EEL 4744

Menu

- Debugging
  - >Why do we need to debug?
  - >When do we need to debug?
  - >How do we debug?
    - – Before/as we code
    - – After we code
  - >Common bugs

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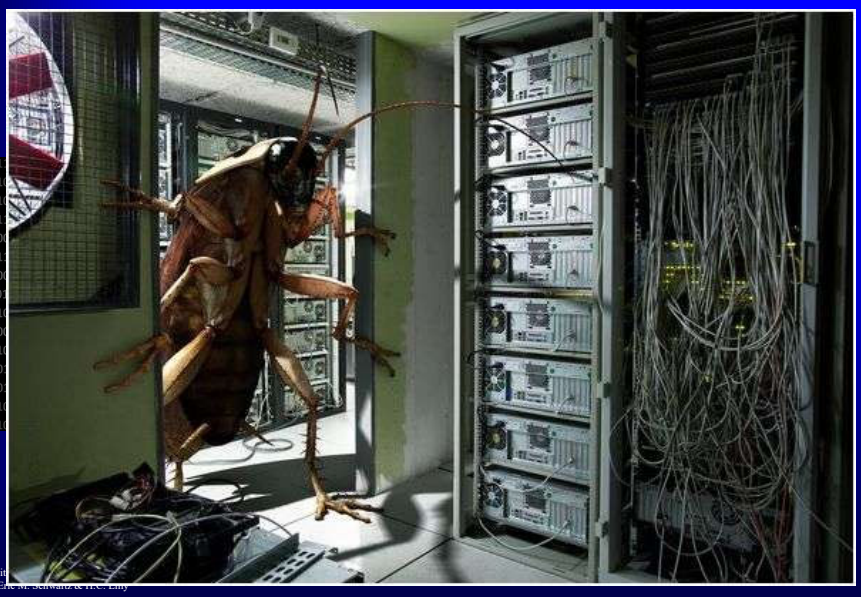
Debugging



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Software/Hardware Bug

- A **software bug** is an error or failure in a program
- Fixing bugs is called **debugging**
- Software bugs cost US economy
  - > In 2002, **$59 billion** = $ 59,000,000,000 Source
  - > In 2016, **$1.1 trillion** = $1,100,000,000,000 Source
  - > In 2020, **$2.1 trillion**! Source
  - > Estimate for 2021, **$6 trillion**! Source
- Grace Brewster Murray Hopper, in 1946 (at Harvard) had an early **electromechanical computer**
  - > It was not working
  - > She found a **bug** (a moth) inside
  - > She remove the bug, and it worked
    - – She **debugged** the computer
  - > She gets credit for the **BUG** in hardware and software

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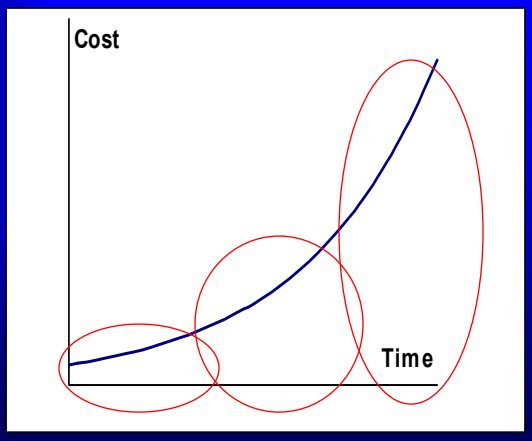
The Cost of Debugging

- Increases exponentially in time



Example:

```
int i,j;
for (;i++;i<50)
```

Cost:

80 hrs * $25/hr = $2000

with overhead, $4000

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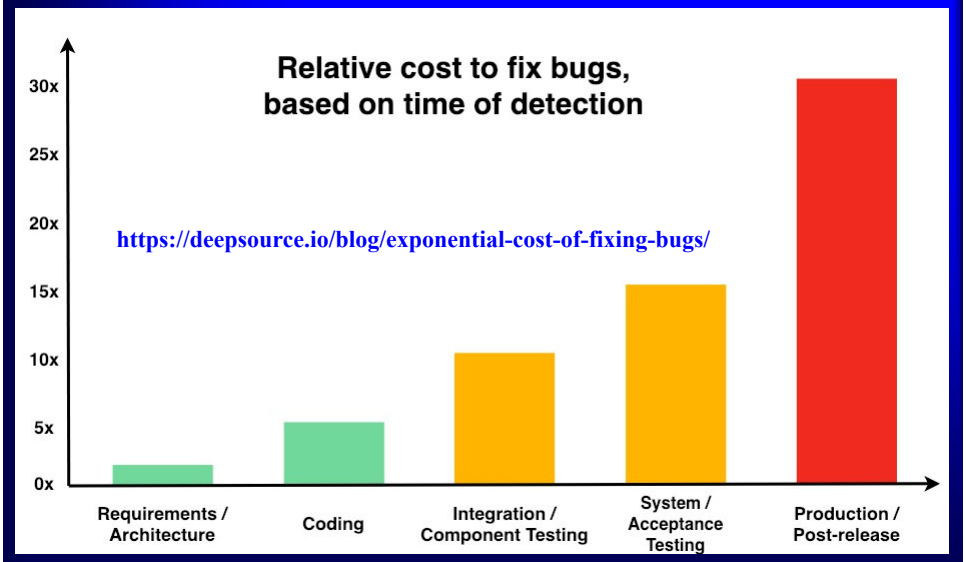
The Cost of Debugging



