11019 MPA

MPLAB® In-Circuit Debuggers for Advanced Users

Class Objective

- **Convey a picture of the MPLAB® Debug Tools the way the developers see them**
  - With emphasis on MPLAB ICD 2
- **Cover the topics that the developers wished the users knew**

Class Objective

- **Compare and Contrast the Debug Tools**
  - MPLAB® REAL ICE™ In-Circuit Emulator
  - MPLAB ICD 2
  - PICkit™ 2 Starter Kit

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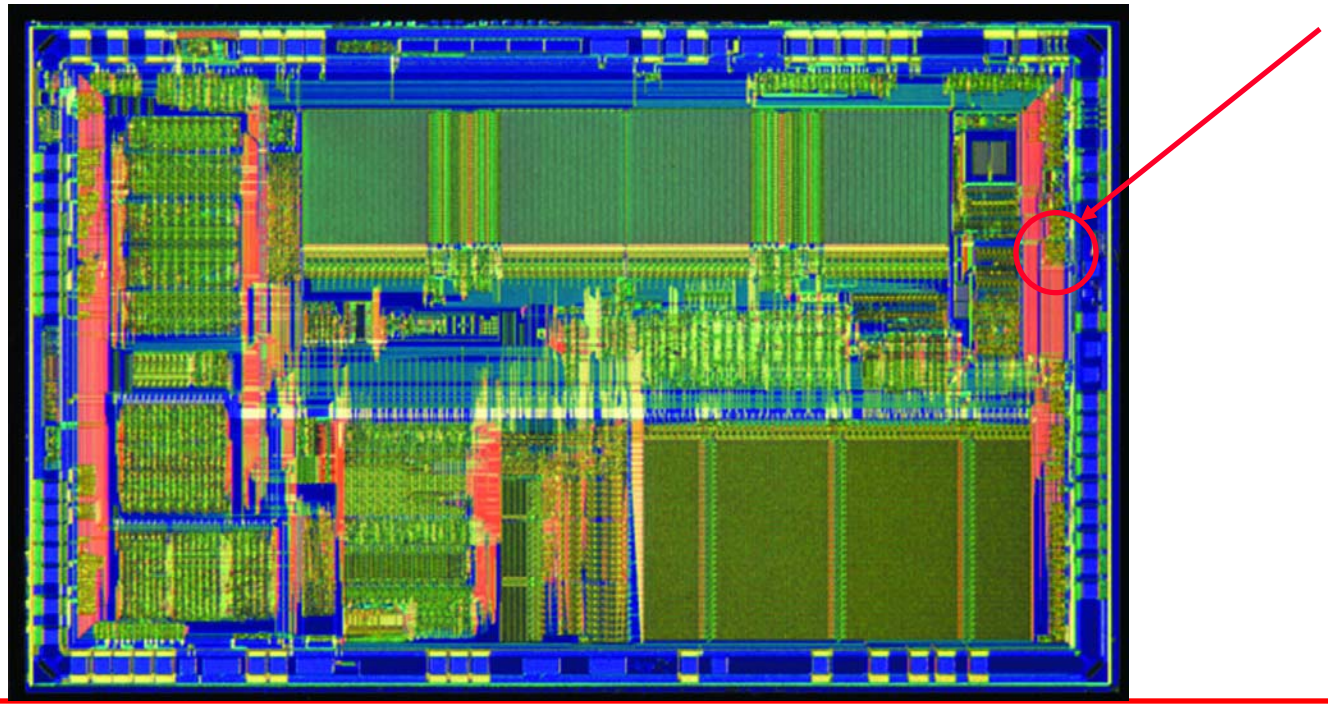
Agenda

- How the MPLAB® Debug Tools Work
- Consequences and Gotchas
- Advanced Breakpoints
- Comparing the Different Tools
- Odds and Ends

How the MPLAB® Debug Tools Work

How the MPLAB® Debug Tools Work

- It all starts with a special Background Debug Module (BDM) inserted into the silicon



How the MPLAB® Debug Tools Work

- The BDM provides a special Non-Maskable Interrupt (NMI) triggered on certain debugging events:
  - External Halt
  - Breakpoint Match
  - Single-Step Execution

- The chip runs in normal user mode until one of these debugging events occurs

How the MPLAB® Debug Tools Work

- When the debug event occurs, the silicon issues the debug NMI (called a Halt) and vectors to a known location
  - May or may not be in user's program memory space
  - The chip is said to be in the INBUG mode at this point
- The Debug Tool programs a special interrupt handler at this location known as a Debug Executive (DE)

How the MPLAB® Debug Tools Work

- The DE simply process commands from the Debug Tool until ordered to return to the user's program
  - Command set is simplistic:
    - Read/Write a register
    - Perform a single step
    - Return to user mode
- The DE often needs user resources to execute

How the MPLAB® Debug Tools Work

- Communications between the DE and Debug Tool are bit-banged through the ICDC and ICDD pins
  - Sometimes called PGC-PGD or RB6-RB7 or EMUC-EMUD
  - Usually the same pins as used for ICSP™ technology
  - The DE controls the bit-bang clock
  - Don’t use these pins in the user code
    - Will cause a HALT or skew the HALT handshake

How the MPLAB® Debug Tools Work

- While the silicon is in INBUG mode, certain SFRs become available which allow control of the BDM
  - These SFRs allow:
    - Specification of breakpoint conditions
    - Single step operation
    - Control of the ICDC and ICDD pins

How the MPLAB® Debug Tools Work

- The Debug Tool system is set up as a master/slave relationship
  - MPLAB® IDE initiates all communications with the Debug Tool
  - The Debug Tool initiates all communications with the DE
  - Simplifies system by not attempting to handle asynchronous bi-directional communications
    - More robust system would have used more user resources

How the MPLAB® Debug Tools Work

- In circuit debugging offers higher fidelity debugging than emulators and simulators
  - Use actual silicon in actual target environment
    - Actual power, clock and timing
  - Not necessarily the most powerful debugging
  - Some smaller parts break this paradigm

Consequences and Gotchas

Consequences and Gotchas

- INBUG, ICSP™ technology and User Modes
- Breakpoints
- Registers

Consequences and Gotchas

INBUG, ICSP™ technology and User Modes

Consequences and Gotchas

INBUG, ICSP™ technology and User Modes

- From the Debug Tool point of view, the target microcontroller can be in 1 of 4 states:
  - Reset : MCLR = V_{il} (boring)
  - ICSP : MCLR = V_{pp} (programming)
  - User : MCLR = V_{dd} (user code)
  - INBUG : MCLR = V_{dd} (debug executive)
- Reset is the default state; the Debug Tool will move the target to Reset whenever there is a problem
- MPLAB® REAL ICE™ In-Circuit Emulator defaults to a tri-state MCLR

Consequences and Gotchas

INBUG, ICSP™ technology and User Modes

- The Debug Tool can only read or write particular memories in specific modes
  - This is slowly changing in certain situations

	Program	File Reg	EEDATA	Config
Reset	-	-	-	-
ICSP	X	-	X	X
User	-	-	-	-
INBUG	-	X	-	-

