

# ***Demonstrating TMS320C2xx Pipeline Operation During an Interrupt***

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*APPLICATION BRIEF: SPRA357*

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# Demonstrating TMS320C2xx Pipeline Operation During an Interrupt

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## Abstract

This application brief describes the behavior of the Texas Instruments (TI™) TMS320C2xx pipeline during an interrupt occurring around the SETC and CLRC instructions. This brief also explains how to change the appropriate bit in the IMR register to protect a block of code without globally disabling interrupts.

Each scenario was tested using the TMS320C209SE ('C209SE) DSP and its internal timer as the interrupt source. Pipeline operation was verified using actual code traces on the XDS511/522 emulator.



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## TMS320C2xx Pipeline Scenarios

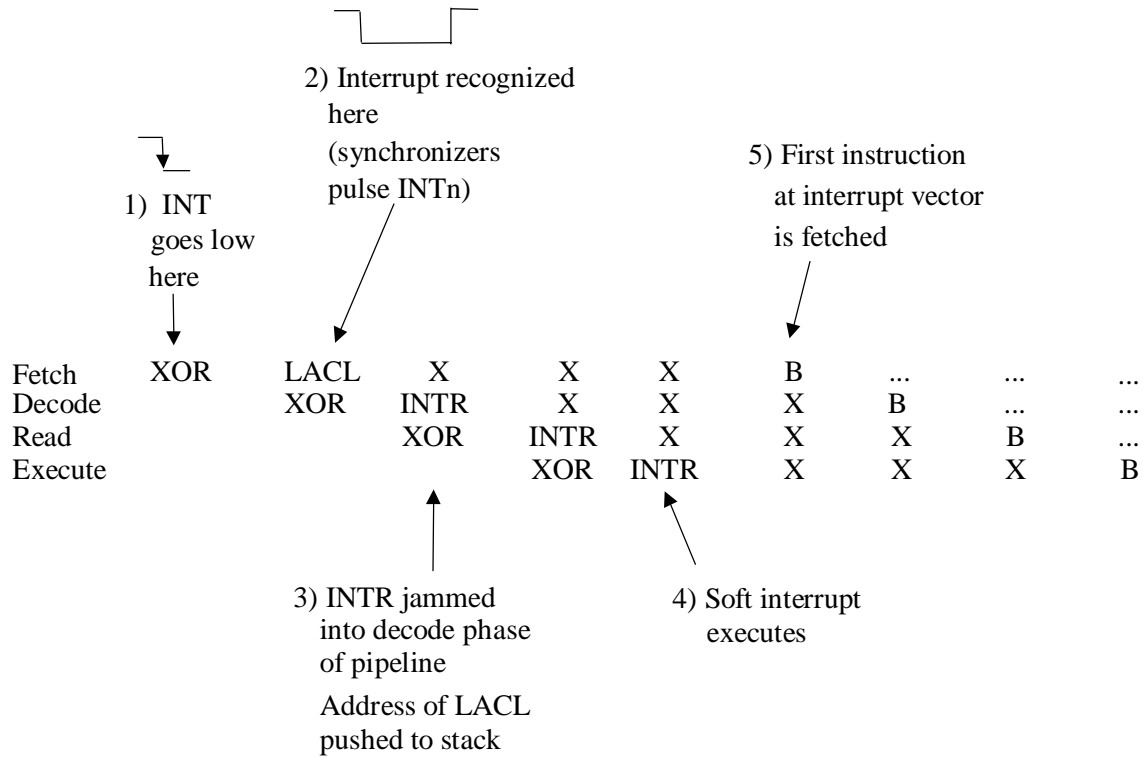
Example 1 through Example 9 show an analysis of the TMS320C2xx DSP pipeline behavior during an interrupt occurring around the SETC and CLRC instructions. Example 10 and Example 11 focus on changing the appropriate bit in the IMR register to protect a block of code without globally disabling interrupts.

For each example:

- ❑ The interrupts have a one-cycle synchronization to the CPU core. When an interrupt occurs, the synchronization circuitry actually recognizes it on the rising edge of the clock (between each cycle). If the interrupt is valid on the clock edge, the synchronization circuitry sends a low pulse to the core (interrupt recognized). There is no interrupt synchronization on the 'C2xlp core, but the diagrams can be adjusted depending on the type of synchronization you have.
- ❑ During a CLRC INTM instruction, the CPU automatically holds off any interrupt through the execution phase for it and the following instruction.
- ❑ An interrupt occurs in the CPU by jamming an INTR instruction into the decode phase of the pipeline. The address of the most recently fetched instruction is pushed to the stack so that normal operation can continue on return from the interrupt.
- ❑ When an interrupt occurs, all instructions in the pipeline will complete through the execute phase.
- ❑ CLRC INTM changes INTM in the execution phase. SETC INTM changes INTM in the decode phase.
- ❑ SACL IMR changes the IMR in the execution phase, and the change in the IMR is not realized until the next cycle.
- ❑ The pipeline is represented with zero wait state operation.