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When should we start debugging?

- Before we code/design (easiest)
- As we code/design
- After we code/design (hardest)

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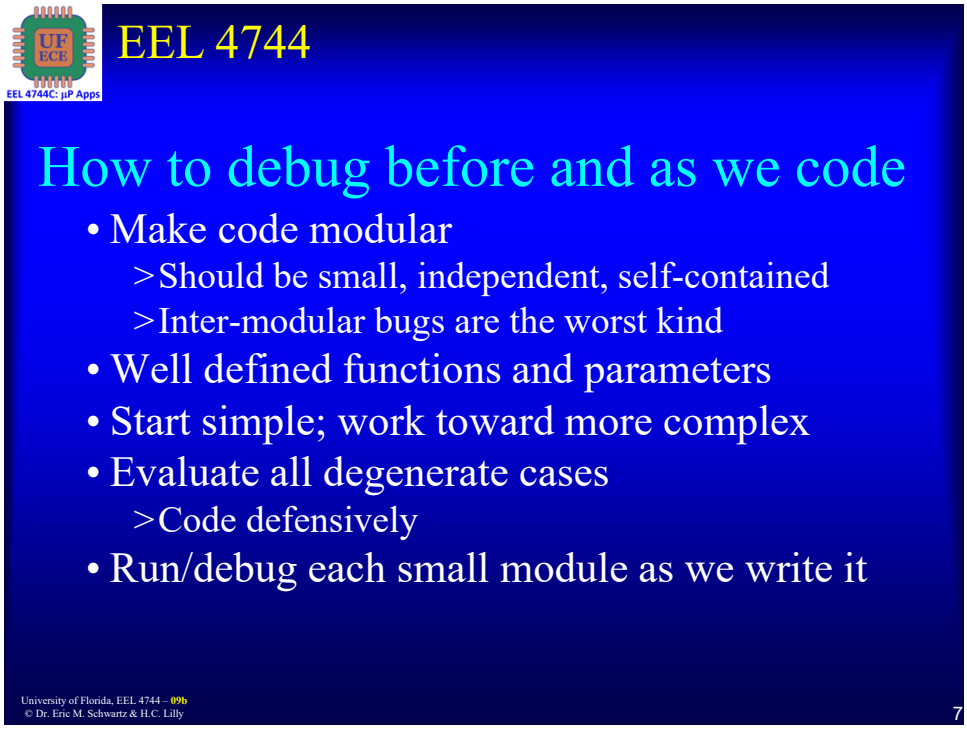
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How to debug before and as we code
• Make code modular
>Should be small, independent, self-contained
>Inter-modular bugs are the worst kind
• Well defined functions and parameters
• Start simple; work toward more complex
• Evaluate all degenerate cases
>Code defensively
• Run/debug each small module as we write it
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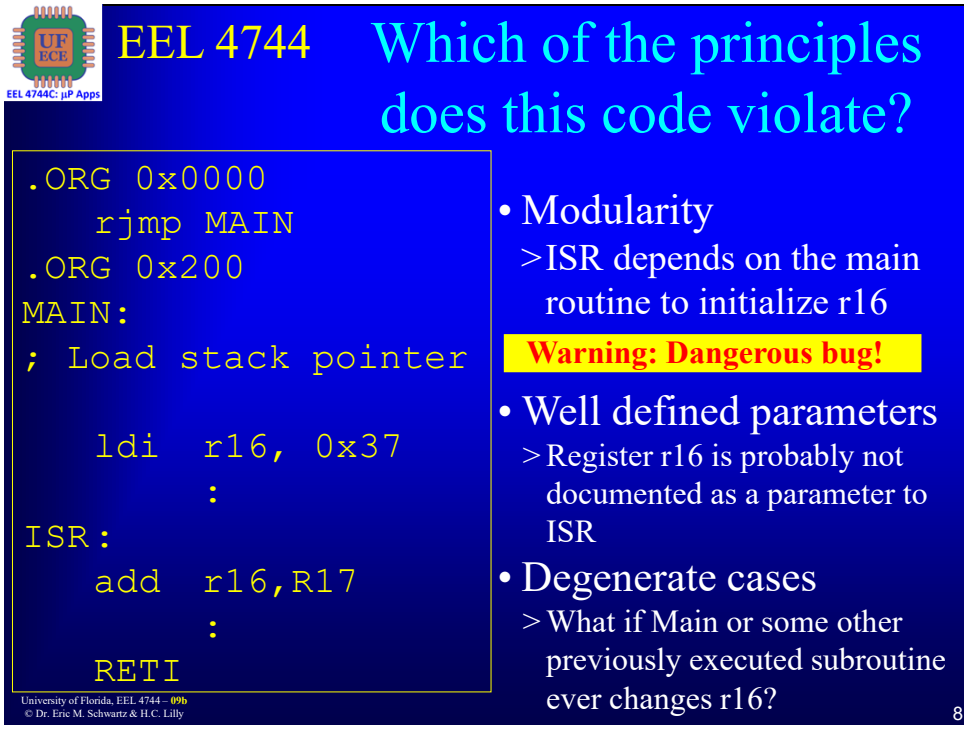
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Which of the principles does this code violate?
.ORG 0x0000
rjmp MAIN
.ORG 0x200
MAIN:
; Load stack pointer
ldi r16, 0x37
:
ISR:
add r16,R17
:
RETI
• Modularity
