Hands-On: Experiencing Enhanced Emulation Debugging

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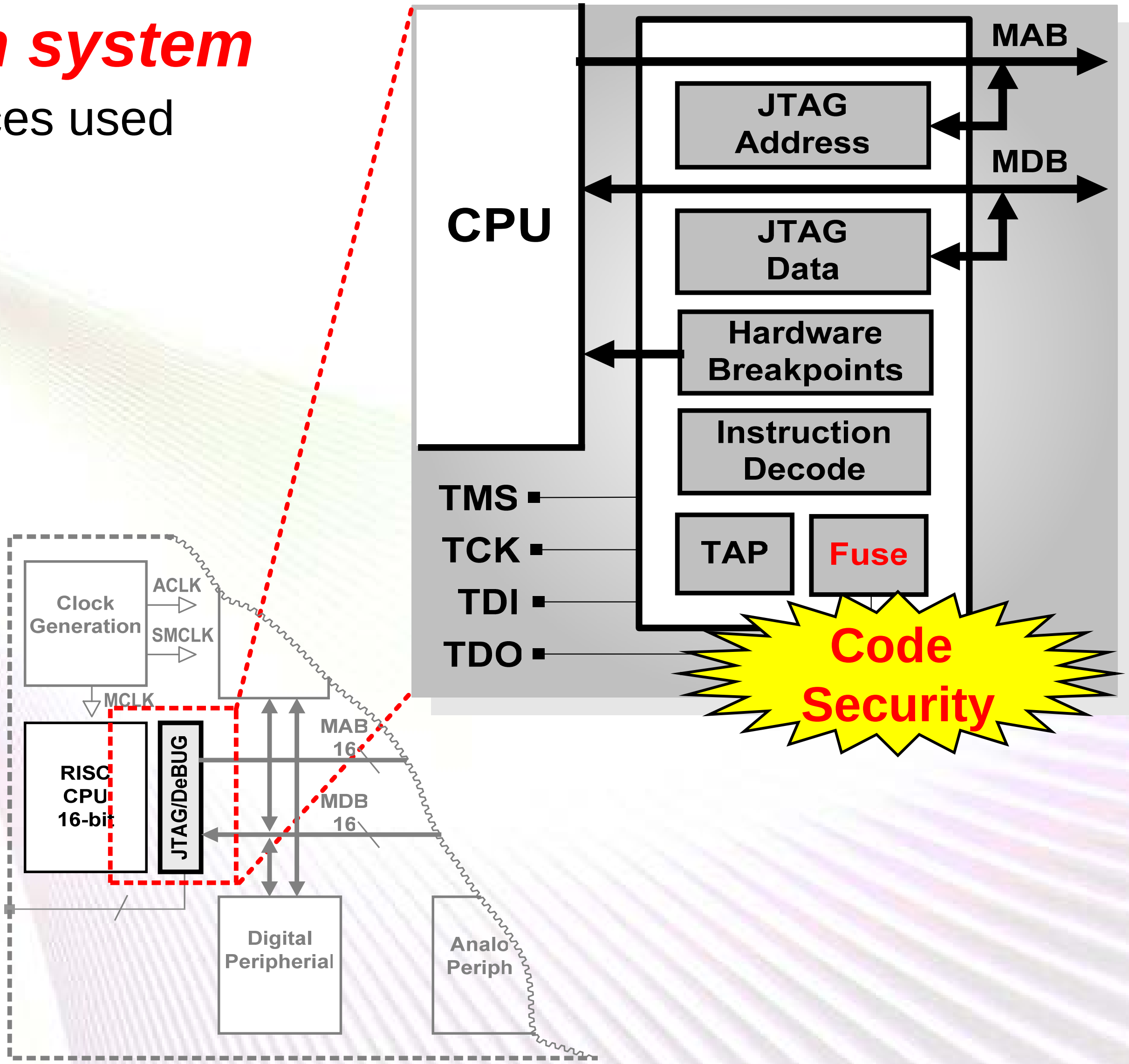
Agenda

- Introduction to the Embedded Debug Logic (Enhanced Emulation Module: EEM)
  - **Show different implementation Levels of the EEM**
  - **EEM Limitations and Behaviors**
- Lab: Setting a Breakpoint on Stack Overflow
  - **Using On-Chip Trace Buffer to see where the problem did occur**
- Lab: Setting a Breakpoint on Fetch outside allowed Area
  - **Using On-Chip Trace Buffer to see where the problem did occur**
- Lab: Setting a Breakpoint on a Variable
  - **Stop on Write**
  - **Trace on Write**
  - **Stop on Write of a dedicated Value**
- Lab: Using the Trigger Sequencer
- Lab: Clock Control
- Lab: Using On-Chip Trace Buffer as Real-Time Watch
- Lab: Building own complex Breakpoints with combining of Triggers