## Interrupt Occurring Around SETC and CLRC

Example 1. C2xx Pipeline Interrupt at XOR



Code Example

int occurs here →

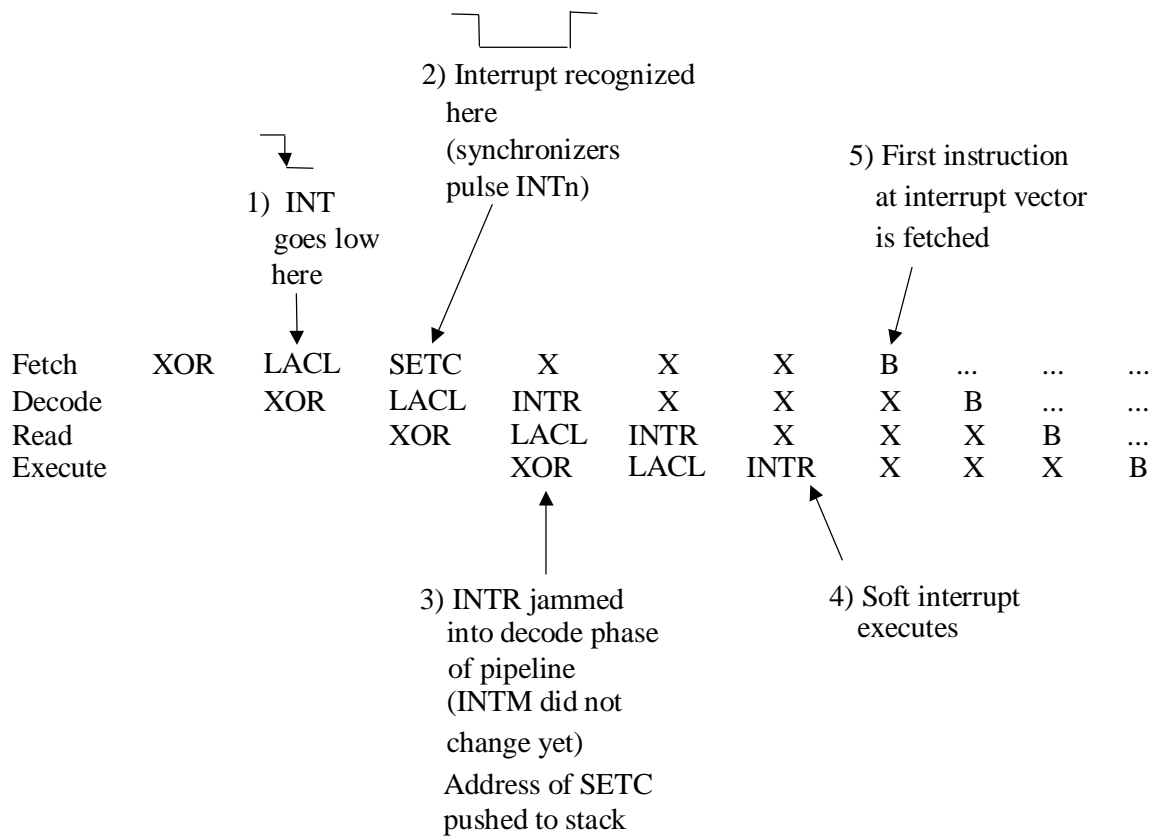
```

XOR    *
LACL   #0
SETC   INTM
ADD    *
SACL   *
CLRC   INTM
SUB    *
SACH   *
AND    *
OR     *