>ISR depends on the main routine to initialize r16
Warning: Dangerous bug!
• Well defined parameters
>Register r16 is probably not documented as a parameter to ISR
• Degenerate cases
>What if Main or some other previously executed subroutine ever changes r16?
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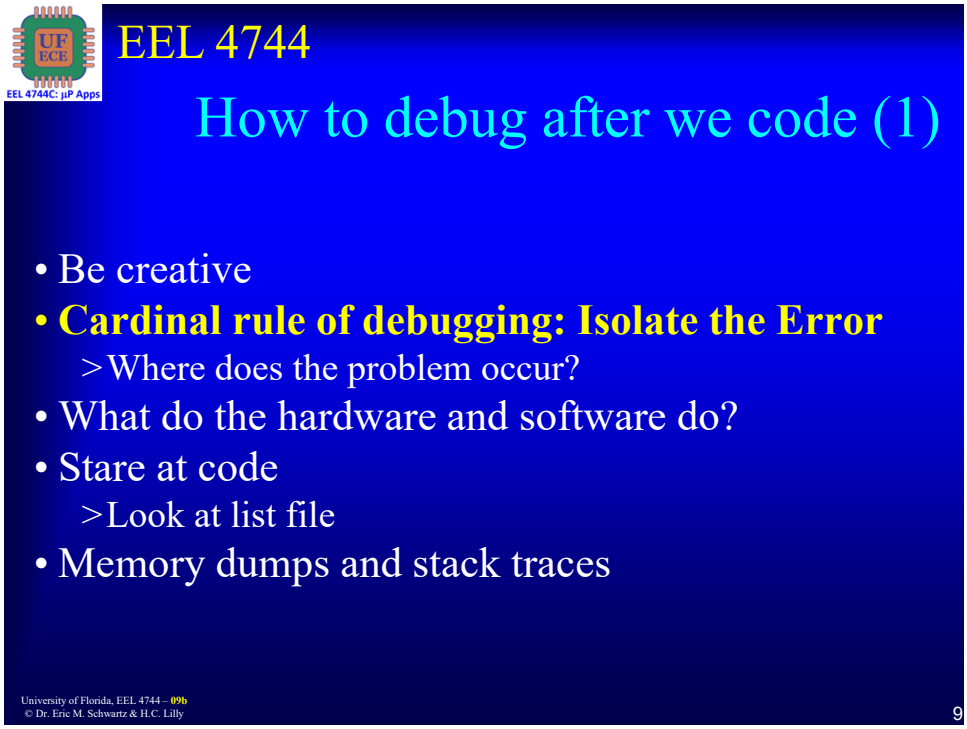
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How to debug after we code (1)
• Be creative
• Cardinal rule of debugging: Isolate the Error
>Where does the problem occur?
• What do the hardware and software do?
• Stare at code
>Look at list file
• Memory dumps and stack traces
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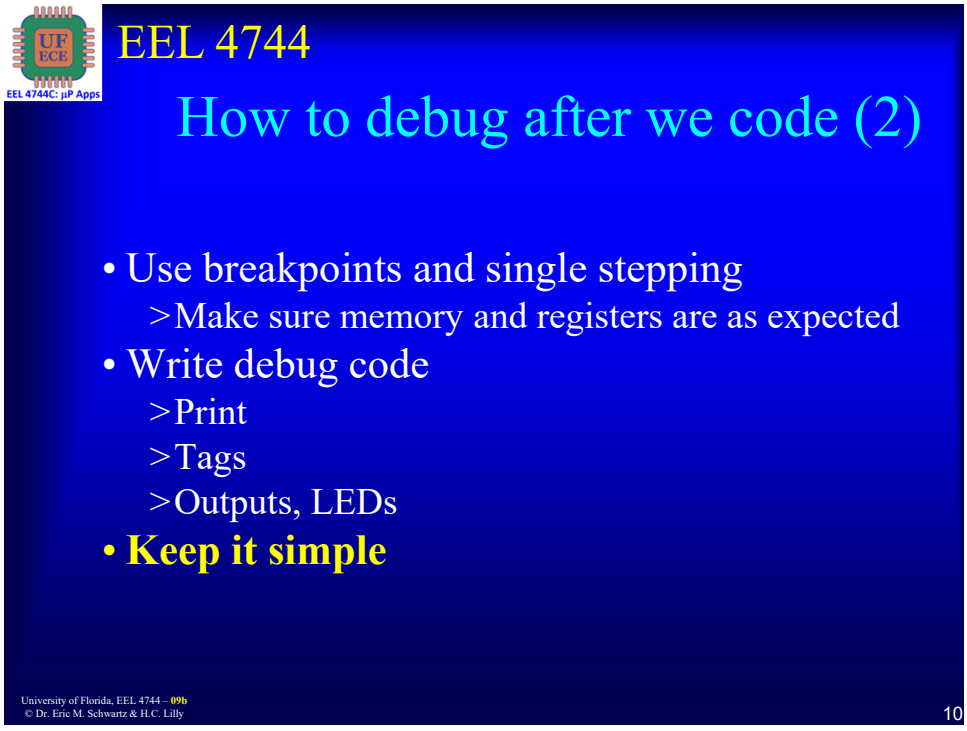
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How to debug after we code (2)
• Use breakpoints and single stepping
>Make sure memory and registers are as expected
• Write debug code
>Print
>Tags
>Outputs, LEDs
• Keep it simple