Consequences and Gotchas

INBUG, ICSP™ technology and User Modes

- Occasionally the Debug Tool is asked to read or write memory in the wrong mode
  - We've eradicated most of these occurrences
  - ICD0157: Attempted target memory access using an invalid type and mode combination (Mem = %s) (Mode = %s) (Type = %s)
- DE could perform INBUG program memory access, but would grow in size to do so
  - For some devices (PIC24, dsPIC30, dsPIC33) we don't care
- *Switching modes causes a target reset*

Consequences and Gotchas

INBUG, ICSP™ technology and User Modes

- One of the most prevalent error messages is
  - ICD0083: Debug: Unable to enter debug mode.
- MCLR is at Vdd, but the Debug Tool is unable to establish communications with the DE

Consequences and Gotchas

INBUG, ICSP™ technology and User Modes

- Hardest part to using a Debug Tool
  - Application must be executable before DE can actually run
  - Is power, oscillator, connection etc. correct
  - Try switching to programmer mode and run a “blinky-light” program

Consequences and Gotchas

Breakpoints

Consequences and Gotchas

Breakpoints

- The Debug Tool sets breakpoints by writing the desired address to INBUG SFRs in the BDM
- While in user mode, the BDM compares each fetched instruction address with the desired break address and generates a HALT on a match
- But the instruction has already entered the microcontroller pipeline so the HALT NMI is delayed until after that instruction finishes execution

Consequences and Gotchas

Breakpoints

- The PC read by the Debug Tool after the HALT contains the address of the *next* instruction to be executed

- This is known as Skidding (demo)
  - Breaking on a 2 word instruction will result in a skid of 2 words rather than 1 word
  - dsPIC® DSC and PIC24F devices skid 2 instructions
  - Breaking on branch instructions can be confusing because of skid (demo)
  - NOPs can be used to ease this problem (demo)

Consequences and Gotchas

Breakpoints

- Breakpoints hit during Animate do *not* skid (demo)
  - Animate is simply automated single stepping
  - MPLAB® IDE compares the address *before* the instruction is executed

- Different microcontrollers offer different numbers of breakpoints
  - PIC10, PIC12 and PIC16 — 1 BP
  - PIC18 — 1 or 3 or 5 BPs
  - dsPIC30 — 1 or 2 BPs
  - PIC24 & dsPIC33 — 4 BPs

Consequences and Gotchas

Breakpoints

- The number of available breakpoints affects Step-Over performance
  - MPLAB® IDE will attempt to temporarily use available breakpoints for step-over target address (demo)
  - If insufficient breakpoints are available, MPLAB IDE will instead switch to *Animate* mode until the step-over target is reached (demo)
    - This may take a long time
  - Note that breakpoints and advanced breakpoints are really the same thing

Consequences and Gotchas

Registers

Consequences and Gotchas

Registers

- To update the value of a register displayed in MPLAB® IDE, the Debug Tool must perform a read operation through the DE
  - This transaction takes a finite amount of time
  - On slow targets, even more time is needed
  - So, the more data you display in MPLAB IDE, the longer it will take Debug Tool to halt or step (demo)
  - Microchip recommends the judicious use of the Watch Window instead of the File Register or SFR Windows

Consequences and Gotchas

Registers

- SFRs are viewed as just more file registers by the Debug Tool
- This presents some challenges for users
  - Reading or writing SFRs typically have side-effects
  - For example, reading the INDF flag has the side effect of incrementing the indirect address
  - Remember that displaying the INDF register in the watch, file register, or SFR windows will result in Debug Tool reading this register on each Halt

Consequences and Gotchas

Registers

- The INDF register is somewhat obvious and the Debug Tool knows to skip over requests to read this SFR (demo)

- Other SFRs can be just as troublesome though
  - For example, the RCREG register
  - We suggest reading the SFR into a GPR and working with the GPR in your software; and watch the GPR instead of the SFR (demo)

Advanced Breakpoints

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Advanced Breakpoints

- Over the years, Microchip has enhanced the capabilities of the BDMs placed in its microcontrollers
- Newer devices have break capabilities beyond simply matching a program memory address
- Exactly what those capabilities are depends upon which device you are targeting
- Access to these Advanced Breakpoints is provided through the Debug menu

Advanced Breakpoints

- PIC10, PIC12 and PIC16 devices have 1 program memory only break point
  - No Advanced BP capability

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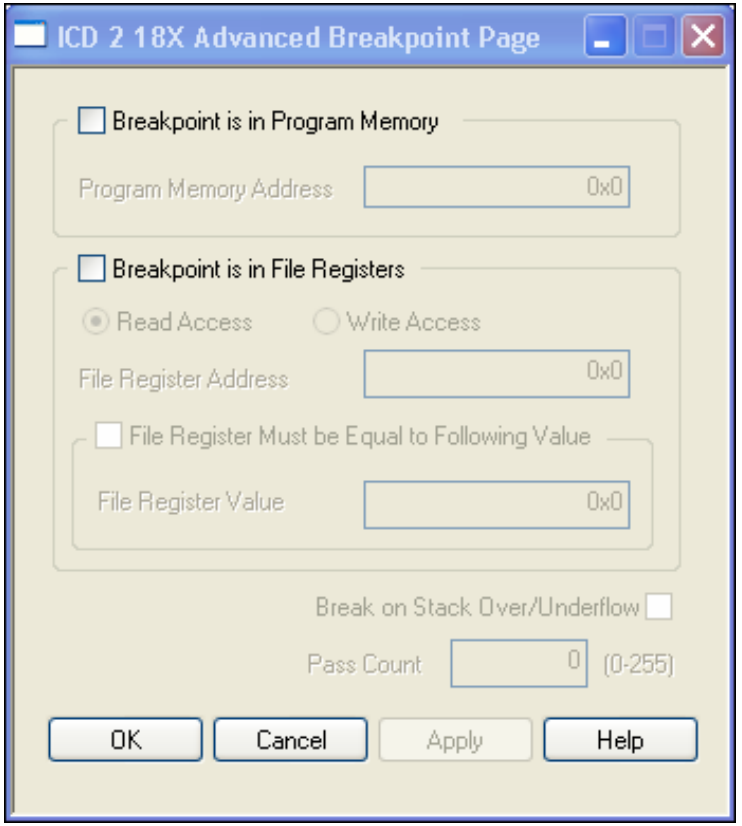
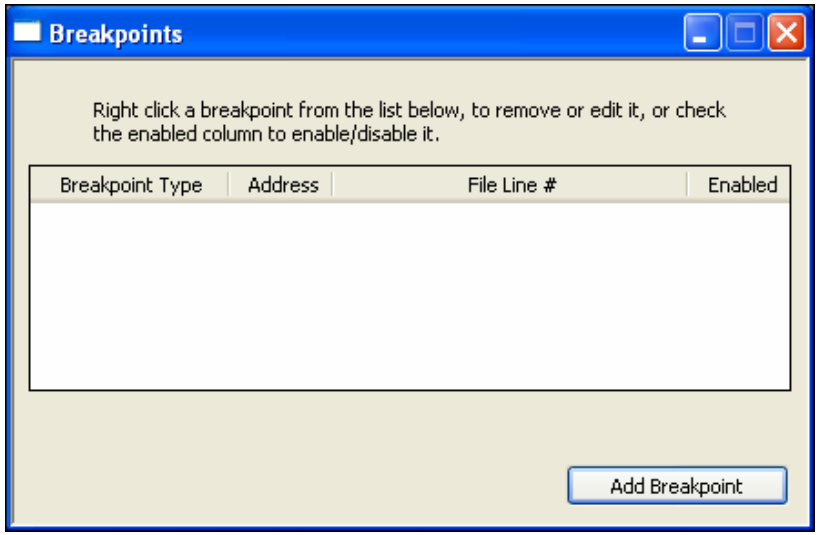
Advanced Breakpoints