```



*Example 2. C2xx Pipeline Interrupt at LACL*



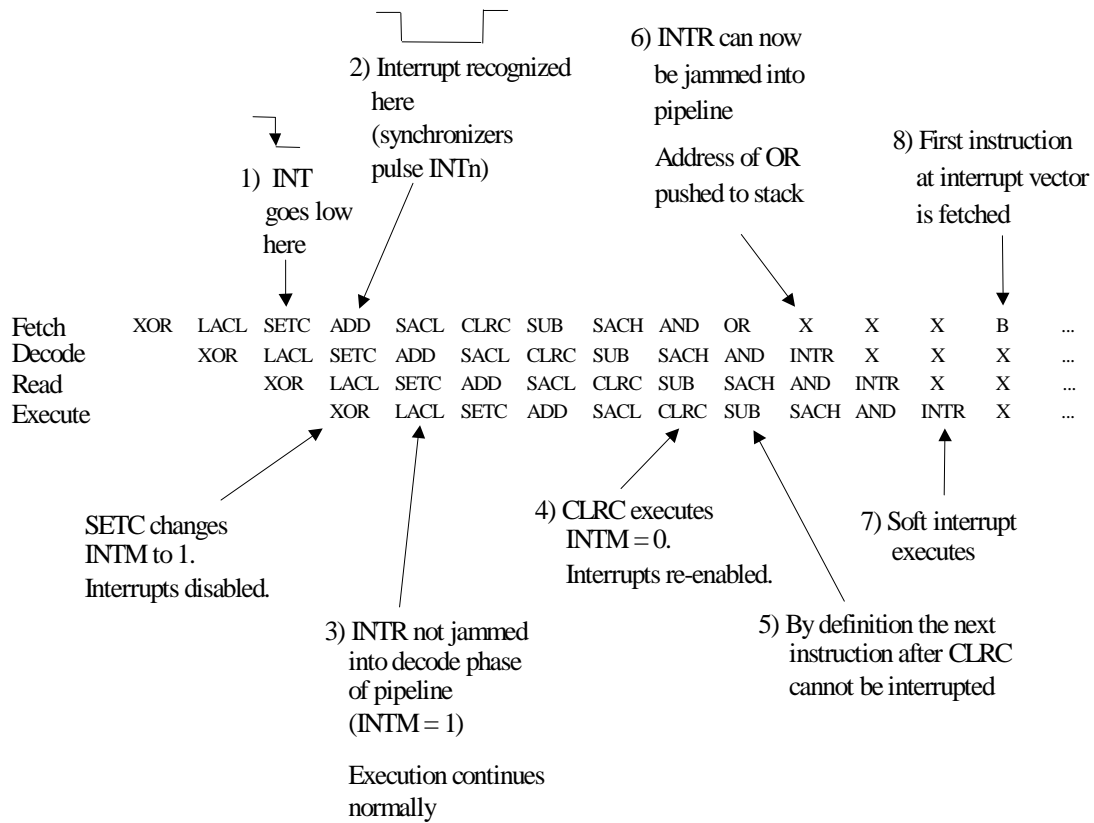
### Code Example

```

int occurs here → XOR      *
                  LACL     #0
                  SETC     INTM
                  ADD      *
                  SACL     *
                  CLRC     INTM
                  SUB      *
                  SACH     *
                  AND      *
                  OR       *

```

### Example 3. C2xx Pipeline Interrupt at SETC



#### Code Example

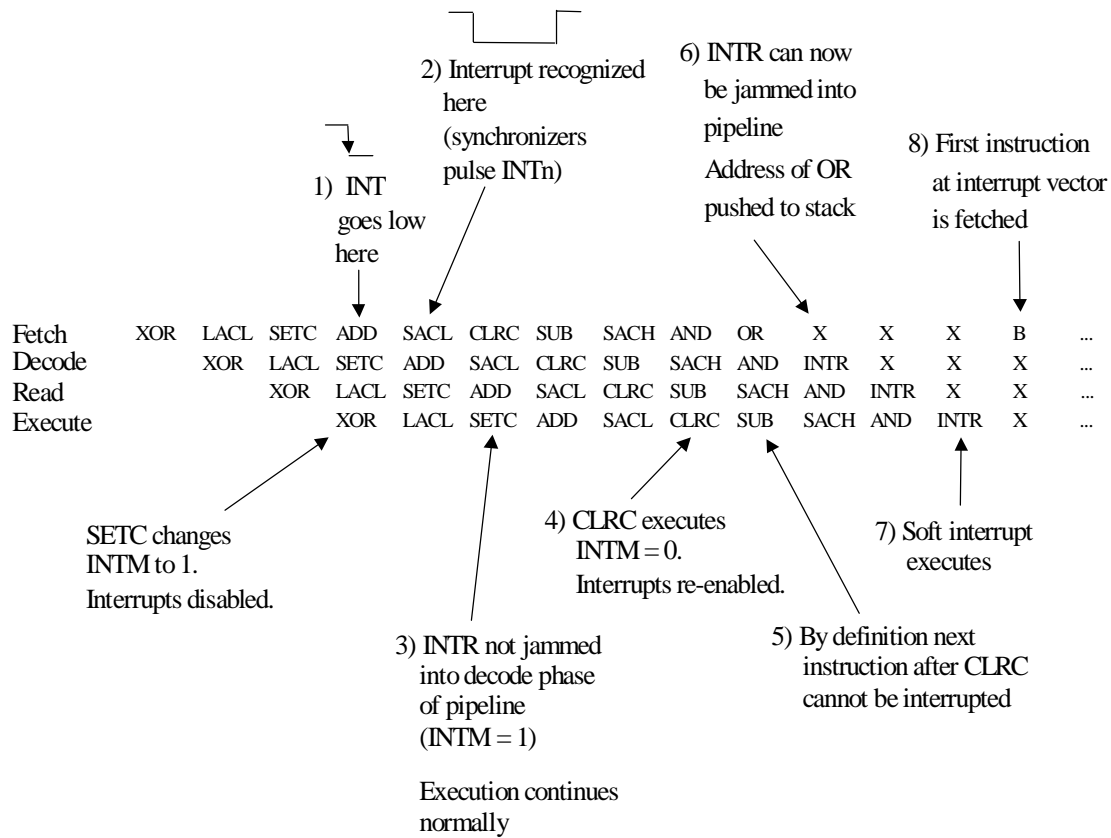
```

XOR      *
LACL     #0
SETC     INTM
ADD      *
SACL     *
CLRC     INTM
SUB      *
SACH     *
AND      *
OR        *
  