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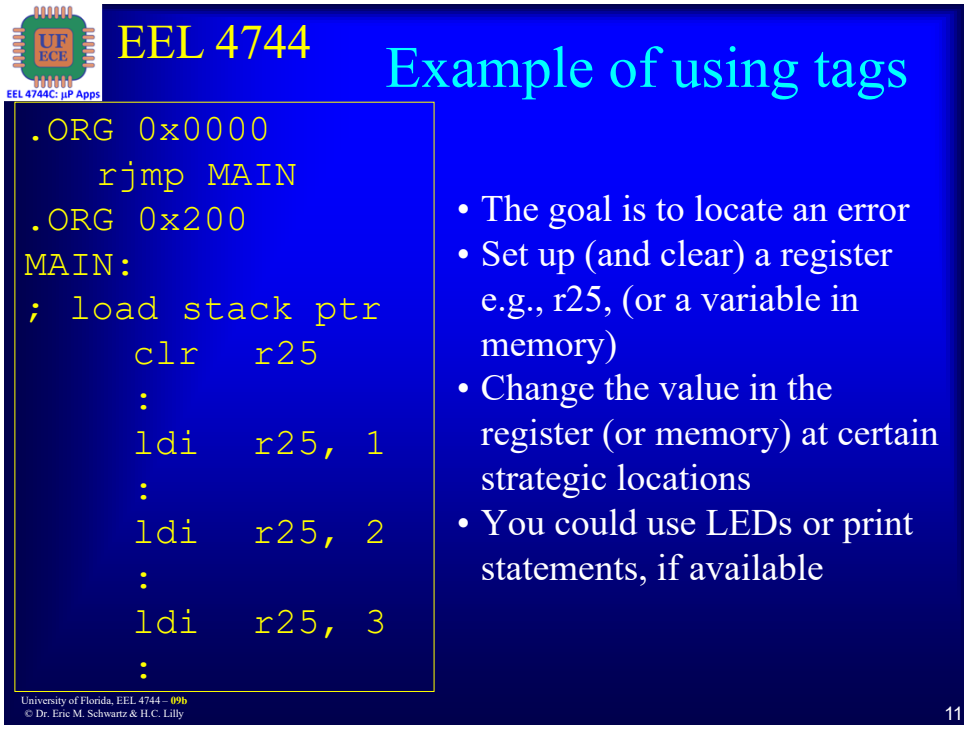
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EEL 4744C: µP Apps
Example of using tags
.ORG 0x0000
rjmp MAIN
.ORG 0x200
MAIN:
; load stack ptr
clr r25
:
ldi r25, 1
:
ldi r25, 2
:
ldi r25, 3
:
• The goal is to locate an error
• Set up (and clear) a register e.g., r25, (or a variable in memory)
• Change the value in the register (or memory) at certain strategic locations
• You could use LEDs or print statements, if available
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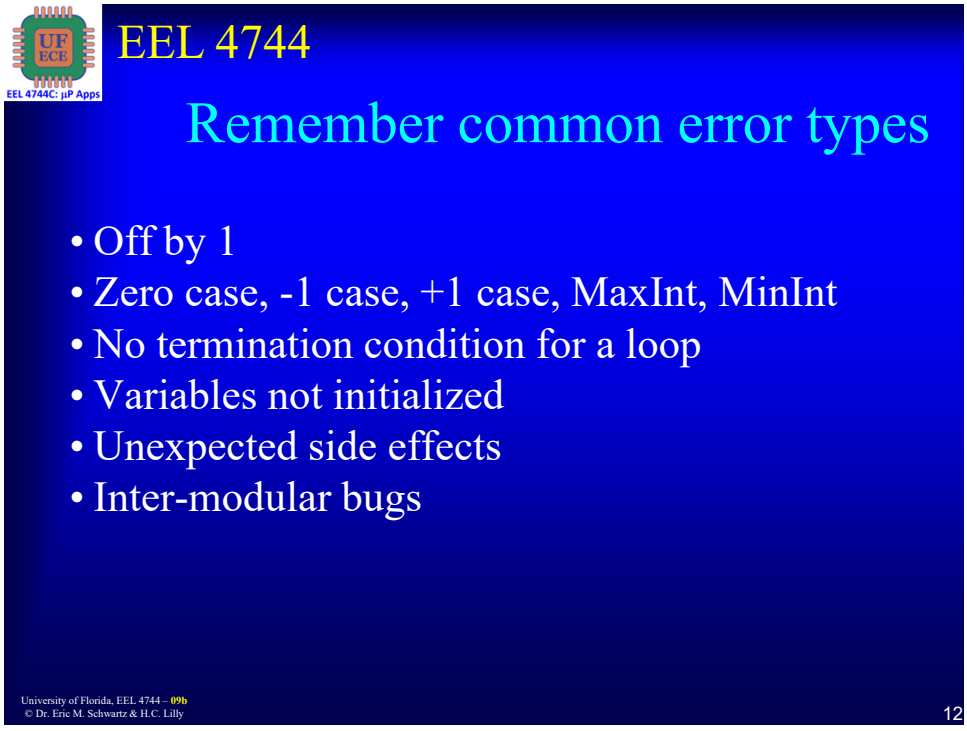
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Remember common error types
• Off by 1
• Zero case, -1 case, +1 case, MaxInt, MinInt
• No termination condition for a loop
• Variables not initialized
• Unexpected side effects
• Inter-modular bugs
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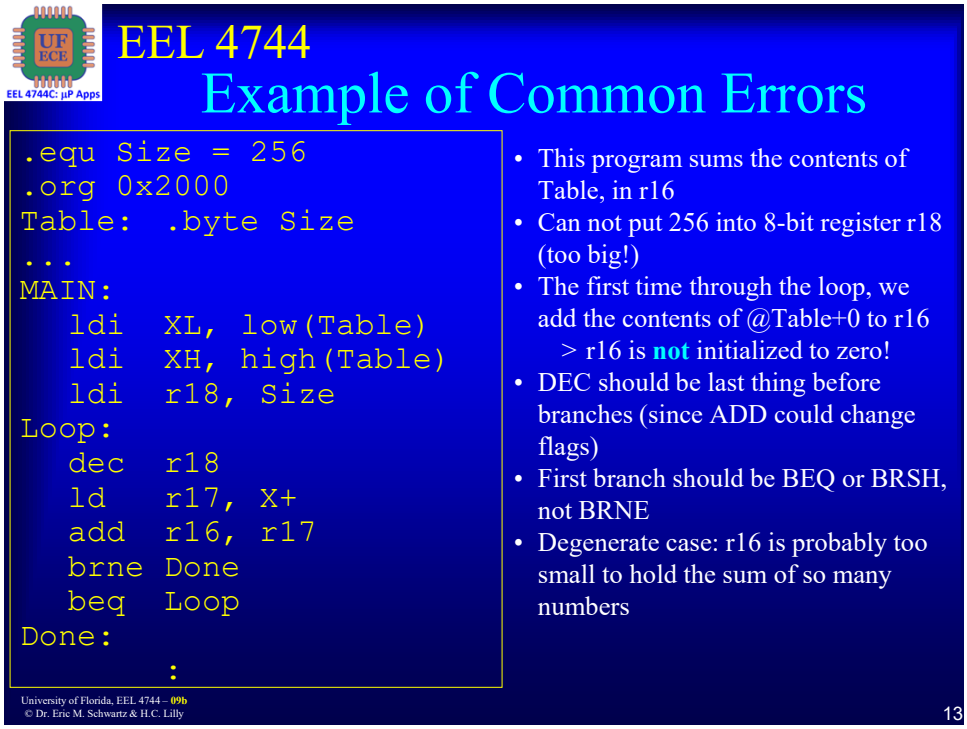