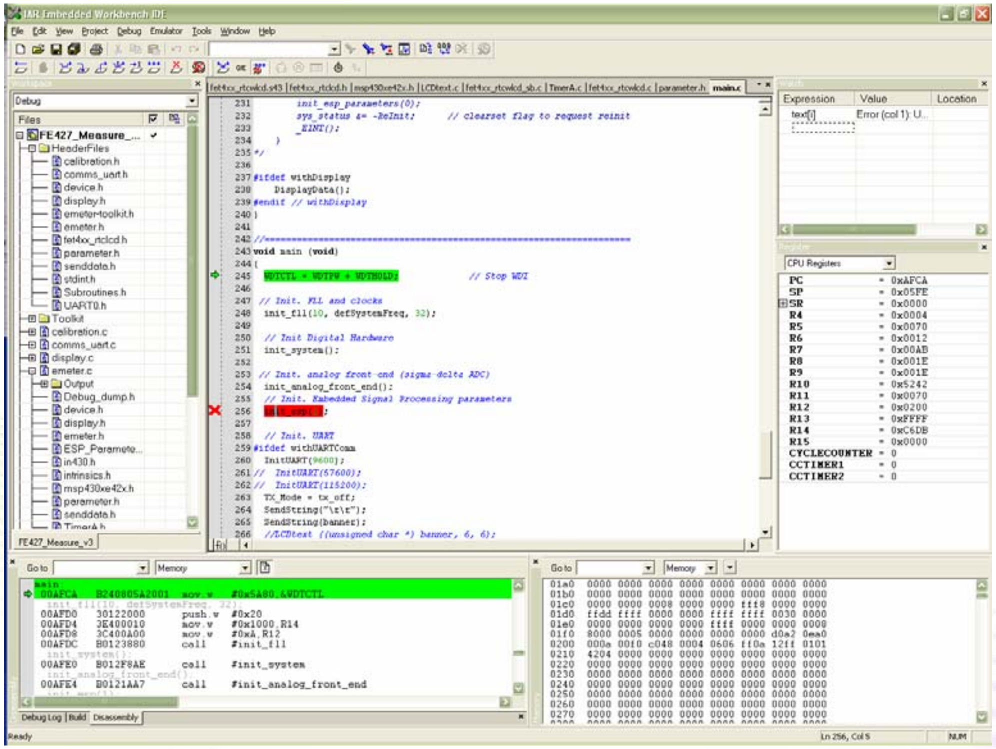
Embedded Emulation

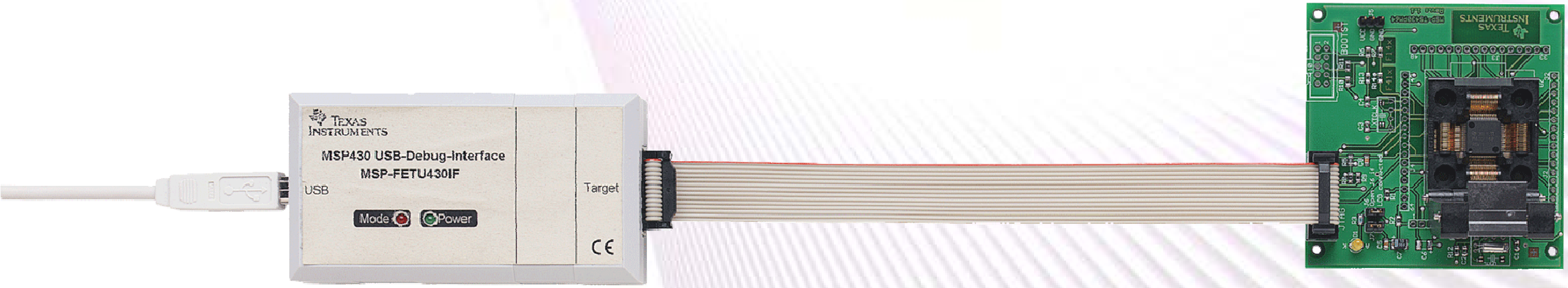
- ***Debug real time in system***
  - No application resources used
  - Full speed
  - Breakpoint
  - Single step
  - Complex trigger
  - Trace



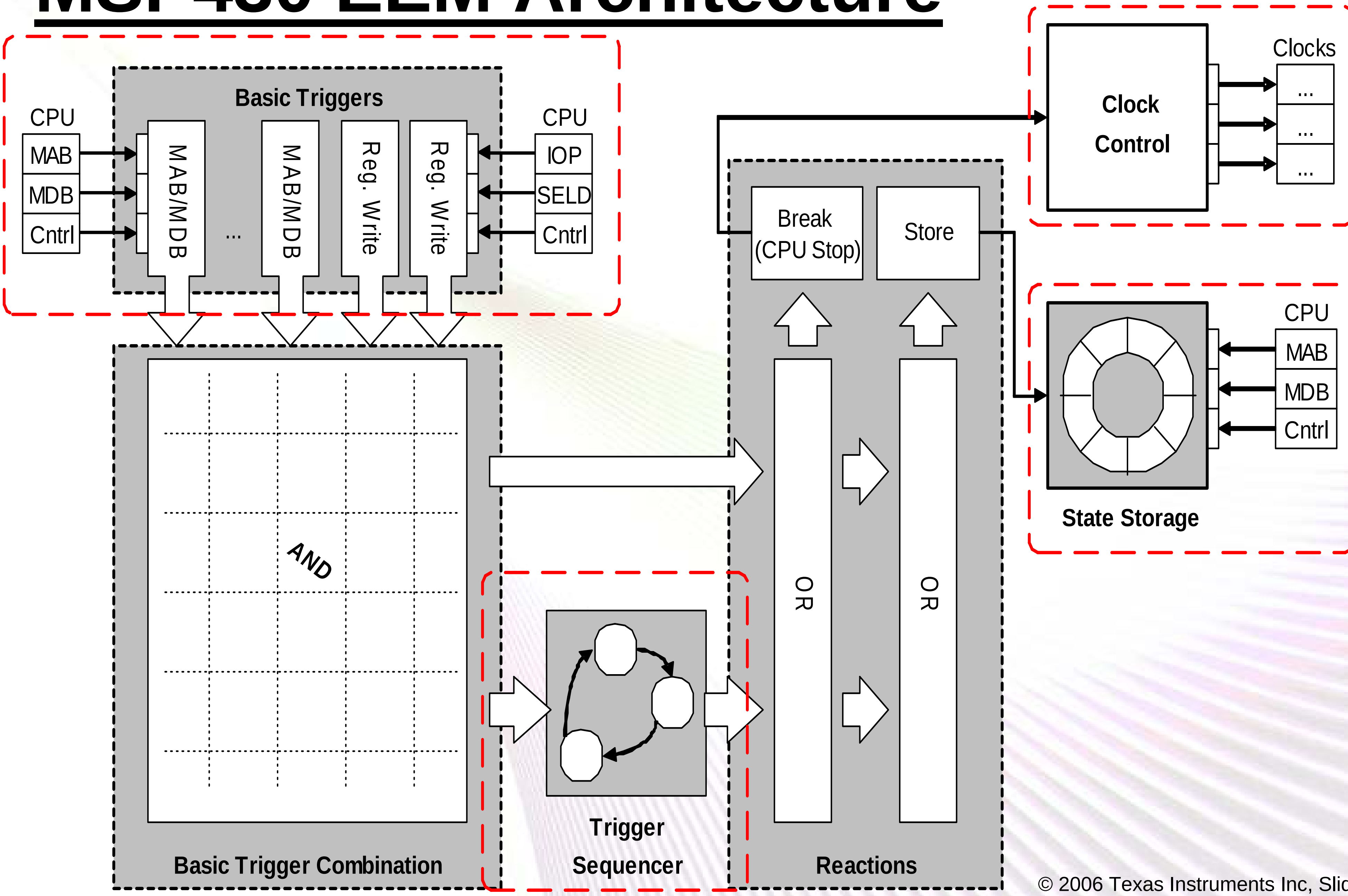
FET – One Tool For Every Device

- **Assembler/linker**
- **4KB C compiler**
- **Common IDE**
- **JTAG interface**
- **Target Board**
- **$149 USD**





MSP430 EEM Architecture



Available EEM Resources

Device	F11x1 / F12x	F12x2	F13x / F14x	F15x / F16x	F20xx / F21x1 / F22xx / F23xx	F41x	FE42x / FW42x	FG43x	F43x / F44x / FG46x
Triggers									
MAB/MDB-Trigger	2	2	3	8	2	2	2	2	8
<=/>=	-	-	X	X	-	-	-	-	X
R/W	-	-	-	X	-	-	-	-	X
DMA	-	X	-	X	-	-	-	X	-
16bit Mask	-	-	-	X	-	-	-	-	X
Reg.-Write-Trigger	-	-	-	2	-	-	-	-	2
<=/>= 1	-	-	-	X	-	-	-	-	X
16bit Mask	-	-	-	X	-	-	-	-	X
Combination	2	2	3	8	2	2	2	2	8
Trigger Sequencer	-	-	-	1	-	-	-	-	1
Reactions									
Break	X	X	X	X	X	X	X	X	X
State Storage	-	-	-	X	-	-	-	-	X
State Storage									
Internal	-	-	-	X	-	-	-	-	X
Clock Control									
Global	-	-	-	X	X	X	X	X	X
Modules	-	-	-	X	-	-	-	X	X

Note: Flash devices only

Influence and Resource Requirement

The EEM:

- **Does not use any internal CPU registers or memory**
- **Does not use interrupt vectors**
- **Does not insert debugging code or software breakpoints**
- **Has no influence on the program until a break event**

Exception:

- **Devices <=28 pin share the JTAG pins with port pins**
- **Spy Bi-Wire: use of RST/NMI pin**

Exceptions

- Complex breakpoints stop the CPU after the instruction causing the break.
- When a break occurs, the execution of the current instruction will always be completed.
- EEM cannot prevent an invalid value from being written into an address or register.
- It is not possible to trigger on timer values. Only the values on the address or data bus can be observed.

