# Microcomputers I – CE 320

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# Announcements

- Your Second quiz is next Thursday, Feb 9!
    - Topic:
        - Lecture 03:Introduction to HCS12
        - Lecture 04: Addressing Modes
        - Lecture 05: Unconditional Branches
        - Lecture 5.1: HCS12 Instructions
        - Lecture 06: Conditional Branches
        - Lecture 07: Comparison Branches
        - Homework Exercise 2 & 3.

# Lecture 7: Comparison Branches

# Today’s Goals

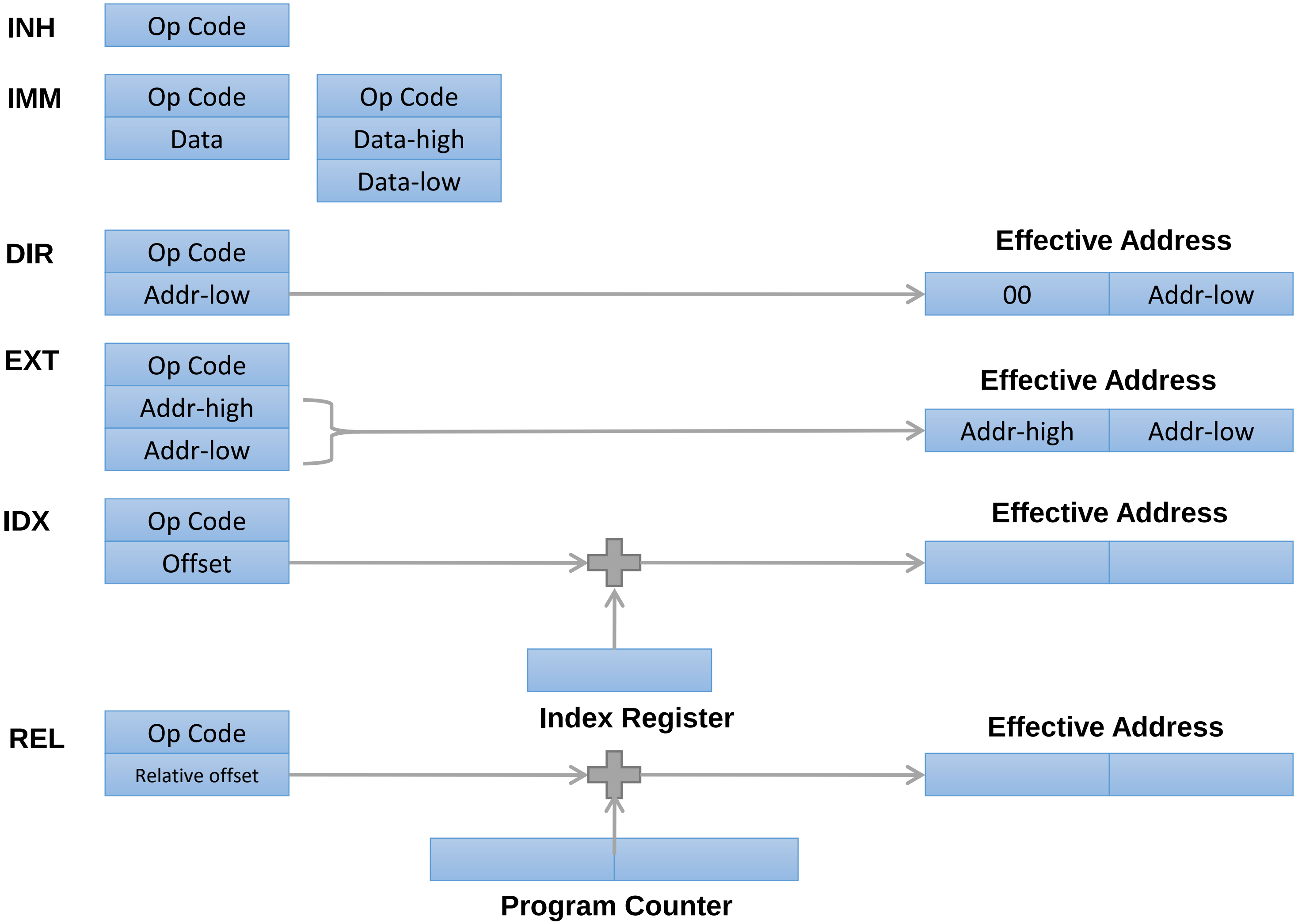
- Review the addressing modes

- Learn more about the basic instructions

- Use the Unsigned and Signed Comparison Branches to control the flow of programs