```

int occurs here →



### Example 4. C2xx Pipeline Interrupt at ADD



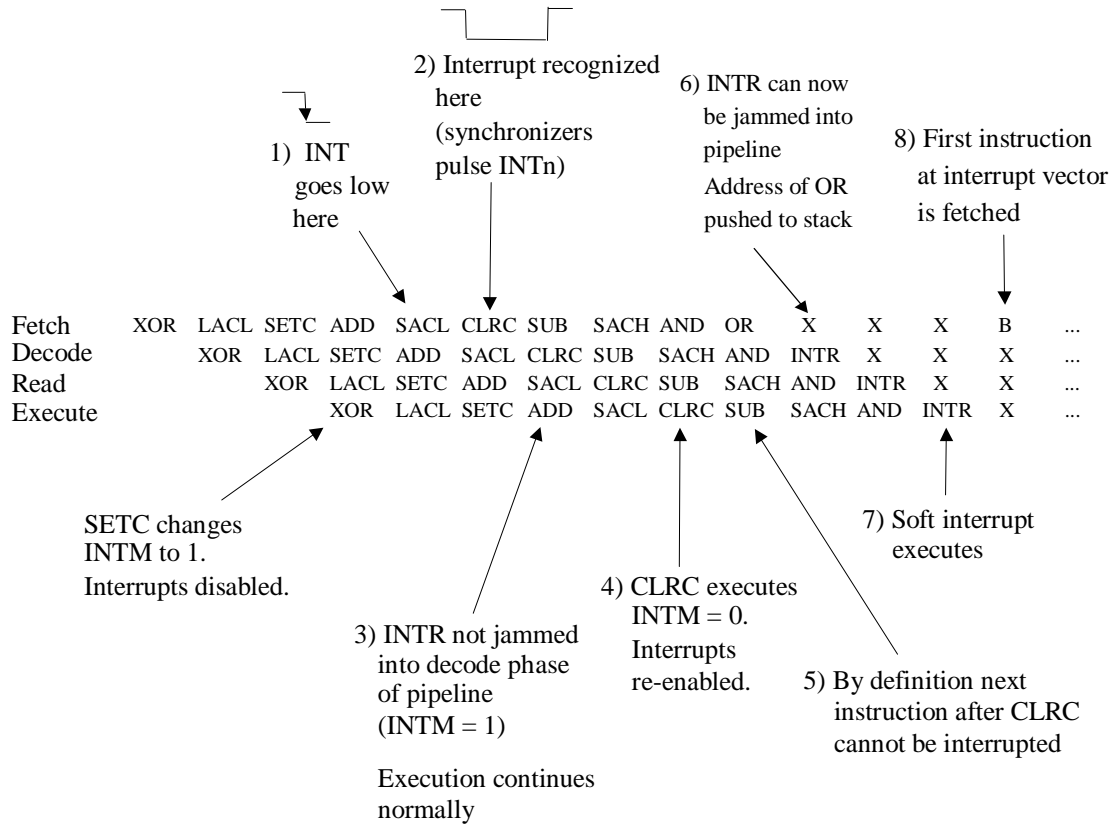
#### Code Example

```

XOR      *
LACL     #0
SETC     INTM
int occurs here → ADD     *
SACL     *
CLRC     INTM
SUB      *
SACH     *
AND      *
OR       *