Where to find the menus

- **Breakpoint:**
  - View | Breakpoint
- **New Breakpoint:**
  - Right Click into the Breakpoint window and select New Breakpoint
- **State Storage Configuration**
  - Emulator | State Storage Control
- **State Storage Window**
  - Emulator | State Storage Window
- **Trigger Sequencer Control**
  - Emulator | Sequencer Control

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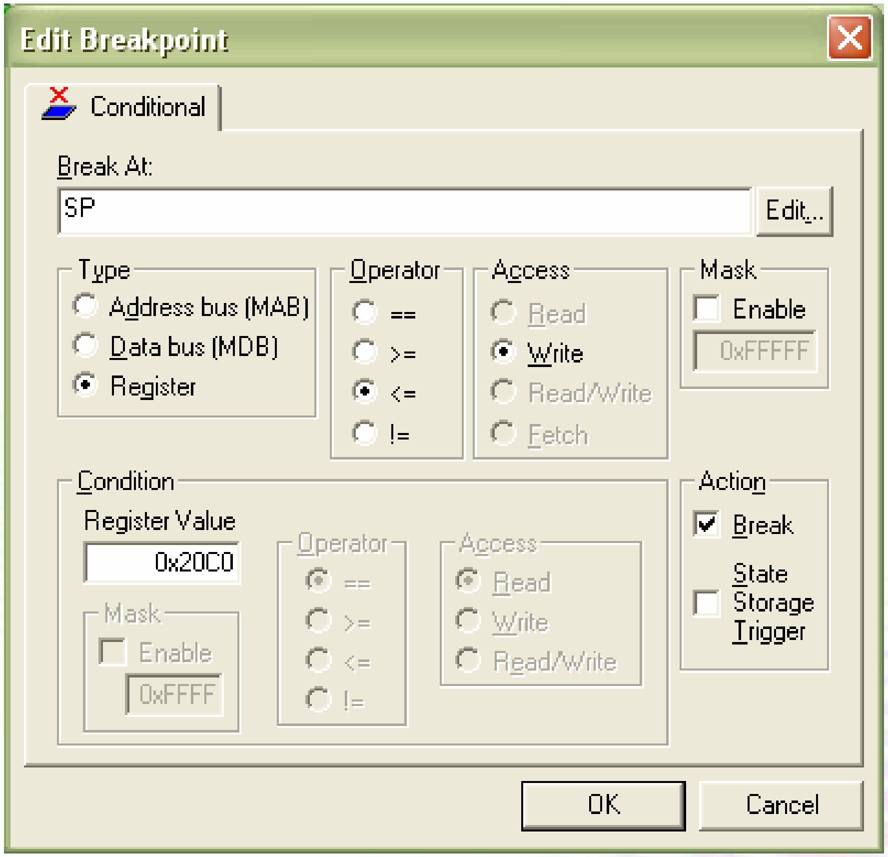
Lab: Stack Observation

- Nested functions or local declarations if arrays could easily lead to this problem
- Set a conditional breakpoint on the Stack Pointer so that the CPU stops if the SP decreases below 0x20C0.



Lab: Stack Observation

Target: **Halt CPU if SP decrements below a certain level**

Demo Program: Clock_TB1.c

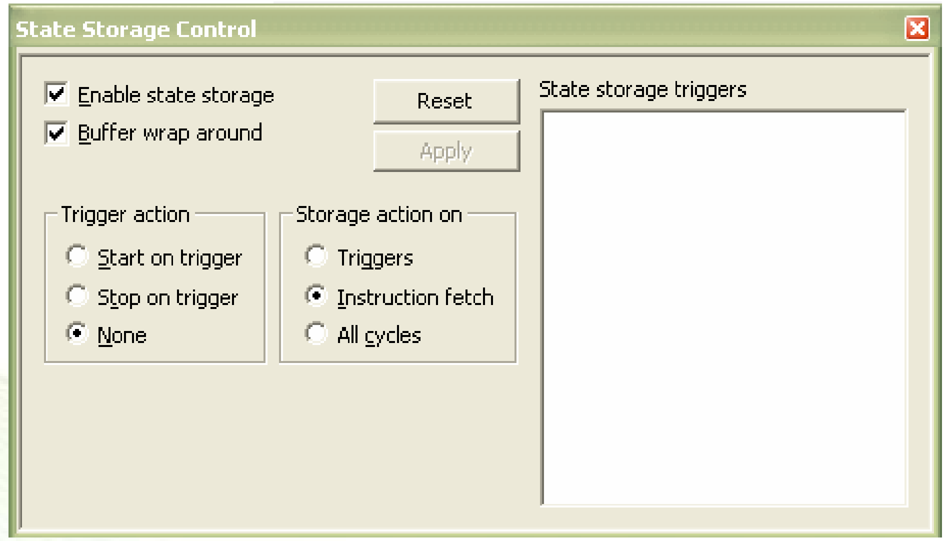
Detailed Lab Instructions:

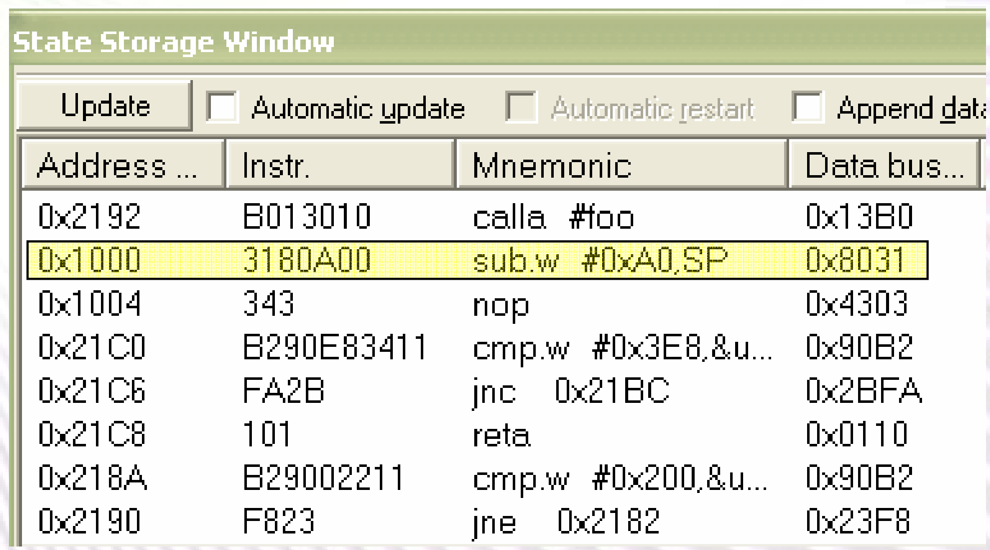
- **Open breakpoint dialog: View | Breakpoints**
- **Clear all previous breakpoints**
- **Create new “Conditional” Breakpoint**
  - Break At: SP (for Stack Pointer – Note: ‘SP’ should be upper case !)
  - Type: Register
  - Operator: <=
  - Access: write
  - Mask: not enabled
  - Condition: 0x20C0
  - Action: Break
- **Close the dialog with OK**
- **Start program execution**
  - Program should stop in the function ‘foo’ after the 80 bytes have been allocated on the stack (This should take approximately 8 seconds.)