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Example of Common Errors
.equ Size = 256
.org 0x2000
Table: .byte Size
...
MAIN:
ldi XL, low(Table)
ldi XH, high(Table)
ldi r18, Size
Loop:
dec r18
ld r17, X+
add r16, r17
brne Done
beq Loop
Done:
:
• This program sums the contents of Table, in r16
• Can not put 256 into 8-bit register r18 (too big!)
• The first time through the loop, we add the contents of @Table+0 to r16
> r16 is not initialized to zero!
• DEC should be last thing before branches (since ADD could change flags)
• First branch should be BEQ or BRSH, not BRNE
• Degenerate case: r16 is probably too small to hold the sum of so many numbers
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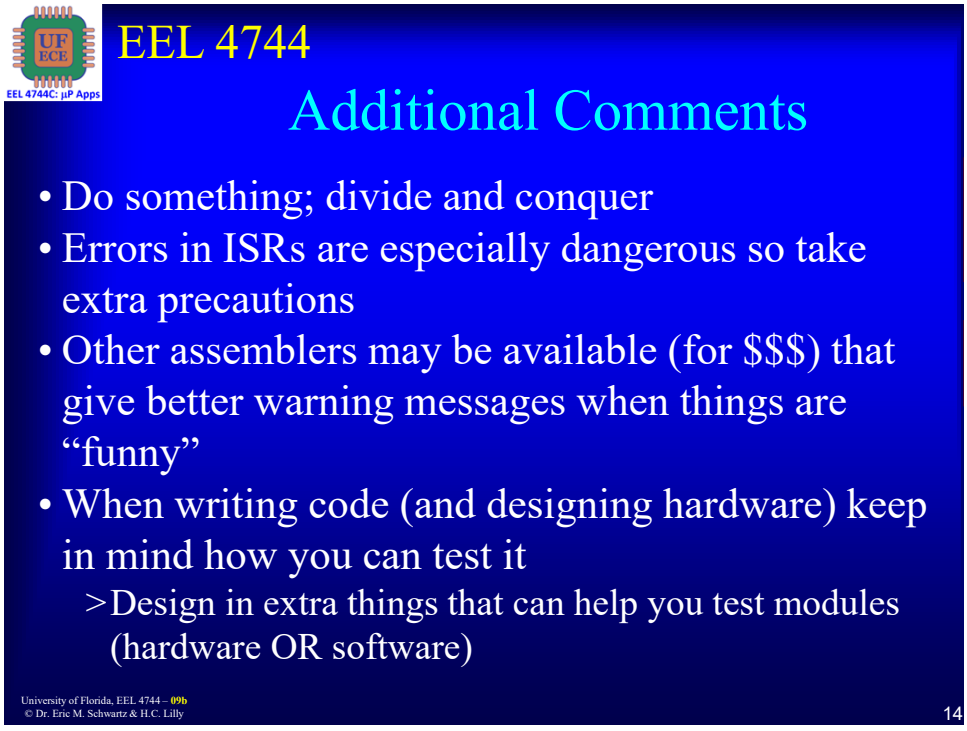
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Additional Comments
• Do something; divide and conquer
• Errors in ISRs are especially dangerous so take extra precautions