```

# Example 5. C2xx Pipeline Interrupt at SACL



## Code Example

```

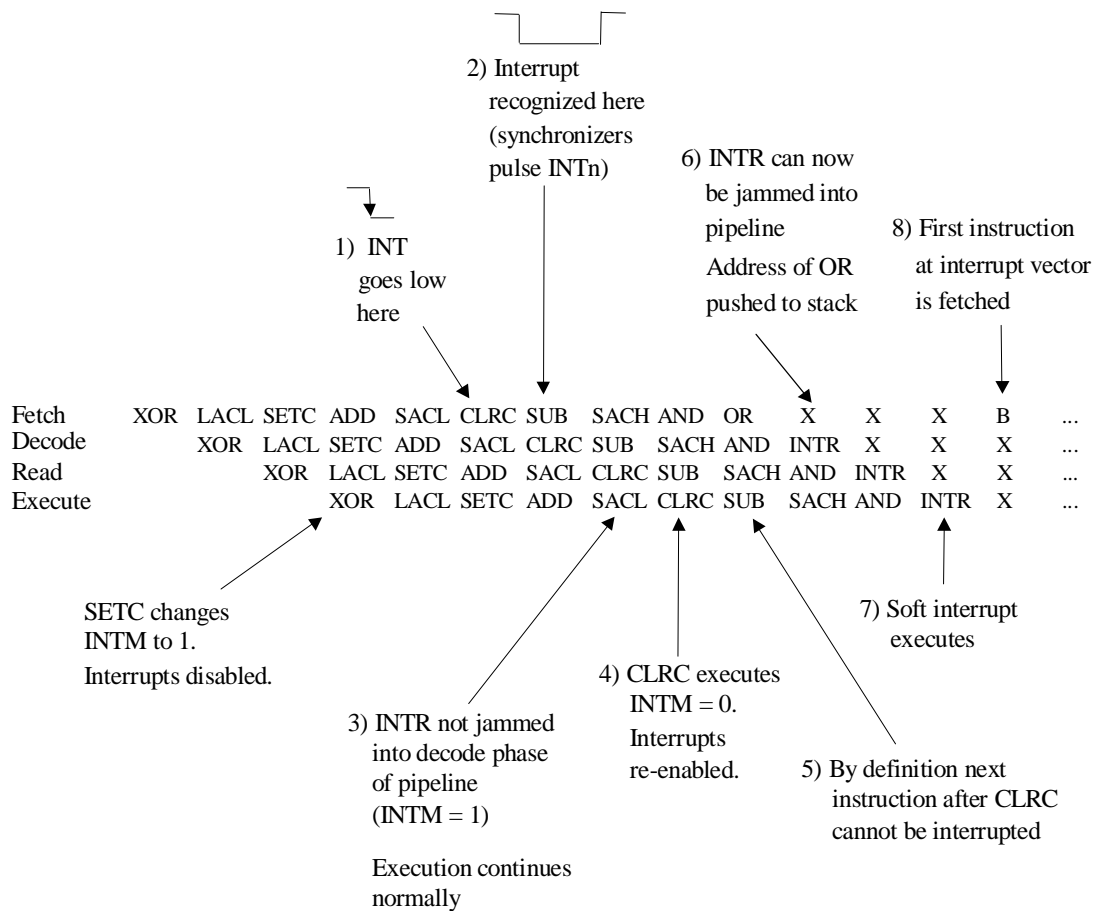
XOR      *
LACL     #0
SETC     INTM
ADD      *
SACL     *
CLRC     INTM
SUB      *
SACH     *
AND      *
OR       *

```

int occurs here →



### Example 6. C2xx Pipeline Interrupt at CLRC



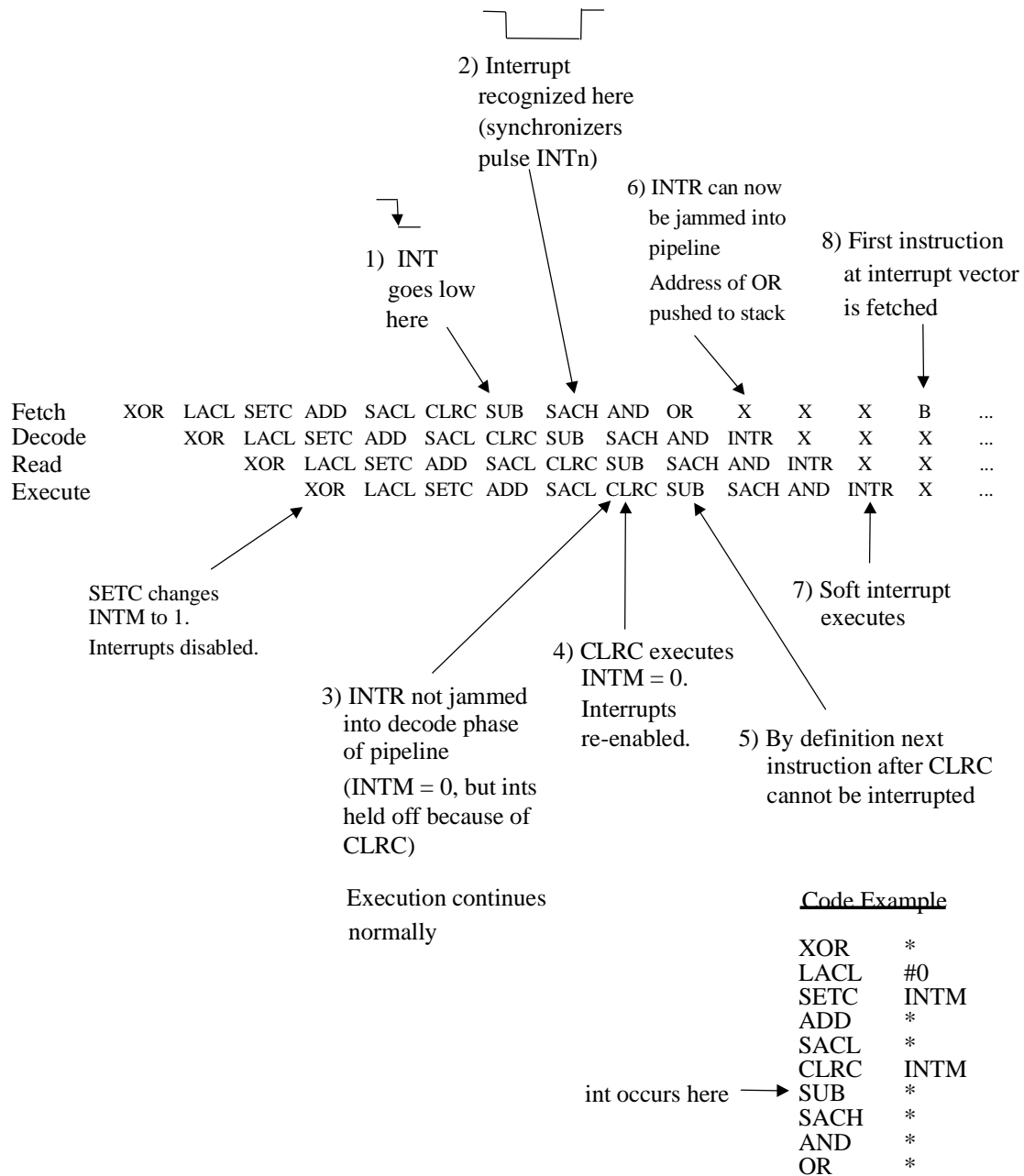
#### Code Example

```

XOR      *
LACL     #0
SETC     INTM
ADD      *
SACL     *
CLRC     INTM
SUB      *
SACH     *
AND      *
OR       *
  