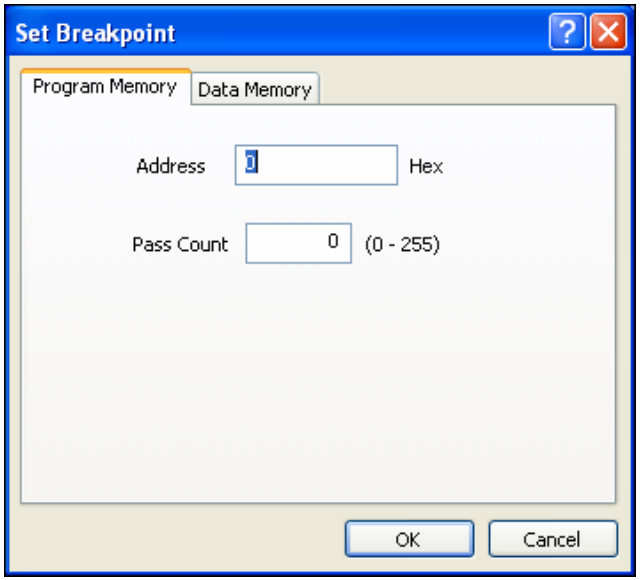
- PIC18F parts have more capabilities, but still only 1 breakpoint
  - Data match (demo)
  - Pass counting
  - *Break on Stack*

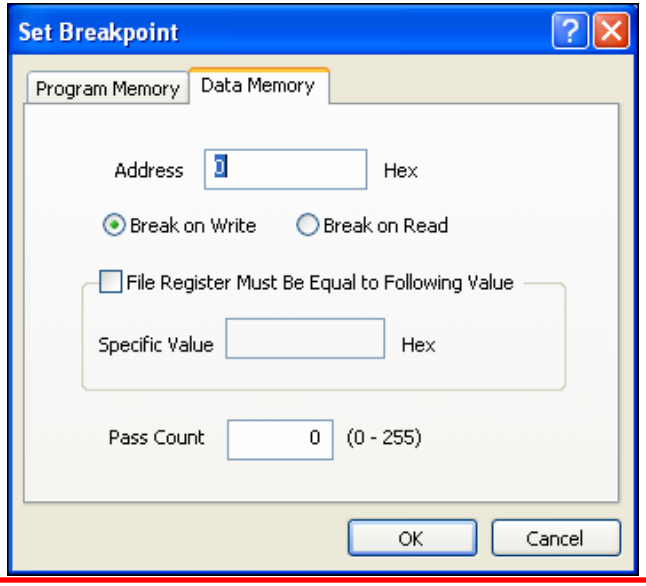


Advanced Breakpoints

- **MPLAB® REAL ICE™ In-Circuit Emulator**
  - Dialogs different
  - Fields the same