• Other assemblers may be available (for $$$) that give better warning messages when things are "funny"
• When writing code (and designing hardware) keep in mind how you can test it
>Design in extra things that can help you test modules (hardware OR software)
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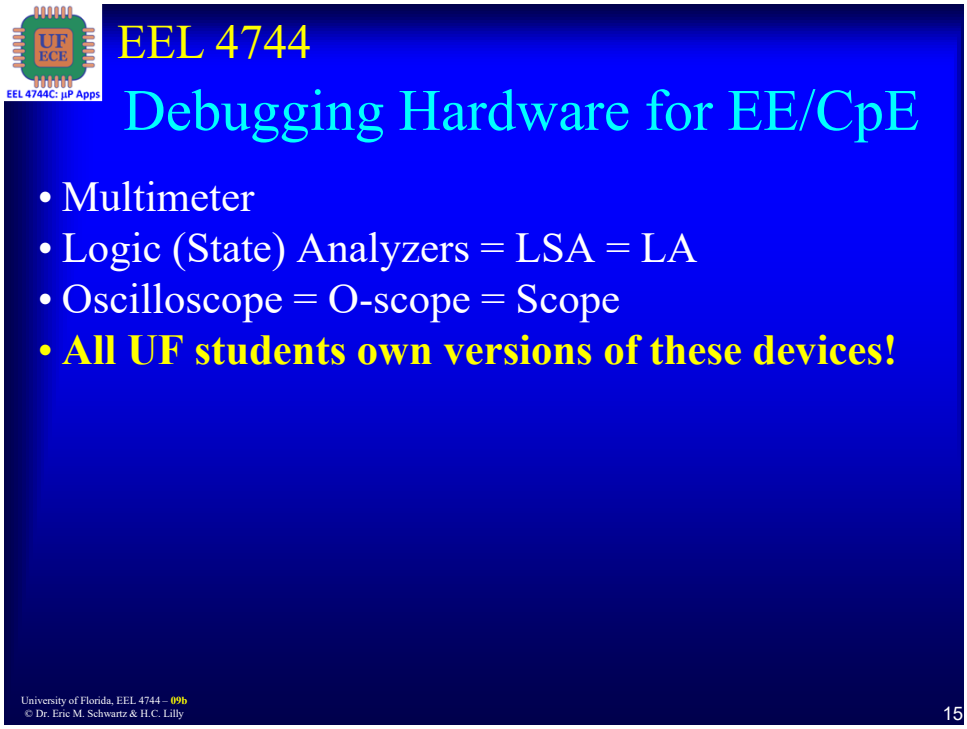
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Debugging Hardware for EE/CpE
• Multimeter
• Logic (State) Analyzers = LSA = LA
• Oscilloscope = O-scope = Scope
• All UF students own versions of these devices!
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Multimeter
• Multimeter measures the following:
>Voltage and current (both AC and DC)
>Resistance
• The one on top cost less than $4.00
>Used to get one in 3701; now it 3111
• The one on the bottom costs ~$900.00
• These are used to measure a single signal at one time
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Logic (State) Analyzer