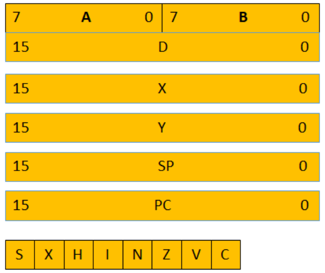
# Addressing Mode Summary

## How to Get an Effective Address



# Basic Instructions

## Load and store instruction



- 8 Bit accumulator **load**
  - **LDAA**: load a value from the specified memory to accumulator A
  - **LDAB**: load a value from the specified memory to accumulator B
- 8 bit accumulator **store**
  - **STAA**: store a value in accumulator A into the specified memory
  - **STAB**: store a value in accumulator B into the specified memory
- 16 bit register load and store
  - **LDD**, **LDX**, **LDY**, **LDS**
  - **STD**, **STX**, **STY**, **STS**
- Examples:
  - Tell the difference between
    - **LDAA #$10** and **LDAA $10**
    - **LDD $1000** and **LDD #$1000**

# Basic Instructions

## Exchange, Move, and Clear

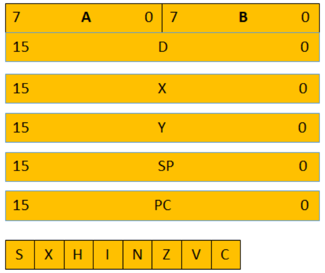
- **Exchange** instructions
  - EXG: exchange register contents
    - EXG X Y
    - EXG A B
    - EXG X B
    - EXG B X
  - XGDX: exchange register D and X
  - XGDY: exchange register D and Y
- **Move**
  - MOVB: move a byte from a memory to another memory
    - MOVB $1000, $2000
  - MOVW: move a word (2 bytes) from a memory to another memory
- **Clear**
  - CLR: clear a byte in the specified memory
    - CLR   $0800     ; set the content at $0800 to 0
  - CLRA (clear accumulator A)
  - CLRB (clear accumulator B)

**Compare Move instructions with Store ones.**

**Move: Memory to Memory**
**Store: Register to Memory**

# Basic Instructions

## Register to register transfer



- Copy a value from one register to another
  - TFR: Transfer a content of one register to another
    - TFR A B
  - TAB: (A) → (B)
  - TBA: (B) → (A)
  - SEX: Sign EXtended transfer from 8 bit register to 16 bit register
    - SEX **A** **D**
  - TPA: (CCR) → (A)
  - TAP: (A) → (CCR)
  - TSX: (SP) → (X)
  - TXS: (X) → (SP)
  - TSY: (SP) → (Y)
  - TYS: (Y) → (SP)

# Basic Instructions

## Increments, Decrements, and Negate

- Increments
  - INC: (M) + 1 → M
  - INCA: (A) + 1 → A
  - INCB
  - INS
  - INX
  - INY
- Decrements
  - DEC
  - DECA
  - DECB
  - DES
  - DEX
  - DEY
- Negate
  - NEG: negate a memory byte
  - NEGA: negate accumulator A
  - NEGB: negate accumulator B

# Basic Instructions

## Comparison

- Comparison instructions
  - Actually, they are subtractions.
  - Discard the answer
  - No change in the registers and the memories
  - CCR bits are affected instead.

**Comparison is nothing but subtraction discarding the answer.**

- **CBA**: Compare B to A:
  - Subtract the B accumulator from the A accumulator
  - (A) – (B)

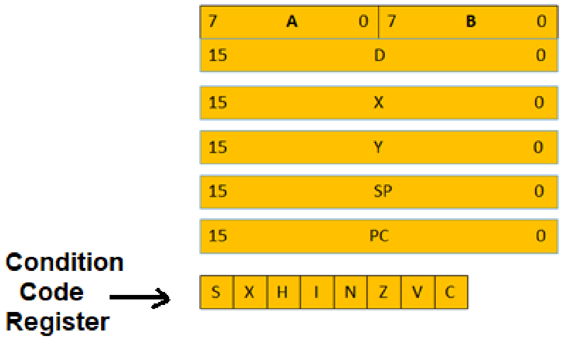
**The order is important!**

**Need to know which one is minuend or which subtrahend to interpret CCR bits.**

- **CMPA**, **CMPB**: Compare accumulator to memory :
  - Subtract the content of a memory from the accumulator
  - (A) – (M), (B)- (M)