```

int occurs here →

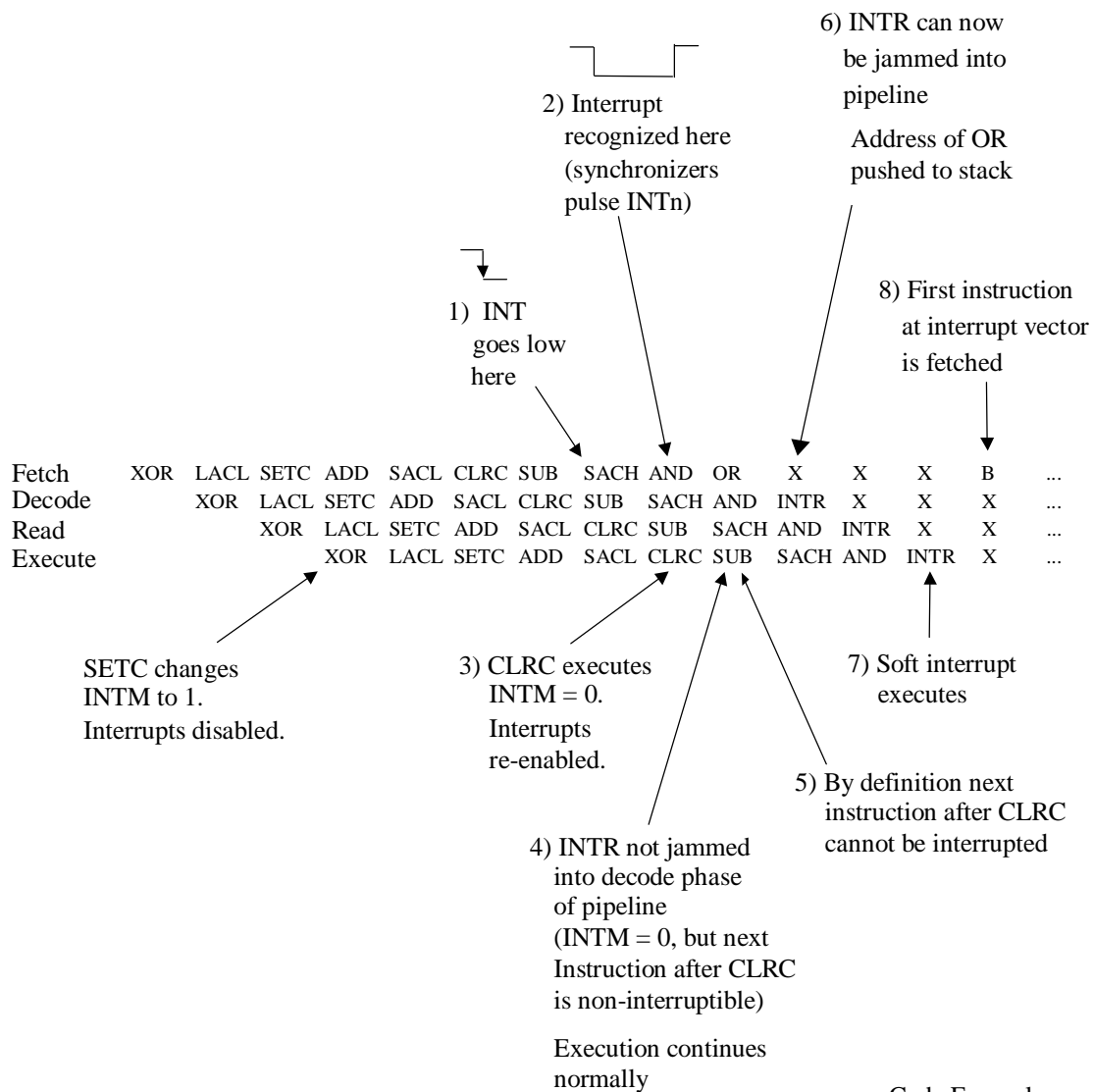
# Example 7. C2xx Pipeline Interrupt at SUB