- Captures and displays multiple **digital** signals from a digital system as a function of time
- The time data can help us determine a design or program mistake
- LSA can use a **trigger** to look for specific combinations of signals (to see if they ever occur)
- Logic Analyzer can display from 1 to 256 signals, depending on the cost and complexity of the LSA
- For computer systems, they are often used to display **address bus**, **data bus**, and **control bus** values for hardware system debugging

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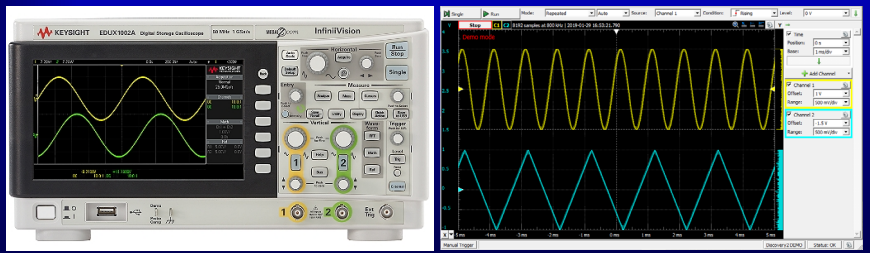
Oscilloscope

- An oscilloscope displays the voltage of a signal as a function of time
- An o-scope is used for non-digital signals
- Most o-scopes have only one, two, or four channels
  - > I.e., the number of signals that you can see at the same time
  - > The scope to the left shows two signal channels
  - > The figure on the right is the **output** of a two channel scope
    - – The top signal is a sinusoid waveform; the bottom is a triangle waveform