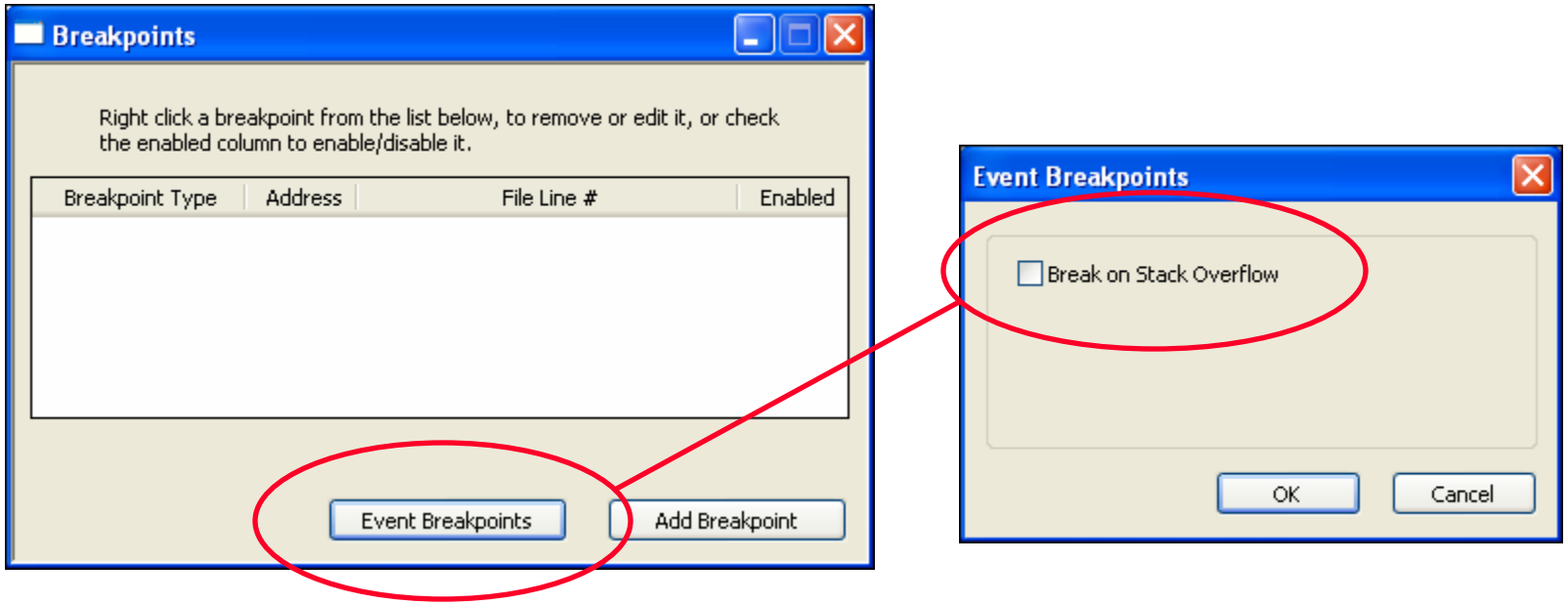






Advanced Breakpoints

- **MPLAB® REAL ICE™ In-Circuit Emulator**
  - Break on Stack works



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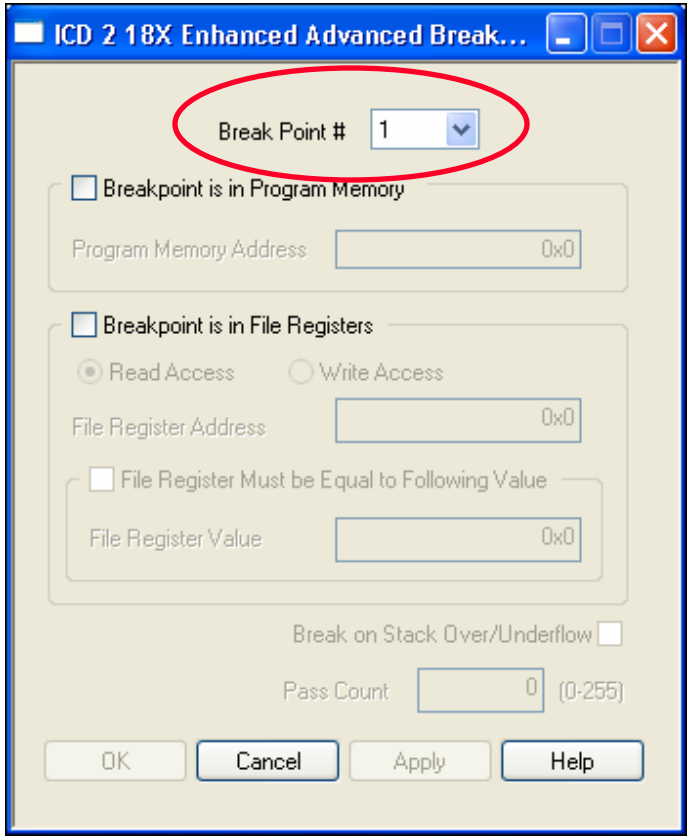
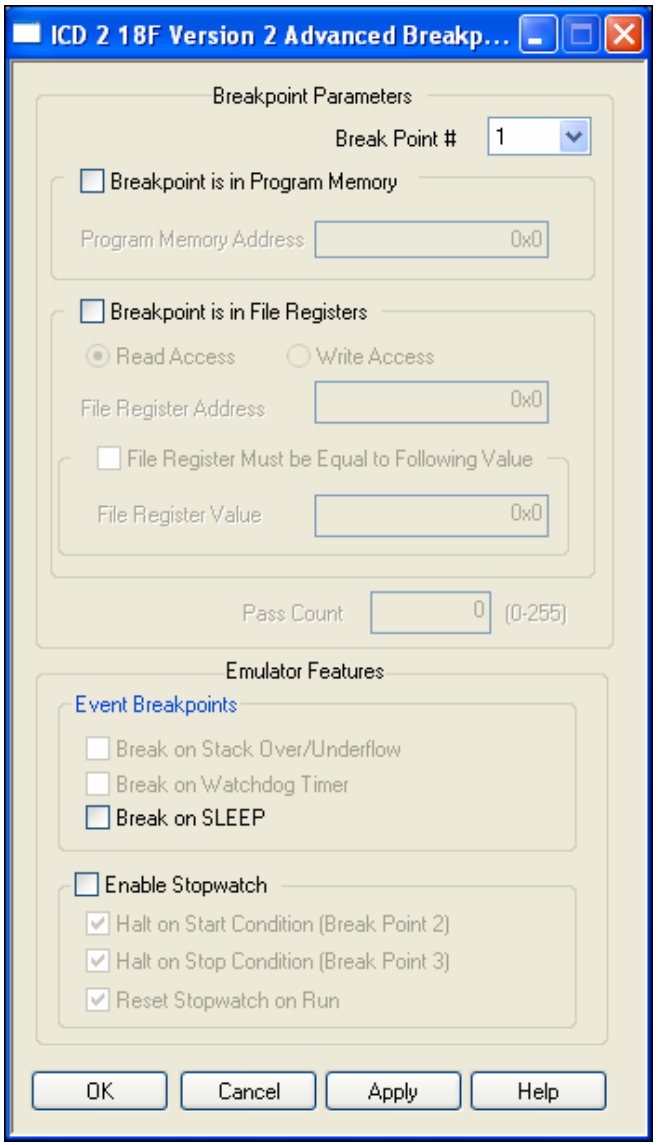
Advanced Breakpoints

- PIC18F Extended parts have the same breakpoint capabilities
  - 3 breakpoints



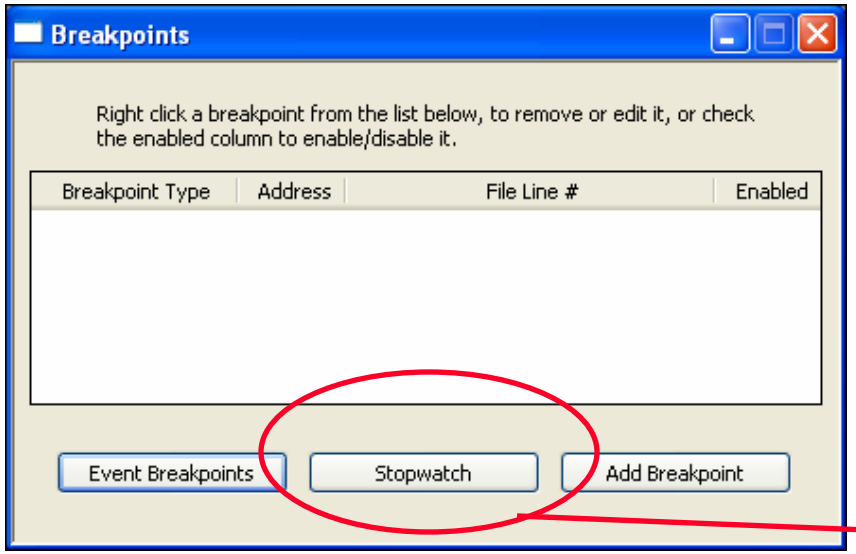
Advanced Breakpoints

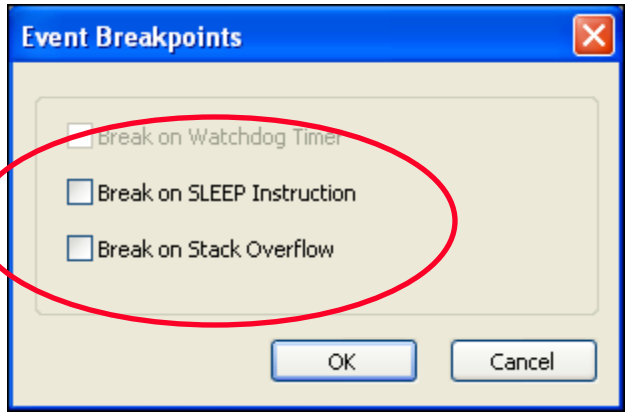
- **PIC18F "J" parts have even more features**
  - Break on Watchdog
  - Break on Sleep
  - Stopwatch
  - *Real-time data watch*