Lab: Using Trace for Stack Observation

- **Open the State Storage Control**
  - Enable state Storage
  - Enable Buffer wrap around
  - Trigger action: None
  - Storage Action on: Instruction Fetch

  → Apply
- **Open the State Storage Window**
- **Execute Program again:**
  - Push the reset Button and execute the program again
  - After the breakpoint was hit observe the output in the State Storage Window





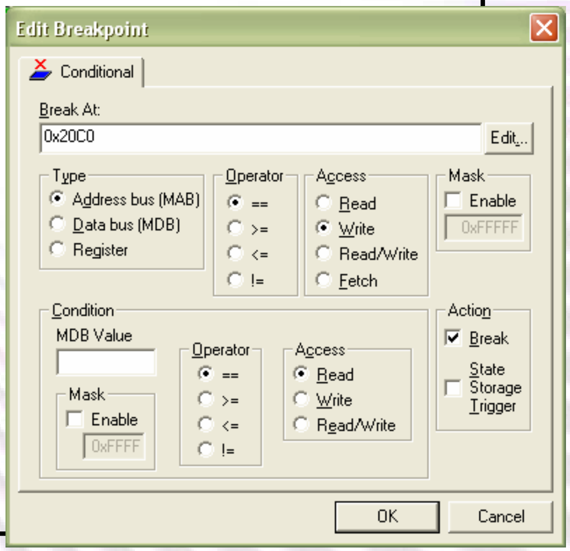
Lab: Stack Observation (MSP430X)

Due to the speed improvements in the MSP430X CPU an additional Breakpoint is required for this CPU to get all Stack overflows

Demo Program: Clock_TB1.c

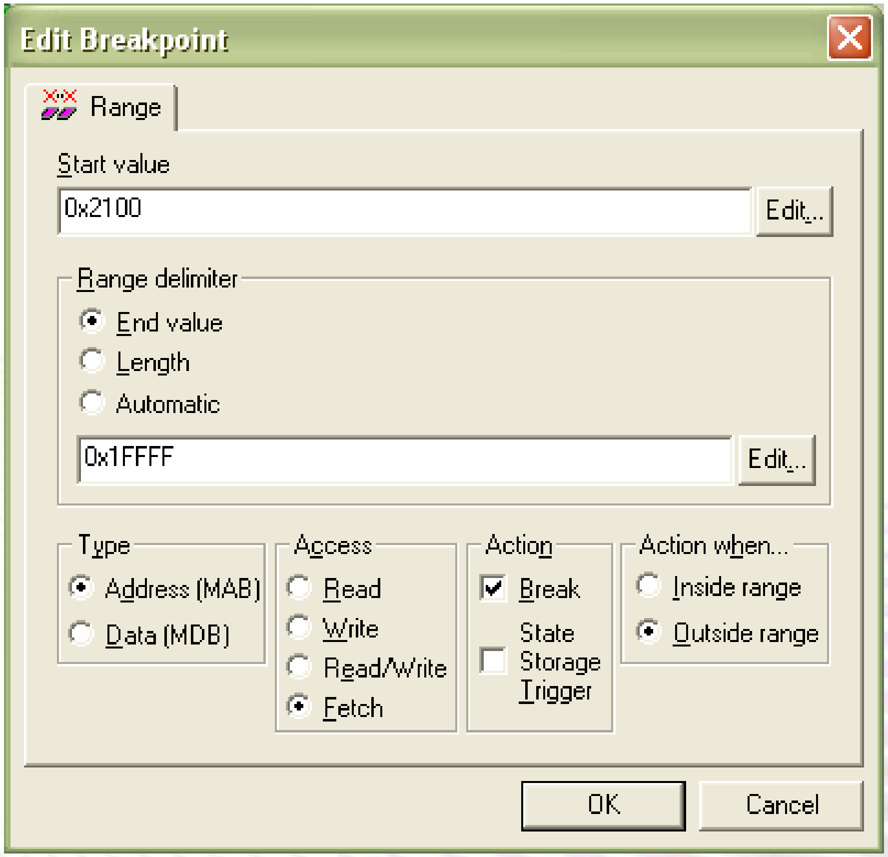
Detailed Lab Instructions: (add this to the previous Lab)

- **Open breakpoint dialog: View | Breakpoints**
- **Modify previous breakpoint to 0x20FA**
- **Start program execution**
  - Program should stop in ‘delay’ function when the return address is saved on the stack but this does not work.
  - Note: Program will also stop (3 times) during the initialization part (CStartup)
- **Create new “Conditional” Breakpoint**
  - **Break At:** 0x20FA
  - **Type:** MAB
  - **Operator:** ==
  - **Access:** write
  - **Mask:** not enabled
  - **Action:** Break
- **Close the dialog with OK**
- **Start program execution**
  - Program should stop now also in the function ‘delay’



Program Fetch Observation

- A problem with function pointers to improve and optimize code or function tables could make the PC jump somewhere. Finding this problems is very hard because the origin of the problem could not be detected.
- Set a range breakpoint:
  Start: 0x2100
  End: 0x1FFFF
  Access on Fetch if outside range



Lab: Program Fetch Observation

Target: **Halt CPU when loading an instruction in invalid range**

Demo Program: **Clock_TB1.c**

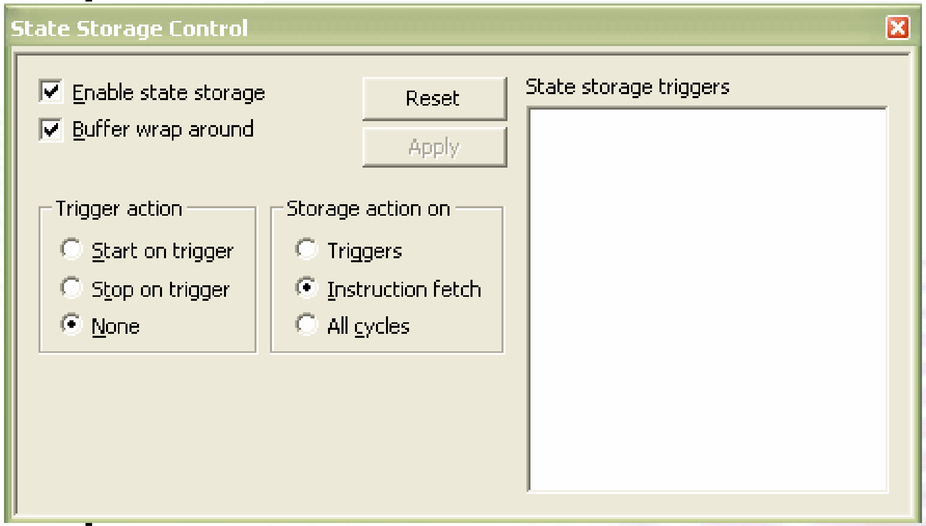
Detailed Lab Instructions:

- **Open breakpoint dialog: View | Breakpoints**
- **Clear all previous breakpoints**
- **Create new "Range" Breakpoint**
  - **Start Value:** 0x2100
  - **Range delimiter:** End Value -> 0x1FFFF
  - **Type:** Address (MAB)
  - **Access:** Fetch
  - **Action:** Break
  - **Action when:** Outside range
- **Close the dialog with OK**
- **Reset and Start program execution**
  - Program should stop when the function 'foo' is called (because 'foo' is placed into info memory at 0x1000) (This should take approximately 8 seconds.)