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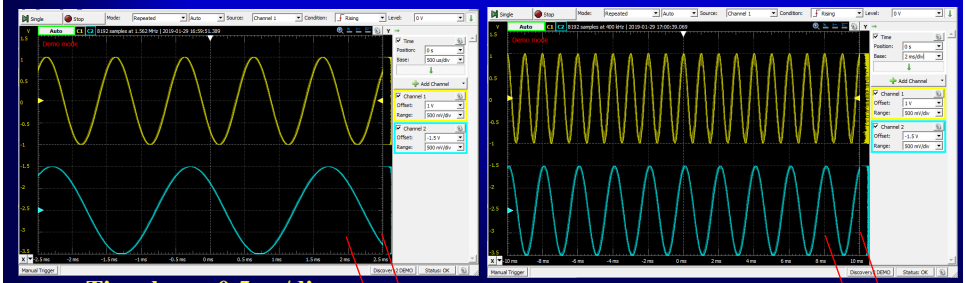
- The **horizontal (time) scale** and vertical (voltage) scale can be changed
  - > The second scope output shows the time scale change by a factor of 4



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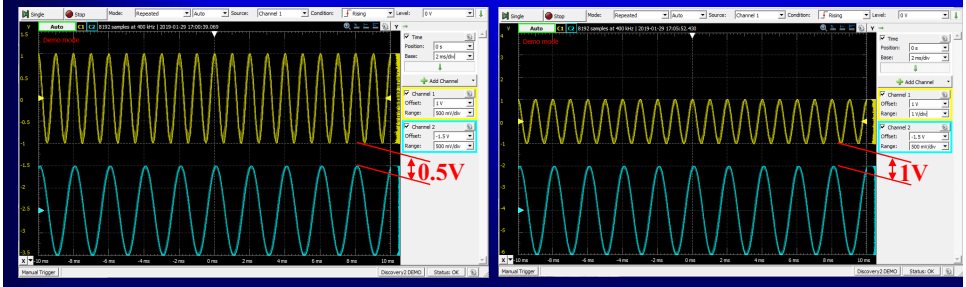
- A similar scaling of the **vertical (voltage)** can be accomplished
  - > The below figure on the right show the top signal voltage changed by a factor of 4



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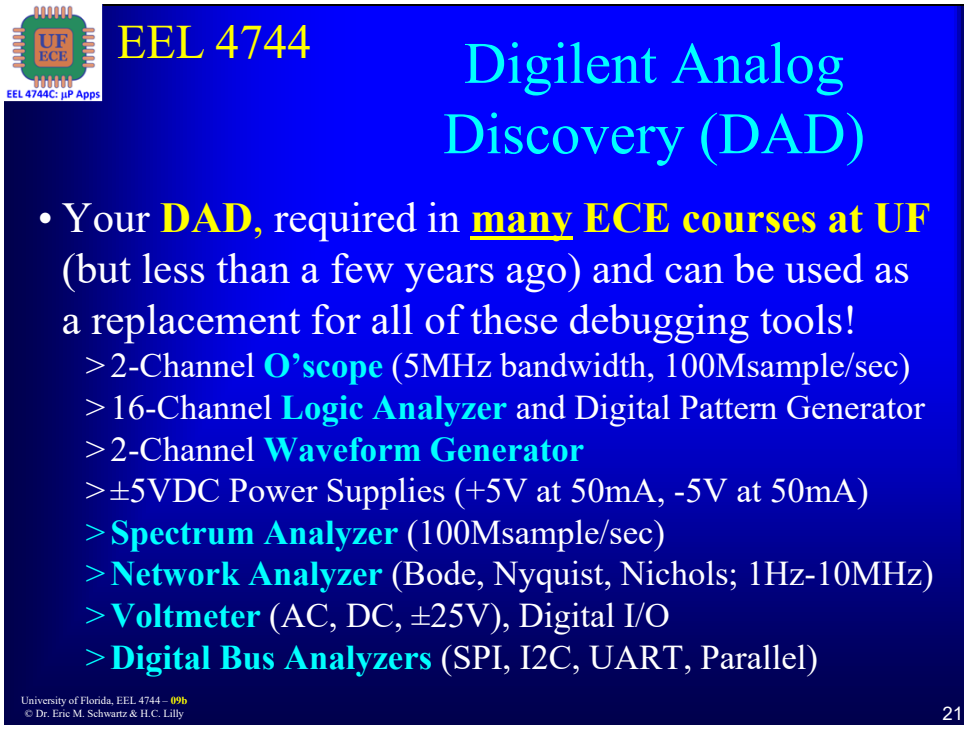
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Digilent Analog Discovery (DAD)
• Your DAD, required in many ECE courses at UF (but less than a few years ago) and can be used as a replacement for all of these debugging tools!
> 2-Channel O'scope (5MHz bandwidth, 100Msample/sec)
> 16-Channel Logic Analyzer and Digital Pattern Generator
> 2-Channel Waveform Generator
> ±5VDC Power Supplies (+5V at 50mA, -5V at 50mA)
> Spectrum Analyzer (100Msample/sec)
> Network Analyzer (Bode, Nyquist, Nichols; 1Hz-10MHz)
> Voltmeter (AC, DC, ±25V), Digital I/O
> Digital Bus Analyzers (SPI, I2C, UART, Parallel)
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The End!
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