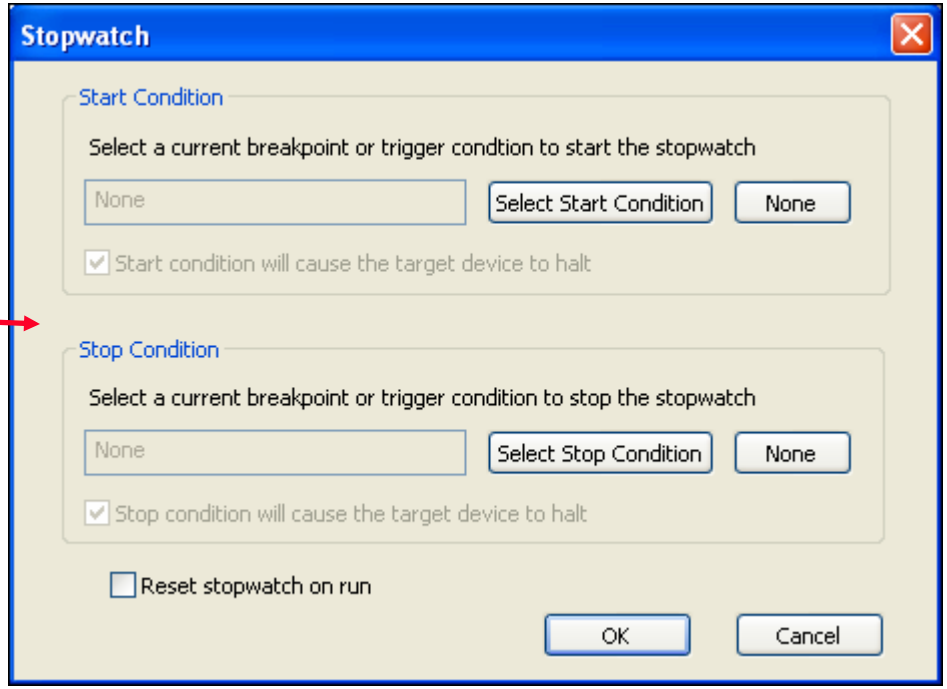


Advanced Breakpoints

- **MPLAB® REAL ICE™ In-Circuit Emulator**

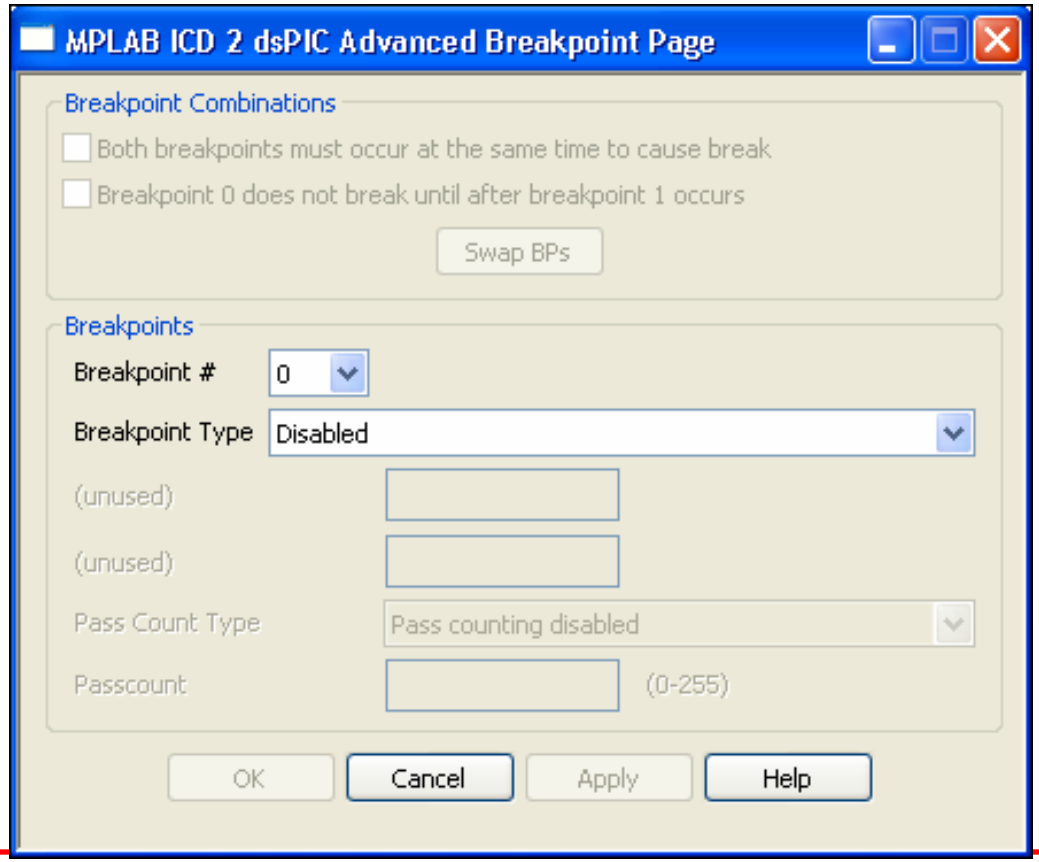






Advanced Breakpoints

- **dsPIC® DSC has a somewhat different approach**
  - Combinations
  - Different busses
  - 2 passcounts



Advanced Breakpoints

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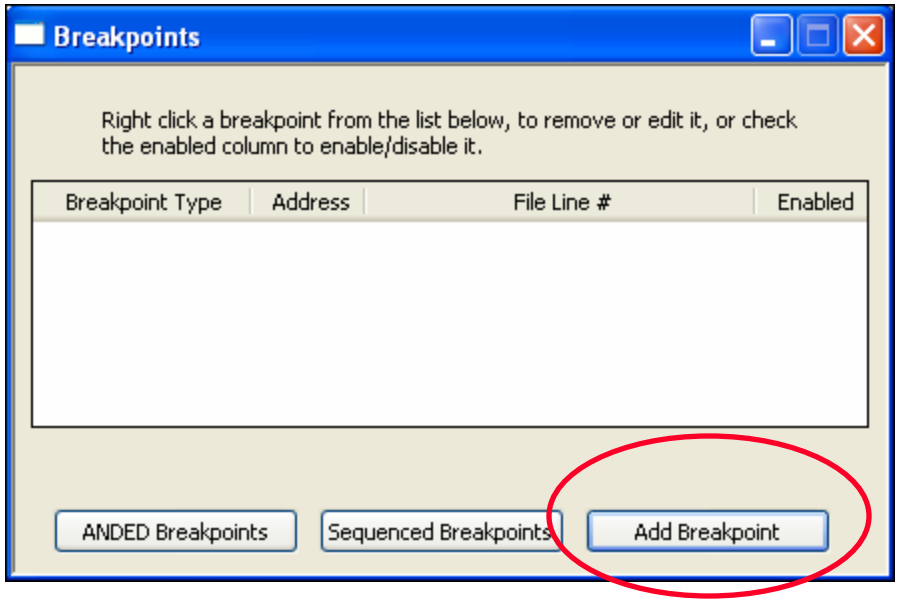