Lab: Using the Trace for Fetch Observation

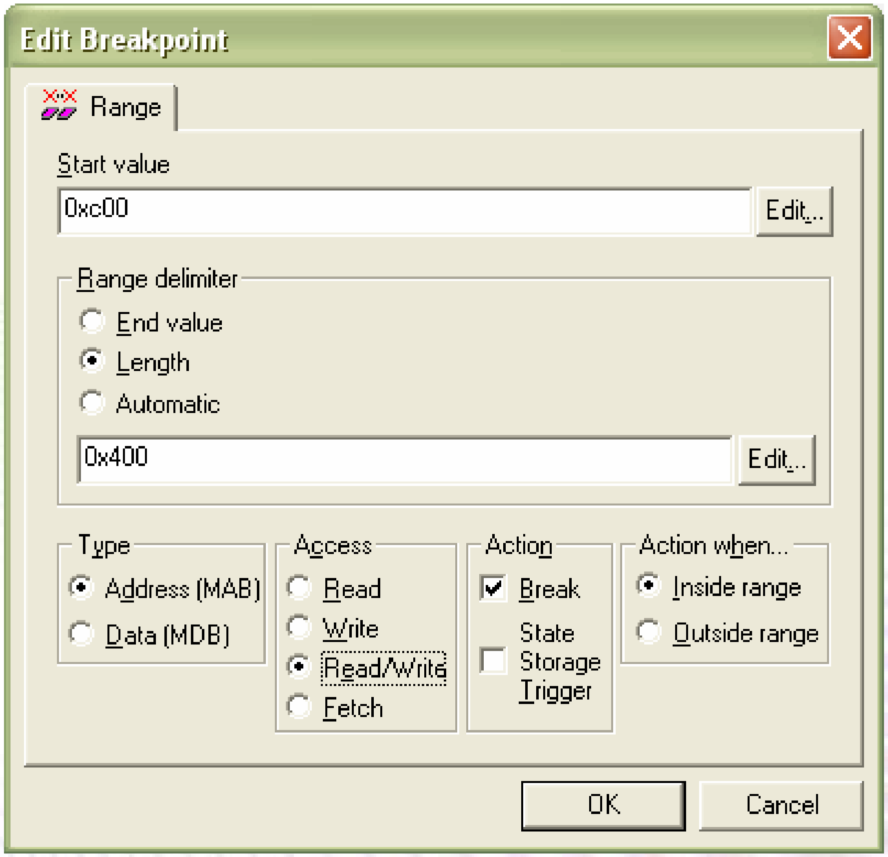
- **Open the State Storage Control**
  - Enable state Storage
  - Enable Buffer wrap around
  - Trigger action: None
  - Storage Action on: Instruction Fetch

  → Apply
- **Open the State Storage Window**
- **Execute Program again:**
  - Push the reset Button and execute the program again
  - After the breakpoint was hit observe the output in the State Storage Window



Break on Read/Write to Invalid Memory

- **Example:**
  The CPU should stop if a read access from a specified memory area occurs (0xC00 to 0xFFF in this case).



Lab: Break on Read/Write to Invalid Memory

Target: Halt CPU when accessing invalid memory

Demo Program: Clock_TB1.c

Detailed Lab Instructions:

- Open breakpoint dialog: View | Breakpoints
- Clear all previous breakpoints
- Create new "Range" Breakpoint
  - **Start Value:** 0xc00
  - **Range delimiter:** End Value -> 0xFFF
  - **Type:** Address (MAB)
  - **Access:** Read/Write
  - **Action:** Break
  - **Action when:** Inside range
- Close the dialog with OK
- Reset and Start program execution
  - Program should stop when the line :" *(ptr + 2) = *ptr + 0x1234;" is executed as this does access the Boot loader Memory.
    Additional step: Try to modify the trigger to Read or Write only. Check the difference within the disassembler window.

Lab: Trace on Write to Memory

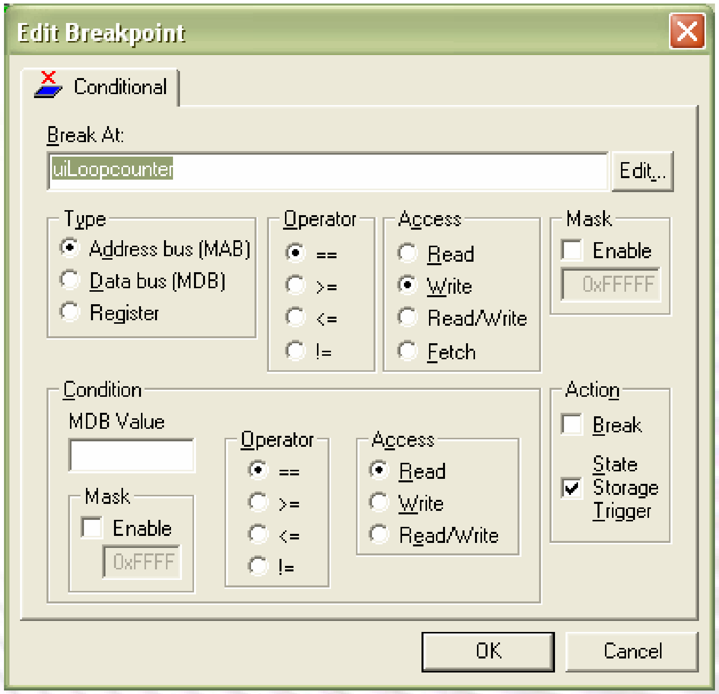
Target: **Trace the information which is written into a dedicated memory address during program execution**

Demo Program: **Clock_TB1.c**

Detailed Lab Instructions:

- **Open breakpoint dialog: View | Breakpoints**
- **Clear all previous breakpoints**
- **Create New "Conditional" Breakpoint:**
  - **Break At:** uiLoopcounter
  - **Type:** MAB
  - **Operator:** ==
  - **Access:** write
  - **Mask:** not enabled
  - **Action:** State Storage Trigger
- **Close the dialog with OK**
- **Setup State Storage:**
  - Enable state Storage
  - Enable Buffer wrap around
  - Trigger action: None (disabled)
  - Storage Action on: Triggers

  → Apply
- **Reset and Start program execution**
  - Start and Stop Program execution or set a breakpoint on the call of the foo function. You should see the last view increments of the uiLoopcounter variable in the State storage window.



Lab: Real-Time Watch

Target: **Trace the information which is written into a dedicated memory address during program execution and read the data without stopping the CPU**

Demo Program: **Clock_TB1.c**

Detailed Lab Instructions: **(add this to the previous)**

- **Start program execution**
- **Open the State Storage Window and press the update button**
  - A snapshot of the last trace entries is read and displayed in the State Storage Window

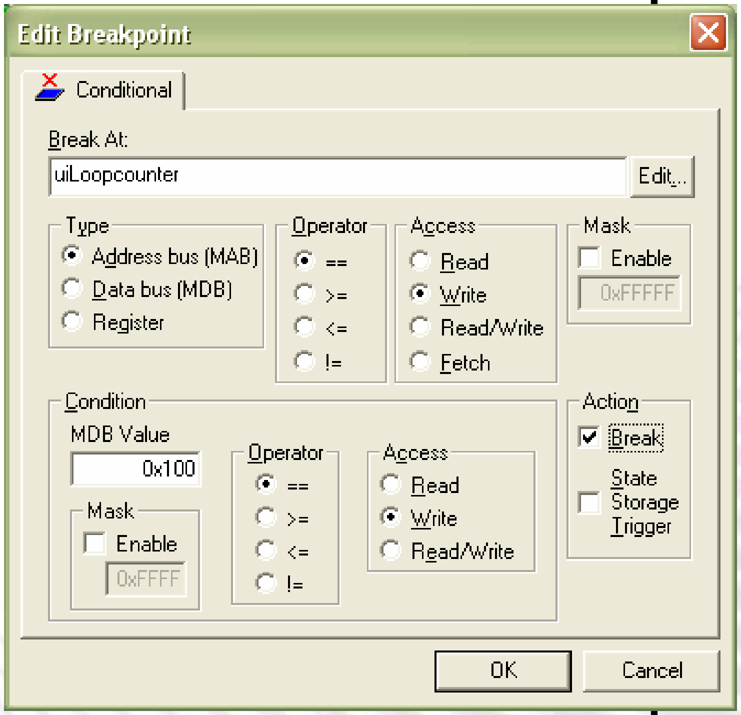
Lab: Stop on Memory Access with dedicated Value

Target: Trace the information which is written into a dedicated memory address during program execution

