problem statement • Technical specs
3. **Ideate**
   Architecture concepts • Trade-off analysis
4. **Prototype**
   Hardware build • Interface development
5. **Test**
   Validation • Performance optimization

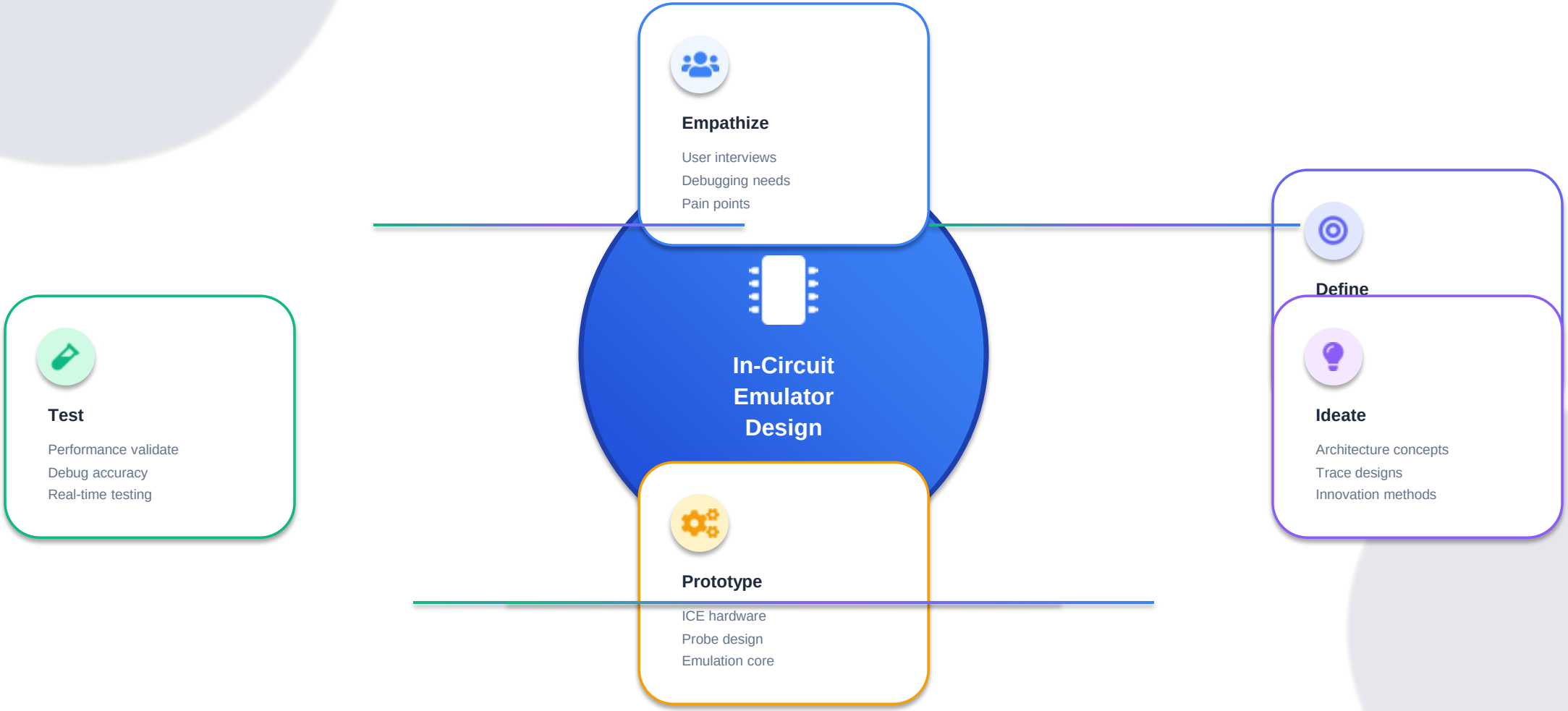


Continuous Iteration

Design thinking is not linear. Feedback from testing informs new empathy needs, creating an iterative cycle that drives continuous ICE improvement.

VISUAL INTEGRATION

Mindmap: 5 Stages in ICE Design



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JTAG Technologies - jtag.com

Microchip Technology - microchip.com

ARM Developer - developer.arm.com

NVIDIA Embedded - developer.nvidia.com

Online Resources

Embedded Systems Design Courses - Coursera, edX

JTAG Boundary Scan Documentation - IEEE Std 1149.1

In-Circuit Emulator Tutorials - YouTube Channels

Embedded Debugging Tools - GitHub Repositories

Design Thinking Resources - Stanford d.school