### Example 8. C2xx Pipeline Interrupt at SACH



#### Code Example

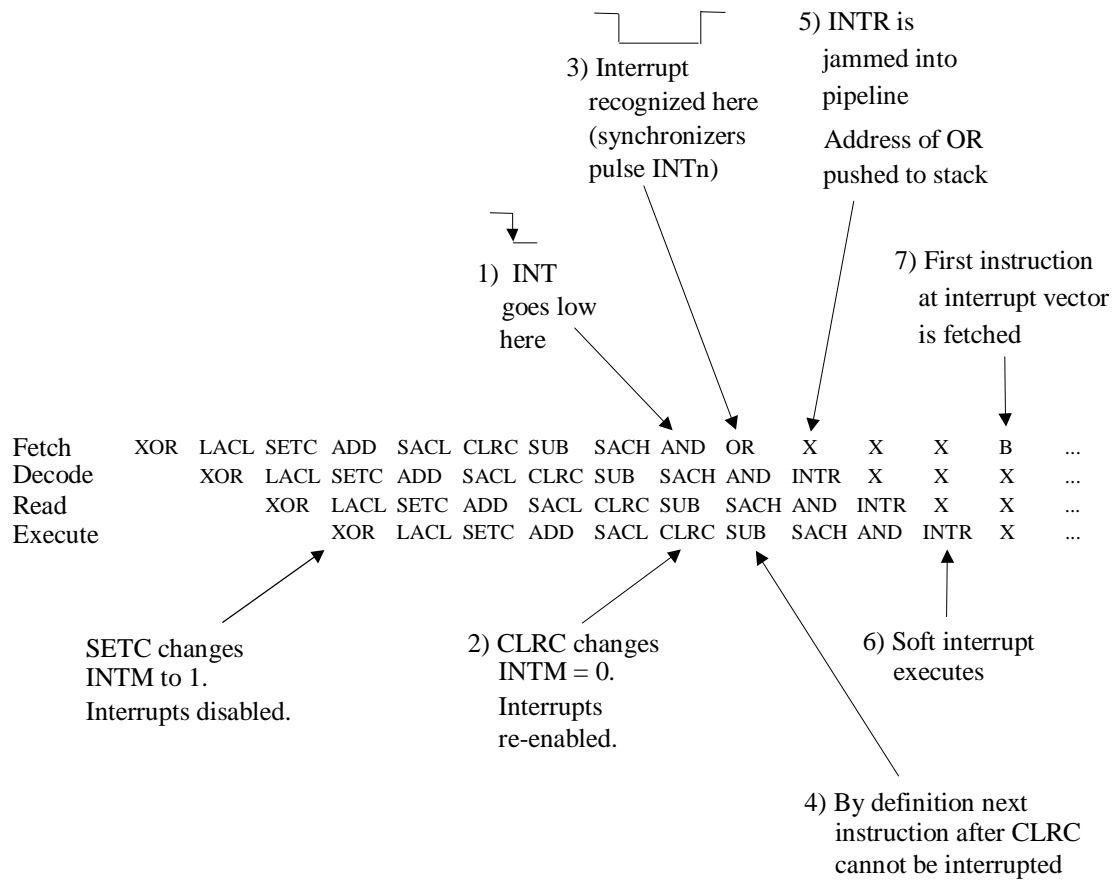
```

XOR      *
LACL     #0
SETC     INTM
ADD      *
SACL     *
CLRC     INTM
SUB      *
SACH     *
AND      *
OR       *