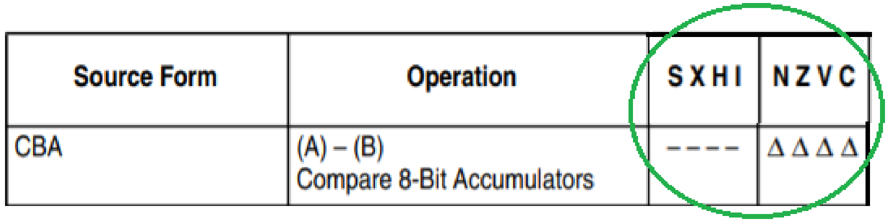
# Comparison Instruction

## Example



- Let register A have 10h, register B have 15h
  - (A) = 10h, (B) = 15h
- **CBA**
  - (A) – (B) = FBh
  - Instead of saving the result, the result $FB affects CCR bits.
  - N: 1, Z: 0, V: 1, C:1

**$FB = 1111 1011**



| Source Form | Operation | S X H I | N Z V C |
|---|---|---|---|
| CBA | (A) – (B)<br>Compare 8-Bit Accumulators | – – – – | Δ Δ Δ Δ |

- **CMPA, CMPB**
  - Assume FFh at address $1000
  - CMPA $1000
    - (A) – ($1000) = 10h – FFh = 11h
    - N: 0, Z: 0, V: 0, C: 1

**11h= 0001 0001**

- Therefore,
  - CBA does not mean that I want to *compare* B and A.
  - Rather, CBA means that I want to know what happens in CCR bits after (A) – (B) operation.

# Comparison Branches

But, actually comparison branches only check the CCR bits.

Therefore, any instruction that can affect CCR bits must be placed before using comparison branches.

- Comparison branches are based on comparing two numbers.
- **Comparison branches** only examine several CCR bits, and for them to function correctly, the CCR must be set by a **subtraction instruction**.
- The format for a subtraction instruction when used to prepare for a branch is as follows:

  Number of Interest – Reference Value = Result

  - This format makes it a little easier for a human to determine whether the branch will be taken by mentally comparing the numbers instead of performing the subtraction as the microcomputer.
  - For example, a “branch if higher” instruction would affect the PC if the Number of Interest was higher than the Reference Value.
- Subtraction instructions fall into three general categories:
  - Actual subtraction
    - Perform operation and keep the result.
  - **Comparison***
    - Perform subtraction and discard the answer.
  - Test
    - Perform subtraction using 00 as the inherent reference.

Logically, comparison instructions are needed before we use comparison branches.

# Comparison Branches

## Instructions

- Two sets of comparison branches:
    - Unsigned values:
        - Higher, Higher or Same, Lower, Lower or Same
    - Signed values:
        - Greater Than, Greater or Equal, Less Than, Less or Equal

| Comparison | Unsigned | Signed |
|---|---|---|
| > | BHI – if higher | BGT – if greater |
| ≥ | BHS – if higher or same | BGE – if greater or equal |
| < | BLO – if lower | BLT – if less than |
| ≤ | BLS – if lower or same | BLE – less than or equal |
| = | BEQ – if equal | BEQ – if equal |
| ≠ | BNE – if not equal | BNE – if not equal |

BHI, BHS, BLO, BLS, LBHI, LBHS, LBLO, LBLS – Branch to an instruction based on a **comparison of unsigned values**.

**BEQ**, **BNE** - Can be used for **either signed or unsigned values.**

BGT, BGE, BLT, BLE, LBGT, LBGE, LBLT, LBLE – Branch to an instruction based on a **comparison of signed values**.

# Comparison Branches

## Example Program

- Trace the program below. Assume the memory locations $2000, $2001, and $2002 are already set to $40, $F0, and $55 respectively.

```
1500   CE 2000           LDX #$2000
1503   180B FF 1000      MOVB #$FF,$1000
1508   C6 02             LDAB #2
150A   27 0E             BEQ 14
150C   A6 00             LDAA 0,X
150E   B1 1000           CMPA $1000
1511   24 03             BHS 3
1513   7A 1000           STAA $1000
1516   08                INX
1517   53                DECB
1518   20 F0             BRA -16
151A   3F                SWI
```