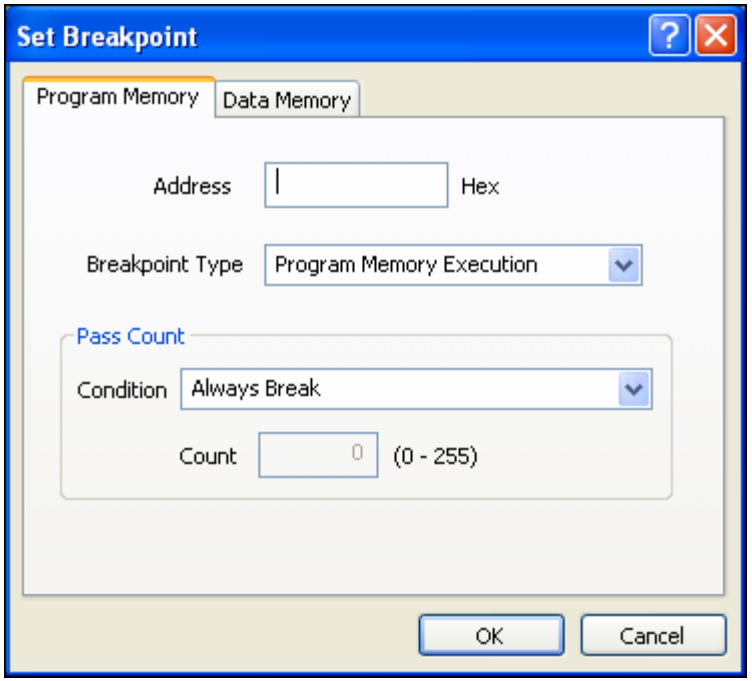

Advanced Breakpoints

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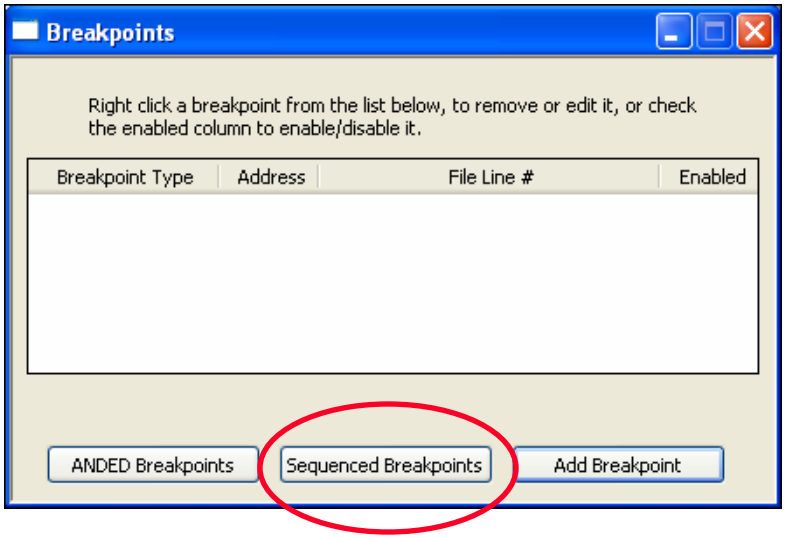