Demo Program: Clock_TB1.c

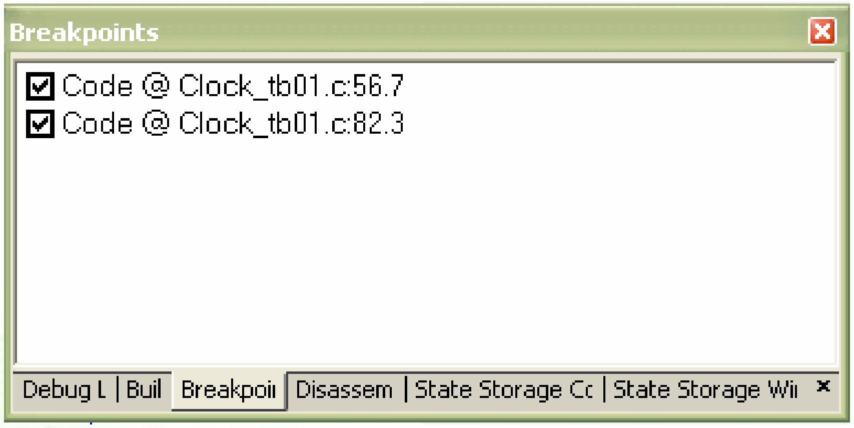
Detailed Lab Instructions:

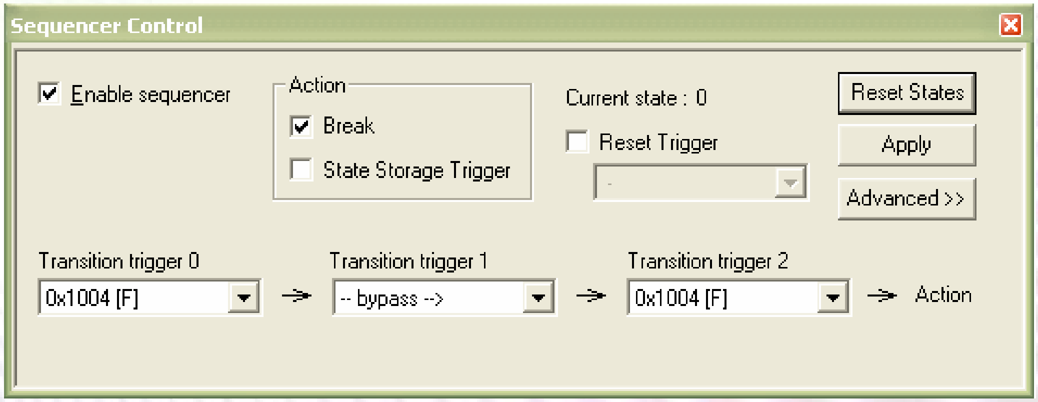
- **Open breakpoint dialog: View | Breakpoints**
- **Modify the previous "Conditional" Breakpoint:**
  - Break At: uiLoopcounter
  - Type: MAB
  - Operator: ==
  - Access: write
  - Mask: not enabled
  - Action: Break
  - Condition MDB value: 0x100
  - Condition Operator: ==
  - Condition Access: write
- **Close the dialog with OK**
- **Add the uiLoopCounter to the Watch Window**
- **Start program execution**
  - Check the content of uiLoopcounter after program execution did stop. It should contain 0x100.



Trigger Sequencer

- Can create a linear program sequence before a trigger is accepted for a break or state storage event
- Useful if an event occurs only after a given sequence in the program has taken place





Lab: Trigger Sequencer

Target: **Halt CPU if a certain program sequence was executed**

Demo Program: **Clock_TB1.c**

Detailed Lab Instructions:

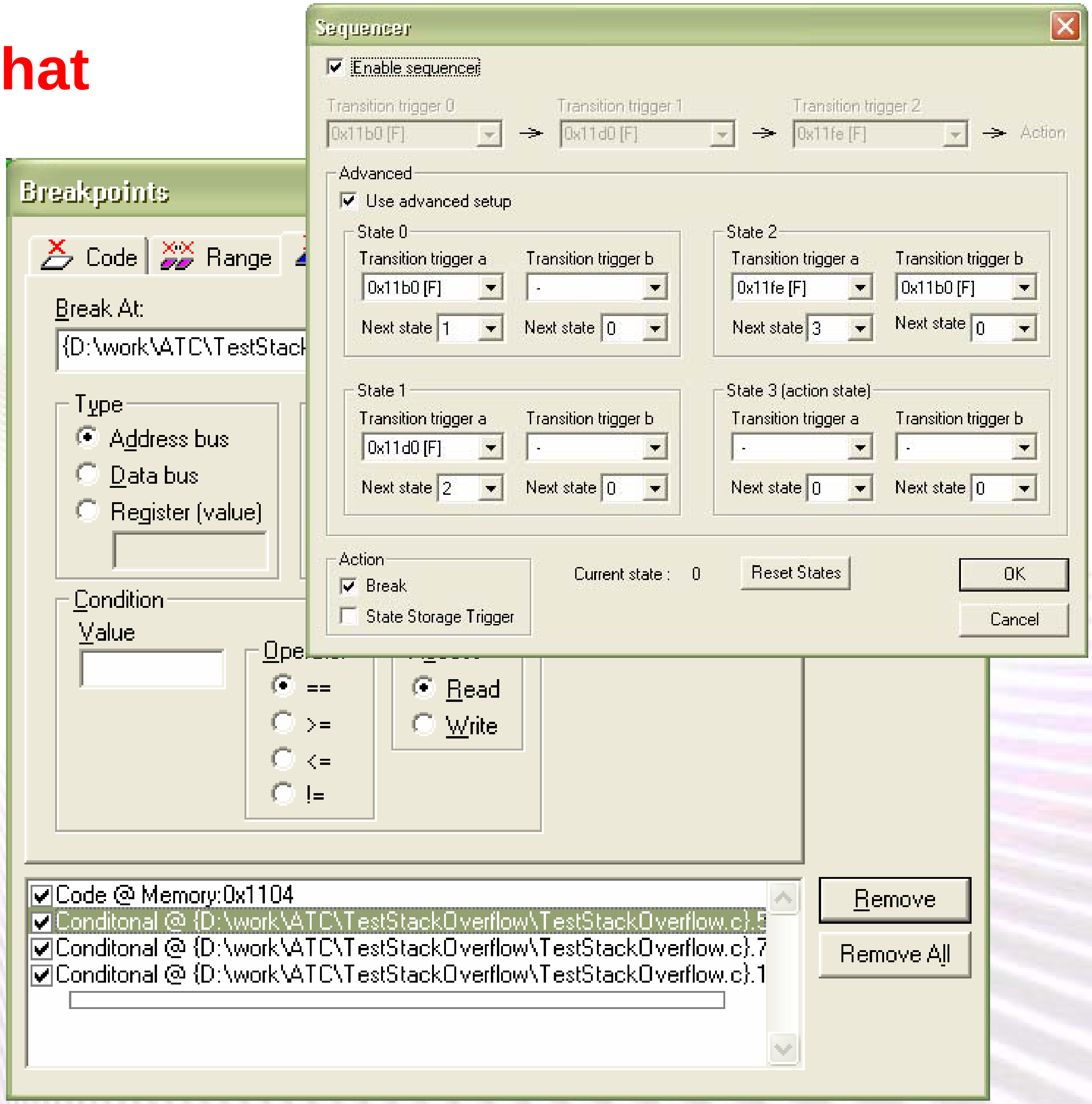
- **Open breakpoint dialog: View | Breakpoints**
- **Clear all previous breakpoints**
- **Set a code breakpoint in line 56: "uiLoopcounter++;"**
- **Set a code breakpoint in line 82: "_NOP();"**
- **Open the Trigger "Sequencer Control" Window**
  - **Enable Sequencer**
  - **Transition Trigger 0:** 0x1004 [F]
  - **Transition Trigger 1:** Bypass
  - **Transition Trigger 2:** 0x2182 [F]
  - **Action:** Break