| | |
|---|---|
| … | |
| 2000 | 40 |
| 2001 | F0 |
| 2002 | 55 |
| … | |

```
1:    1500   CE 2000          LDX #$2000
2:    1503   180B FF 1000     MOVB #$FF,$1000
3:    1508   C6 02            LDAB #2
4:    150A   27 0E            BEQ 14
5:    150C   A6 00            LDAA 0,X
6:    150E   B1 1000          CMPA $1000
7:    1511   24 03            BHS 3
8:    1513   7A 1000          STAA $1000
9:    1516   08               INX
10:   1517   53               DECB
11:   1518   20 F0            BRA -16
12:   151A   3F               SWI
```

| | |
|---|---|
| … | |
| 1000 | |
| … | |
| 2000 | 40 |
| 2001 | F0 |
| 2002 | 55 |
| … | |

| Trace | Line | PC | A | B | X | N | Z | V | C |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1503 | - | - | 2000 | 0 | 0 | 0 | - |
| 2 | 2 | 1508 | - | - | 2000 | 0 | 0 | 0 | - |
| 3 | 3 | 150A | - | 02 | 2000 | 0 | 0 | 0 | - |
| 4 | 4 | 150C | - | 02 | 2000 | 0 | 0 | 0 | - |
| 5 | 5 | 150E | 40 | 02 | 2000 | 0 | 0 | 0 | - |
| 6 | 6 | 1511 | 40 | 02 | 2000 | 0 | 0 | 0 | 1 |
| 7 | 7 | 1513 | 40 | 02 | 2000 | 0 | 0 | 0 | 1 |
| 8 | 8 | 1516 | 40 | 02 | 2000 | 0 | 0 | 0 | 1 |
| 9 | 9 | 1517 | 40 | 02 | 2001 | 0 | 0 | 0 | 1 |
| 10 | 10 | 1518 | 40 | 01 | 2001 | 0 | 0 | 0 | 1 |

# Continued

```
1:      1500    CE 2000         LDX #$2000
2:      1503    180B FF 1000    MOVB #$FF,$1000
3:      1508    C6 02           LDAB #2
4:      150A    27 0E           BEQ 14
5:      150C    A6 00           LDAA 0,X
6:      150E    B1 1000         CMPA $1000
7:      1511    24 03           BHS 3
8:      1513    7A 1000         STAA $1000
9:      1516    08              INX
10:     1517    53              DECB
11:     1518    20 F0           BRA -16
12:     151A    3F              SWI
```

| | |
|---|---|
| … | |
| 1000 | |
| … | |
| 2000 | 40 |
| 2001 | F0 |
| 2002 | 55 |
| … | |

FF → 40

| Trace | Line | PC | A | B | X | N | Z | V | C |
|---|---|---|---|---|---|---|---|---|---|
| 11 | 11 | 150A | 40 | 01 | 2001 | 0 | 0 | 0 | 1 |
| 12 | 4 | 150C | 40 | 01 | 2001 | 0 | 0 | 0 | 1 |
| 13 | 5 | 150E | F0 | 01 | 2001 | 1 | 0 | 0 | 1 |
| 14 | 6 | 1511 | F0 | 01 | 2001 | 1 | 0 | 0 | 0 |
| 15 | 7 | 1516 | F0 | 01 | 2001 | 1 | 0 | 0 | 0 |
| 16 | 9 | 1517 | F0 | 01 | 2002 | 1 | 0 | 0 | 0 |
| 17 | 10 | 1518 | F0 | 00 | 2002 | 0 | 1 | 0 | 0 |
| 18 | 11 | 150A | F0 | 00 | 2002 | 0 | 1 | 0 | 0 |
| 19 | 4 | 151A | F0 | 00 | 2002 | 0 | 1 | 0 | 0 |
| 20 | 12 | - | - | - | - | - | - | - | - |

# Homework: Questions

- What does this program do?
  - Get a minimum value from the values from $2000 to ($2000 + the initial content in register B)
- What changes are needed to process 200 bytes?
  - Line 3: LDAB #2 → LDAB #200 (or #$C8 or #C8h)
- What changes are needed to process signed numbers?
  - Line 7: BHS → BGT
  - Line 2: #$FF → #$7F (or #7Fh)
- What changes are needed if the list of data begins at $3000?
  - Line 1: #$2000 → #$3000h (or #3000h)
- What changes are needed if the answer must be stored to location $3FFF?
  - Line 2, 6, and 8: $1000 → $3FFF (or 3FFFh)

# Questions?

# Wrap-up

## What we’ve learned

- Comparison branches
  - Unsigned
    - BHI, BGT, BHS, BGE
  - Signed
    - BLO, BLT, BLS, BLE
  - Either signed or unsigned
    - BEQ, BNE

# What to Come

- Assembly language

- Flowchart