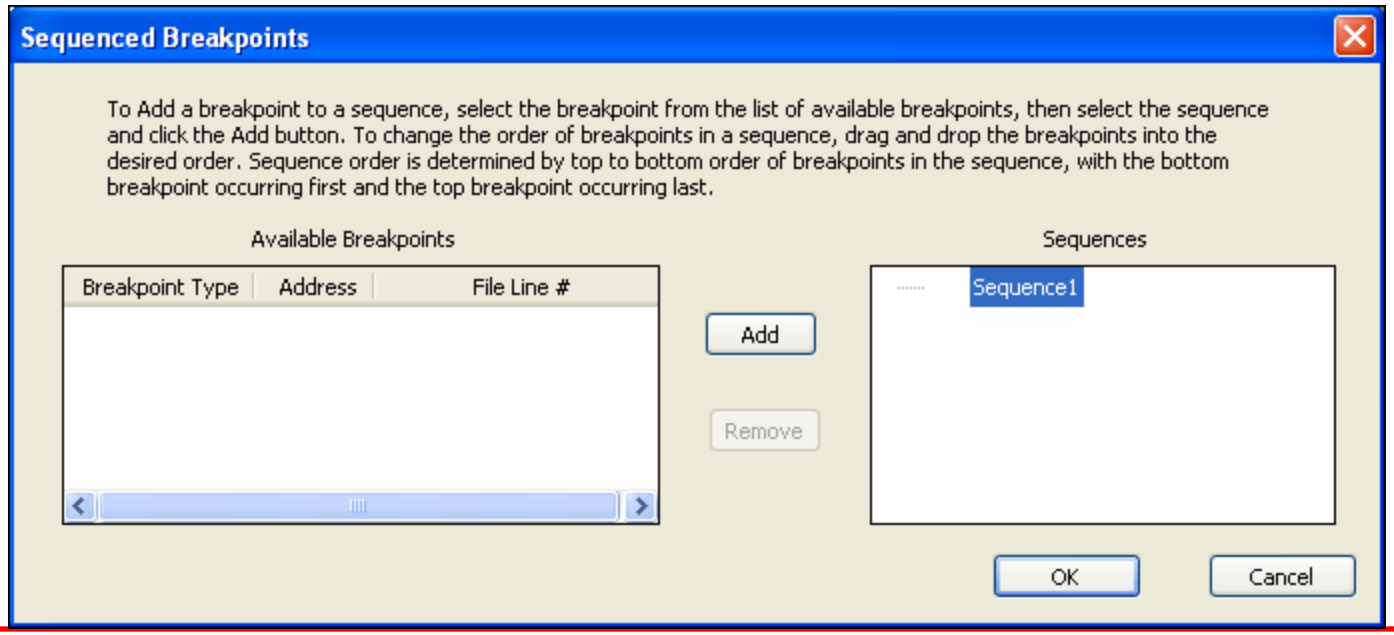

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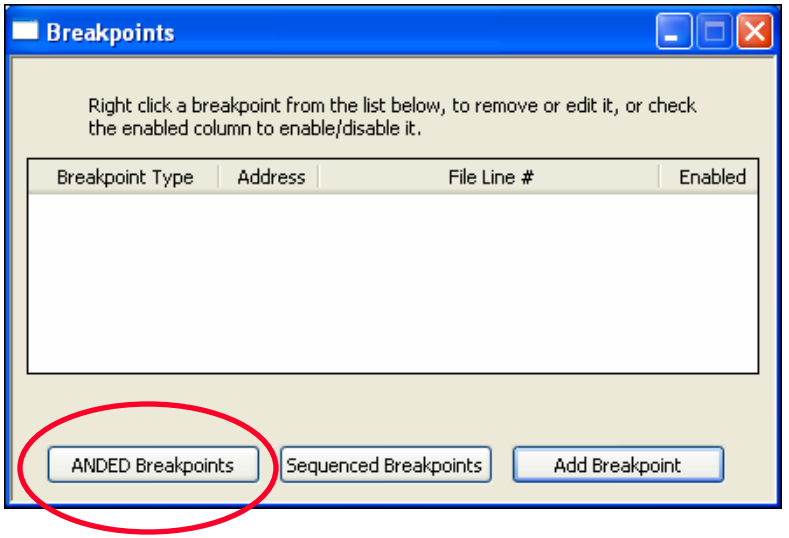
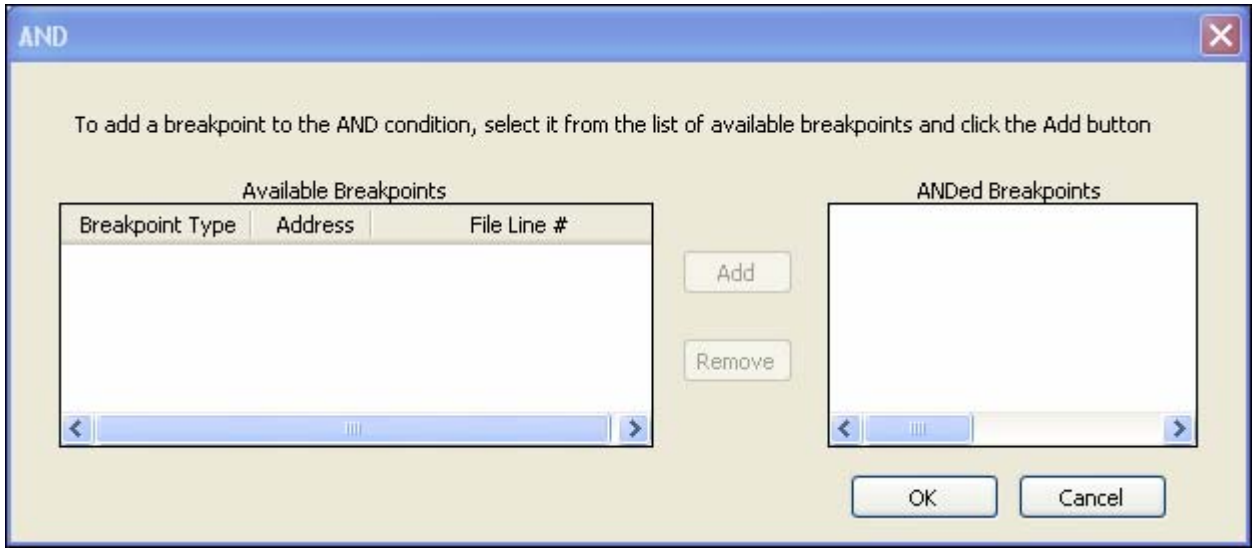
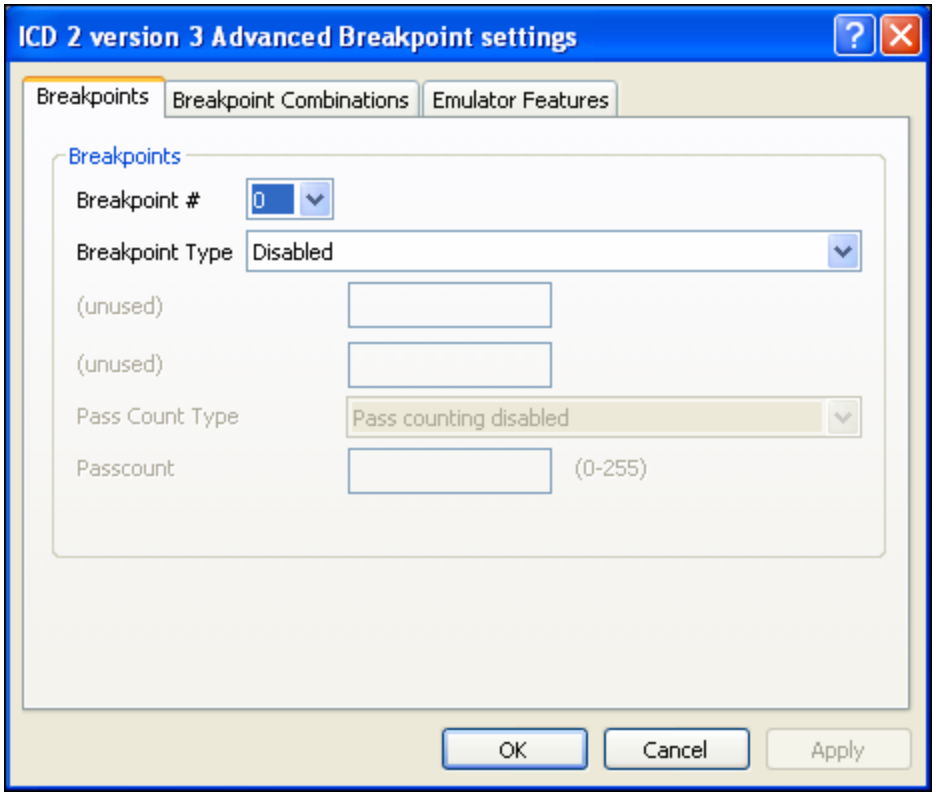




Advanced Breakpoints

- **PIC24 and dsPIC33 have all the features of both**
  - Tabbed presentation



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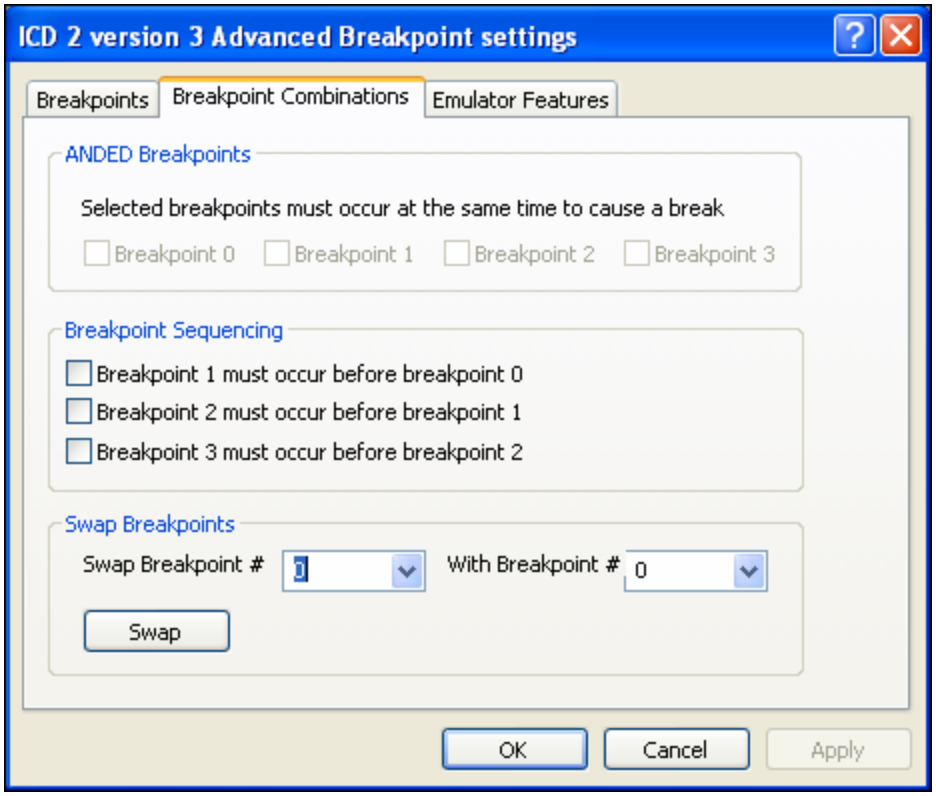