```

int occurs here →

### Example 9. C2xx Pipeline Interrupt at AND



#### Code Example

```

XOR      *
LACL     #0
SETC     INTM
ADD      *
SACL     *
CLRC     INTM
SUB      *
SACH     *
AND      *
OR       *

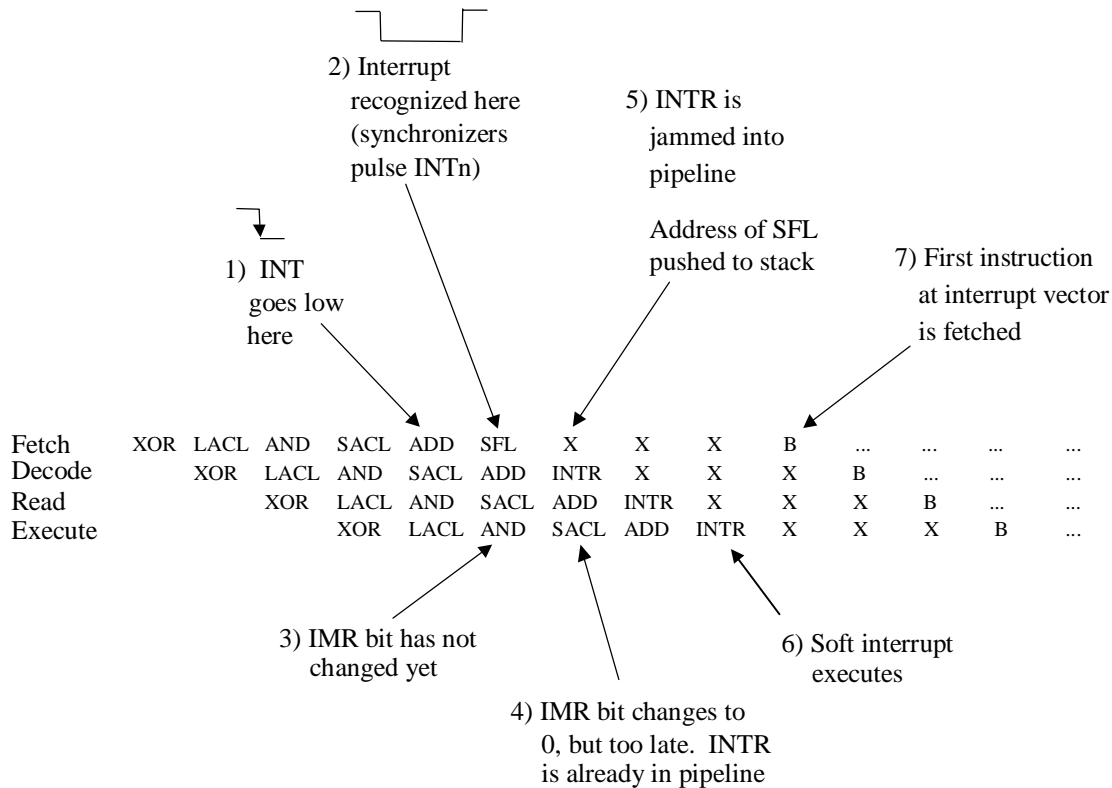
```

int occurs here →



## Changing IMR Register Bit to Protect Code without Globally Disabling Interrupts

### Example 10. Unprotected Code During an IMR Change



If you want to protect a block of code without globally disabling interrupts, you must change the appropriate bit in the IMR register. This method, however, poses some different problems that the user must be aware of. First, you must realize that a SACL IMR instruction changes the IMR in the execution phase. This is a problem, because if the interrupt comes in as shown above, the interrupt will be executed during the code that you wanted to protect.

#### Code Example

int occurs here →

```

XOR      *
LACL     #0
AND      IMR
SACL     IMR
ADD      *
SFL      *
LACL     #8
OR       IMR
SACL     IMR
SUB      *
SACH     *
AND      *
OR       *
  
```

Fetch  
Decode  
Read  
Execute

XOR SETC LACL AND SACL CLRC ADD SFL LACL OR SACL SUB SACH AND OR X X X B  
XOR SETC LACL AND SACL CLRC ADD SFL LACL OR SACL SUB SACH AND INTR X X X  
XOR SETC LACL AND SACL CLRC ADD SFL LACL OR SACL SUB SACH AND INTR X X X

1) INT goes low here

2) Interrupt recognized here (synchronizers pulse INT<sub>n</sub>)

3) IMR bit changes to 0. That interrupt is disabled

4) INTR is not jammed into pipeline. Global interrupts still disabled

5) First chance to enable global interrupts after IMR has changed. CLRC executes to do that

6) Global interrupts enabled, but IMR bit is set to 0. Interrupt is held off. Execution continues normally.

7) Interrupt re-enabled after write to IMR

8) CPU now realizes it can act upon the interrupt

9) INTR jammed into pipeline. Address of OR pushed to stack

10) Soft interrupt executes

11) First instruction at interrupt vector is fetched

int occurs here  $\longrightarrow$

Code Example		
XOR	*	;unprotected code
SETC	INTM	;disable global ints to change IMR
LACL	#0	;setup to disable int in IMR
AND	IMR	
SACL	IMR	;change bit in IMR
CLRC	INTM	;enable global ints
ADD	*	;protected code
SFL	*	;protected code
LACL	#8	;setup to enable int in IMR
OR	IMR	
SACL	IMR	;change IMR to enable int
SUB	*	;protected code
SACH	*	;protected code
AND	*	;protected code
OR	*	;unprotected code