JTAG Security and Trust

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Introduction to Hardware Security & Trust
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Agenda

- Introduction to JTAG
- High-Level JTAG Exploits
- Popular JTAG Exploits
- Security Options
JTAG Introduction

- ‘‘JTAG’’ refers to IEEE Std. 1149.1, Standard Test Access Port and Boundary Scan Architecture

- IEEE Std. 1532, Boundary-Scan-Based In-System Configuration of Programmable Devices
Goals/Benefits of JTAG

- Low Cost
- Inter-circuit testing without need of physical test-probes
- Increased fault detection coverage
- Lower test time
Physical Components

- **TAP**
  - Test Access Port
  - Interprets JTAG protocol
  - Controlled by TMS signal

- **BSR**
  - Boundary Scan Registers
  - Between module and TAP
JTAG Control

- TDO
  - Test Data Output
- TDI
  - Test Data Input
- TMS
  - Test Mode Select
- TCK
  - Test Clock
- TRST
  - Resets TAP Controller
JTAG Modes

- **Bypass**
  - Connects TDI to TDO
  - One cycle delay

- **ExTest**
  - Asserts data on output pins

- **InTest**
  - Asserts data on input pins
  - Reads data from output pins

Diagram:

- Standard computer with JTAG interface
- TDO
- TMS
- TCK
- TRST
- TDI
- Device 1
- Device 2
- Device 4
- Device 5
- Device 3
JTAG Overview

- JTAG Benefits
  - Low Cost
  - Ease of testing

- Physical Components
  - TAP, BSR

- JTAG Pins
  - TDI, TDO, TMS, TCK, TRST

- JTAG Modes
  - Bypass, ExTest, InTest
High-Level JTAG Exploits

- Sniff TDI/TDO signals
- Modify TDI/TDO signals
- Control TMS and TCK signals
Sniff TDI/TDO Signals

- Used to intercept secrets being sent to or from a chip
- Preceding or chip after victim chip behaves differently during bypass to intercept message
Can modify Test Vectors and Test Responses

Can be used to fake correct or false tests

Attacker can either be upstream or downstream of victim based on attack

Modify TDI/TDO Signals
For many exploits, TMS and TCK signals need to be controlled.

Attacker needs to be able to overpower the signal sent by TAP.

Attacking device needs to be able to force TMS and TCK above or below logic threshold voltage.

Can be done by combining lines to make a more powerful driver or using multiple attackers to overcome TMS and TCK signals.
Xbox 360 Exploit

- Used to override Microsoft security features
- Allows homebrew code to be run, installation of HD, game modification, ripping of games
- JTAG is used to extract secret keys needed to perform exploits and to change programming
Security Options

- Buffers in the JTAG Chain

- JTAG system connected in “Star” pattern instead of being chained (Separate TMS and TCK)

- Encryption/Authentication for JTAG use
  - Most of the research in JTAG security would be classified under this
  - Although it would provide much better protection, like all security hardware, increases cost and space.
Challenge, Response

- Requires PUF or randomly burned fuses
- Requires Set_Challenge and Get_Response instructions in JTAG implementation
- A Challenge input is given to the JTAG module, and the module will hash this with the value of its fuses to create the response
- Only a known, trusted module will give a correct response
- So, can be determined if modules are trusted or not
Public/Private Key Authentication

- Tester/Updater is required to have a certificate of authentication signed by a designated third party.
- Authenticators public key is known to JTAG system
- Using the known public key, the JTAG system can decrypt the certificate and determine whether the tester/updater is trusted
- Trusted testers/updaters are allowed access to JTAG system, un-trusted are blocked
User Permissions

- A user permission level, $i$, allows them access to instructions with a level less than $i$.
- Requires extra hardware to authenticate user and set permission level, and to save settings for what each permission level can and cannot do.
- Ex. In memory, a permission level is saved for each module in the JTAG system. When that module is trying to be accessed, the saved level is compared to the current permission level.
Removal/Destruction of JTAG

To completely defend against JTAG attacks, one thought is to remove the JTAG hardware all together
- Does not leave a way to in-field test
- Can use BIST for testing

Similarly to removal of JTAG, some companies use security fuses to disable JTAG before the hardware leaves the factory
- Can implement different levels of disabled JTAG use
Acknowledgments