Advanced Breakpoints

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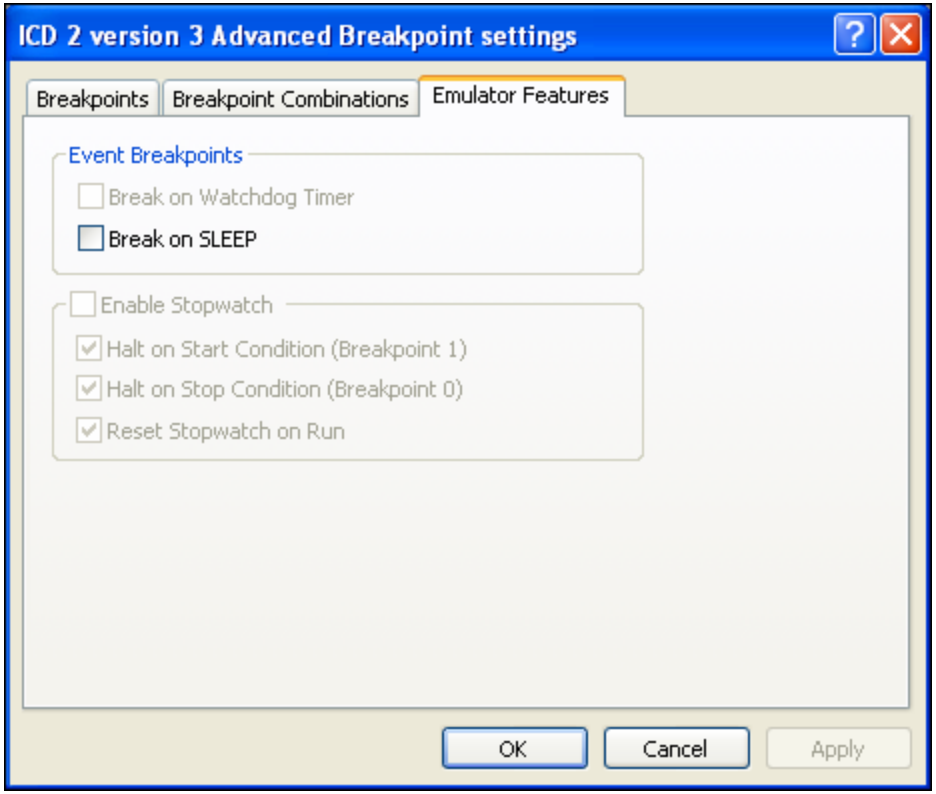

Advanced Breakpoints

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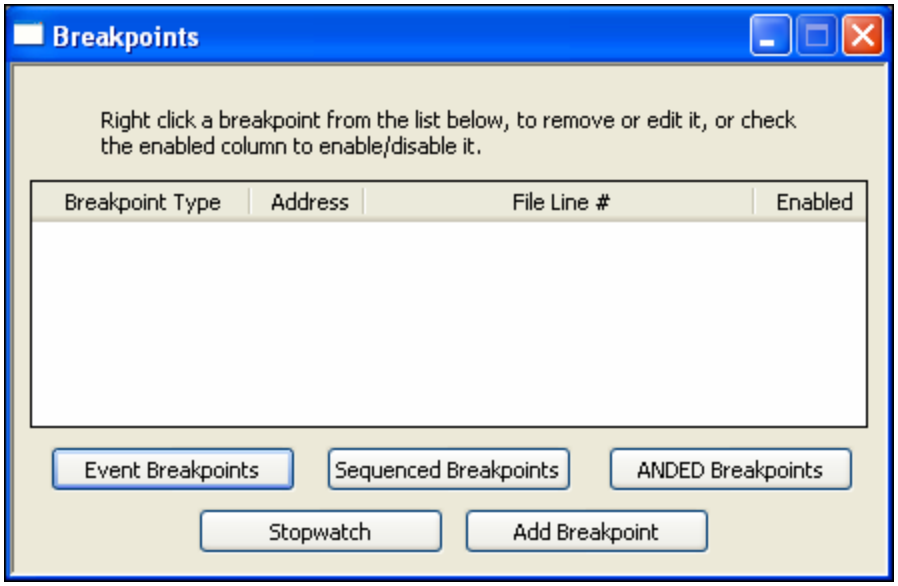

Comparing the Different Tools

Comparing the Different Tools

- **The BDM means that at some level all the Debug Tools have the same functionality**
- **So why choose one tool over any other?**
- **Price is usually the first discriminating criteria used!**
  - These prices were pulled from the Microchip Web page. They may be different today, and ARE different here at MASTERs!
    - **PICkit™ 2 Starter Kit** **$35**
    - **MPLAB® ICD 2** **$160**
    - **MPLAB REAL ICE™ In-Circuit Emulator** **$500**
- **There MUST be a reason for these price differences!**

Comparing the Different Tools

- **Let's start by looking at communications**
  - PICkit™ 2 Starter Kit
    - **Uses full speed USB, Human Interface Device**
      - No special driver needed
      - Packets limited to 64 bytes
  - MPLAB® ICD 2
    - **Uses full speed USB, Custom Bulk Device**
      - Special Microchip driver needed
      - Large packets allowed
  - MPLAB REAL ICE™ In-Circuit Emulator
    - **Uses high speed USB, Custom Bulk Device**
      - Special Microchip driver needed
      - Large packets allowed

Comparing the Different Tools

- **Next let's examine on board resources**
  - PICkit™ 2 Starter Kit
    - **PIC18F2550**
      - 32K Flash, 4K RAM, 48 MHz
  - MPLAB® ICD 2
    - **PIC16F877**
      - 8K Flash, .5K RAM, 20 MHz
  - MPLAB REAL ICE™ In-Circuit Emulator
    - **dsPIC30F6014A**
      - 48K Flash, 10K RAM, 120 MHz

Comparing the Different Tools

- **Supported Parts**
  - PICkit™ 2 Starter Kit
    - **About 40 selected PIC10, PIC12, PIC16 and PIC18 devices**
    - **More being added slowly**
  - MPLAB® ICD 2
    - **All PIC10F, PIC12F, PIC16F, PIC18F, PIC24F, dsPIC30Fand dsPIC33F devices**
  - MPLAB REAL ICE™ In-Circuit Emulator
    - **All PIC18F, PIC24F, dsPIC30F and dsPIC33F devices**
    - **PIC10F, PIC12F and PIC16F coming soon**

Comparing the Different Tools

- **PICkit™ 2 Starter Kit specifics**
  - Very inexpensive
  - Limited part support
  - Works with MPLAB® IDE or standalone
  - Slow
  - No protection on clock, data and MCLR lines
    - **Cross-talk interference, etc.**

Comparing the Different Tools

- **MPLAB® ICD 2 specifics**
  - Medium price
  - Supports everything
  - Tons of line protection
  - Tons of software protection
    - **Code protect, invalid config fields, power checks, etc.**
  - Mature tool, not many kinks left
  - Technology getting old; questionable debugging capability for newer, larger faster devices

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Comparing the Different Tools

- **MPLAB® REAL ICE™ In-Circuit Emulator**
  - Pricey, but value is there
  - No support for PIC10, PIC12, or PIC16 yet but will be there soon
  - **Hot pluggable!**
  - **Real time data watch!**
    - Combines very nicely with Data Monitor and Control Interface plugging
  - **Instrumented trace!**
  - **Long cable option!**
  - Good line protection
  - A lot of the software protection still to come, but will be there eventually
  - Technology new so the tool will be useable for many years to come

Comparing the Different Tools

- **So which tool do you use?**
  - Depends on your needs and budget
  - Some customers will buy one or two MPLAB® REAL ICE™ In-Circuit Emulator tools for the lab and MPLAB ICD 2 tools for each engineer's desk
  - If you are debugging a high speed data intensive application, MPLAB REAL ICE In-Circuit Emulator is probably the way to go

Odds and Ends

Odds and Ends

- **None of the tools can perform a Power-On-Reset**
  - PICkit 2 Starter Kit can provide power up to 50mA from the USB bus
  - MPLAB® ICD 2 can provide power up to 250mA, but not from the USB bus
  - MPLAB REAL ICE™ In-Circuit Emulator will not provide target power
  - Microchip recommends that the target provide its own power

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Odds and Ends

- Forums are a great place to look for help
  - http://forum.microchip.com/

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