  → Reset States

  → Apply
- **Reset and Start program execution**
  - Program should stop after "uiLoopcounter++;" but the variable is already incremented to 513. So the Breakpoint is activated after the funtion foo was exectued. To repeat the test goto the Trigger Sequencer window and push the "Reset States" Button

Complex Trigger Sequencer

- No Lab – just to show that this is also available
- Allows a trigger on complex system sequences
- Restart and reset conditions for the sequencer can also be defined

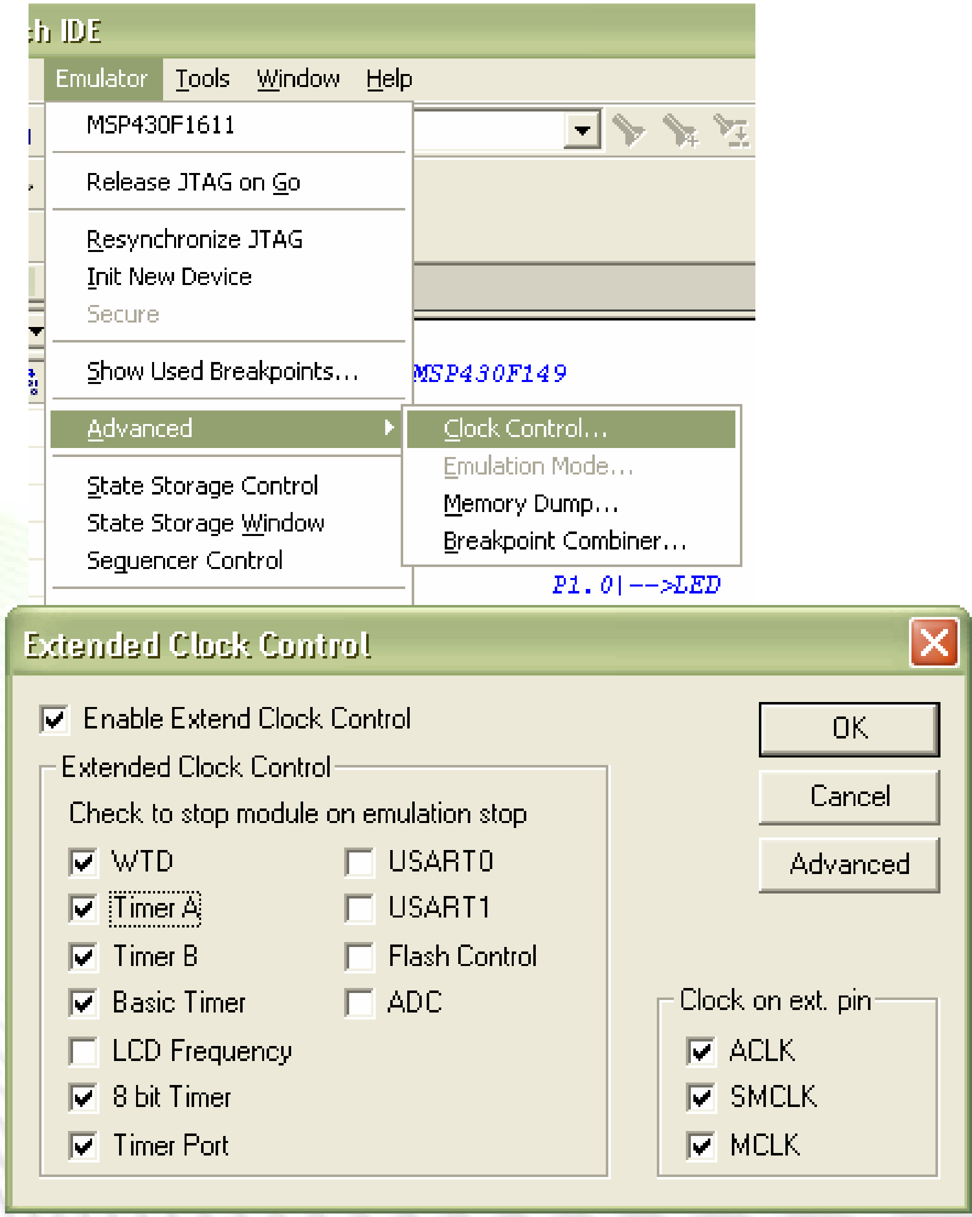


Clock Control

- **Different applications have different requirements for the clock control during debug**
- **For instance, it might be dangerous to stop a clock for a timer which is generating a PWM signal for a motor.**
  - Similar requirements could exists for the Flash, UART, ADC, etc.
- **Clock control may be needed when the clock is triggering a counter which continuously requests interrupts during the stop time, for example an RTC**

Clock Control

- Stop & release Clock for TimerB
- Check PWM output (P2.2)
- Check debugging. If ISR is active set a breakpoint in the ISR
- Test single stepping with Clock for TimerB stopped and released



Lab: Clock Control

Target: **Check device operation w/ different clock control setup**

Demo Program: **Clock_TB1.c**

Detailed Lab Instructions:

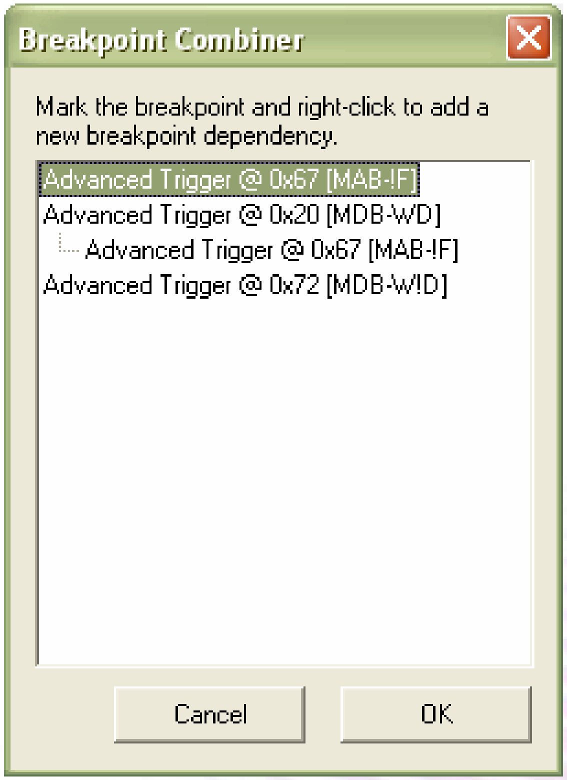
- **Open breakpoint dialog: View | Breakpoints**
- **Clear all previous breakpoints**
- **Close the dialog with OK**
- **Start Debugger**
- **Open Emulator | Advanced | Clock Control Dialog**
  - Click on the Advanced Button
  - Enable Extended Clock Control
  - Check TimerB → so that Clock for TimerB is stopped on Emulation hold
- **Close the dialog with OK**
- **Accept reset of the CPU**
- **Start program execution**
  - Check PWM output (P2.2 - LED1)
  - Check software toggled output (P2.1 - LED2)

Lab: Clock Control

- **Stop program execution**
  - Check PWM output (P2.2 - LED1)
  - Check software toggled output (P2.1 - LED2)
- **Try to single step through the program (esp. main program)**
- **Open Emulator | Advanced | Clock Control Dialog**
- **Enable Extended Clock Control**
- **Uncheck TimerB → so that clock for TimerB is not stopped on Emulation hold**
- **Close the dialog with OK**
- **Accept reset of the CPU**
- **Start Program execution**
  - Check PWM output (P2.2 - LED1)
  - Check software toggled output (P2.1 - LED2)
- **Stop Program execution**
  - Check PWM output (P2.2 - LED1)
  - Check software toggled output (P2.1 - LED2)
- **Try to single step through the program (esp. main program)**

Combining Breakpoints

- **The Breakpoint Combiner dialog (Emulator | Advanced) allows the combination of two or more individual breakpoints or triggers**
- **The Sub-Trigger is added to the Main-Trigger with an AND combination**
- **The Sub-Trigger stays unmodified in the system**
  - A break action set on the Sub-Trigger stops execution independent from the Main-Trigger
  - Normally the Break Action should not be set for the Sub-Trigger



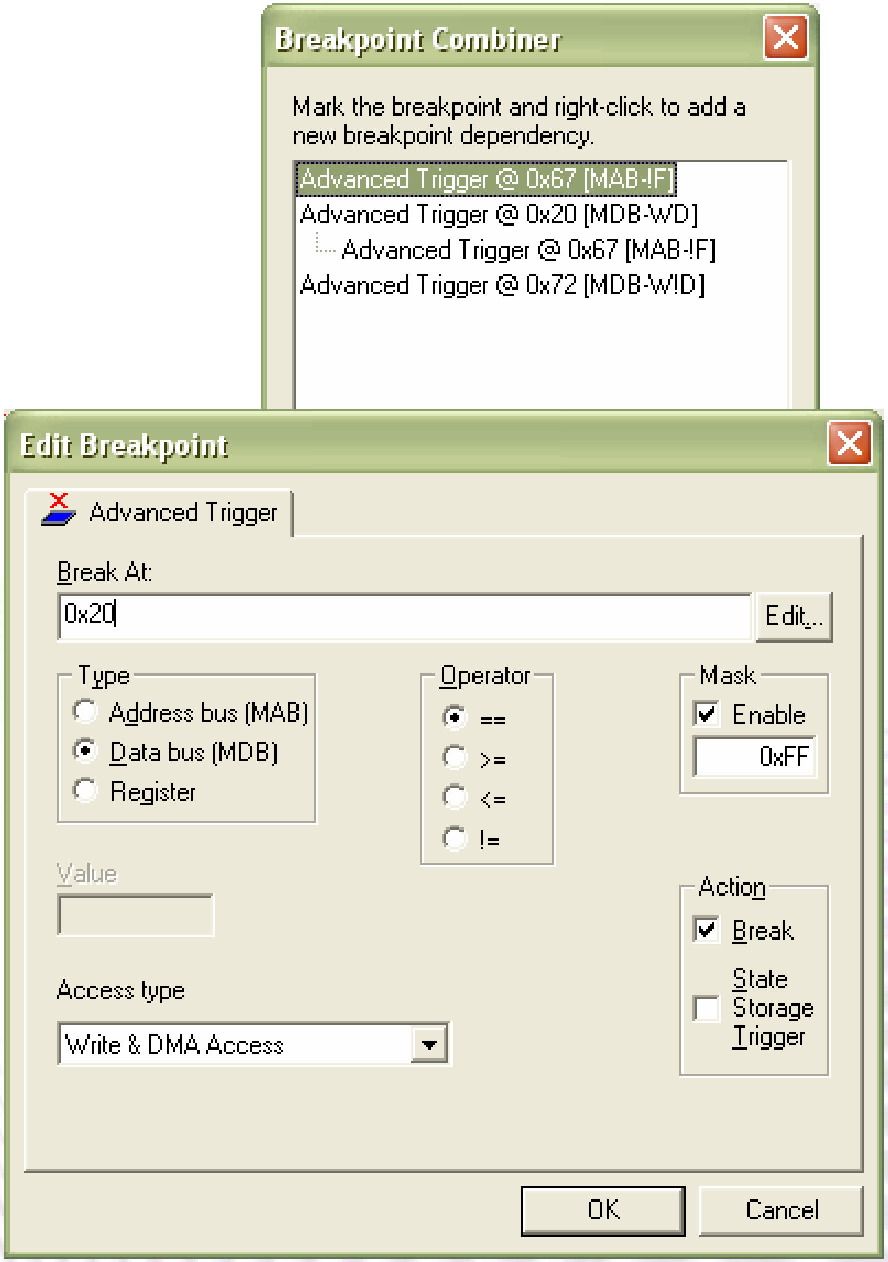
DMA Trigger

- During Program execution a single memory location could be accessed by the CPU and/or the DMA
- Allowing Trigger to detect between these two different types of accesses provides better control over software execution and maintaining real-time behavior of the system as much as possible without stopping the CPU

DMA Trigger

Setting a break on a DMA transfer means that the CPU will stop only if a certain value is written into a dedicated address by the DMA

- **Use Breakpoint Combiner to combine MAB & MDB Triggers**
  - Only the Main Trigger should have the Break Action set!
- **The CPU should stop if a DMA transfer of the Space Character into the UART TX Buffer is done**



Lab: DMA Trigger

Target: **Halt CPU the 0x20 moves to UCA0TXBUF via the DMA**

Demo Program: **ATC2006_DMA_Demo.c**

Detailed Lab Instructions:

- **Open breakpoint dialog: View | Breakpoints**
- **Clear all previous breakpoints**
- **Create new "Advanced Trigger", set first trigger:**
  - **Break At:** UCA0TXBUF (0x6F)
  - **Type:** MAB
  - **Operator:** ==
  - **Mask:** not enabled
  - **Access Type:** No Instruction Fetch
  - **Action:** No Break

  → OK

Lab: DMA Trigger

- **Set second trigger:**
  - **Break At:** 0x20 (“space” character)
  - **Type:** MDB
  - **Operator:** ==
  - **Mask:** Enable: 0x00FF   (only Byte access)
  - **Access Type:** Write & DMA Access
  - **Action:** Break

  → OK
- **Close the dialog with OK**
- **Open “Breakpoint Combiner” dialog:**
  Emulator | Advanced | Breakpoint Combiner
- **Right click on ‘Advanced Trigger @ 0x20 [MDB-WD]’**
  - Add trigger ‘Advanced Trigger @ 0x67 [MAB-!f]
- **Close the dialog with OK**
- **Start program execution**
- **Program should stop each time the DMA transfers the ‘space’ character to the UART TX buffer but. Note: It does not stop on the first transmitted character which is sent directly by the CPU.**

Lab: DMA Trigger

- **Open breakpoint dialog: View | Breakpoints**
- **Create new "Advanced Trigger"**
  - **Break At:** 0x72 ('r' character)
  - **Type:** MDB
  - **Operator:** ==
  - **Mask:** Enable: 0x00FF   (only Byte access)
  - **Access Type:** Write & No DMA Access
  - **Action:** Break

  → Apply
- **Close the dialog with OK**
- **Open terminal program: 9600 / 8N1**
- **Open "Breakpoint Combiner" dialog :**
  Emulator | Advanced | Breakpoint Combiner
- **Right click on 'Advanced Trigger @ 0x72 [MDB-W!D]'**
  - Add trigger 'Advanced Trigger @ 0x67 [MAB-!f]
- **Close the dialog with OK, reset program, start program execution**
- **Program should stop when software transmits 'r' but not 'space' to the UART TX buffer. Also stops each time the DMA transfer 'space'.**

Summary

- The EEM logic allows powerful trigger and break settings making hard to find errors easily identifiable
- No additional hardware testing is necessary after development and evaluation with EEM
- Cost effective and efficient method of debugging
- Compatible across all products
- Facilitates true analog performance and behavior
- In-system and in-field debugging possible
- Observation of variables in a running system enables a deeper view into the application
- Given the flexibility of the EEM, implementation of additional features are possible and will be added in the near future including statistical code coverage and better implementation of real-time watches